Final Technical Results Report

2024

'Ripper Gauge' - Demonstrating the benefits of soil amelioration and controlled traffic practices across a broad range of soil types in Western Australia

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REPORT SENSITIVITY

Does the report have any of the following sensitivities?

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ABSTRACT

The 'Ripper Gauge' project, conducted from 2018 to 2022, aimed to evaluate and demonstrate the benefits of soil amelioration across various soil types in Western Australia. The study involved twenty demonstration sites across five port zones, testing soil types ranging from sands to loamy soils, gravel, and clay-based soils. The project also explored early post-emergent deep ripping as an alternative to traditional pre-seeding deep ripping.

From 2018 to 2020, the study focused on soil amelioration practices, including ripping to 30cm, ripping to 60cm, and local grower-based solutions. Results showed significant variation in crop response, with deep ripping demonstrating consistent benefits on deep sands but less clear benefits on other soil types. Economic analysis revealed a positive benefit for 60% of treatments, with a mean cumulative net return of $164/ha for positive returns and -$154/ha for negative returns. The study concluded that deep ripping other soil types offers small and inconsistent benefits, necessitating thorough investigation by growers before considering ameliorating these soils.

From 2021 to 2022, the project evaluated early post-emergent deep ripping. Four sites were established to compare pre-seeding, 1 week after sowing (1WAS), 3WAS, and 6WAS treatments against a control. Results indicated reduced plant establishment and early vigour across all early post-emergent treatments, negatively impacting grain yield. Pre-seeding ripping increased grain yield compared to the control, while early post-emergent treatments did not show significant benefits.

Key recommendations include understanding soil constraints through detailed analysis, staying informed about new machinery, conducting small-scale trials, thoroughly assessing options, progressively adopting practices, and continuously monitoring and adapting amelioration techniques. Collaboration with other growers and experts, considering environmental impacts, and conducting detailed economic analysis are also crucial for successful soil amelioration.

The project highlights the importance of a data-driven approach to soil amelioration, tailored to specific soil conditions. By following these recommendations, growers can enhance the productivity and sustainability of their farming operations.

EXECUTIVE SUMMARY

Overview

Soil amelioration is a critical strategy for overcoming soil limitations to crop production in Western Australian farming systems. This project, spanning from 2018 to 2022, was completed in two phases; 2018-2020 focused on Soil Amelioration vs Soil Type and 2021-2022 focused on Effects of Early Post Emergent Ripping. The overall aim was to evaluate and demonstrate the benefits of soil amelioration across a diverse range of soil types common to the WA grain-growing region. The study involved a network of demonstration sites established across five port zones, with twenty-four sites set up in the 2018-2020 period by nine collaborating grower groups. The soil types tested ranged from sands to loamy soils, gravel and sand duplexes, forest gravels, and clay-based soils. The project also explored the effects of early post-emergent deep ripping as an alternative to traditional pre-seeding deep ripping.

2018-2020: Soil Amelioration vs Soil Type

The initial phase of the project focused on evaluating soil amelioration practices across various soil types. Three standard treatments—ripping to 30cm, ripping to 60cm, and a local grower-based solution—were tested against a control (no amelioration). The range of crop species grown included predominantly cereal crops in 2018 and 2019, with half of the sites sown to canola in 2020.

The results showed significant variation in crop response to amelioration between sites, crop types, years, and seasonal conditions. While deep ripping demonstrated consistent benefits on deep sands, the benefits were less clear for other soil types. There was a trend of diminishing benefit for each soil amelioration treatment from 2018 to 2020. Treatments that resulted in a small grain yield benefit (less than 0.5t/ha) or negative yield penalty in the first year generally did not lead to increased grain yield in subsequent years. A key indicator that new soil amelioration practices will be effective in the medium term is a significant (greater than 0.5t/ha) grain yield benefit in the first year.

Economic analysis revealed a positive benefit for 60% of the soil amelioration treatments implemented across all sites after three years. The mean cumulative net return over three years was $164/ha for treatments with a positive return and -$154/ha for those with a negative return. The study concluded that there is a small and inconsistent benefit to deep ripping soil types other than the sandy soil types commonly deep ripped, and this practice should be thoroughly investigated by growers before developing a soil amelioration plan for their property.

2021-2022: Effects of Early Post Emergent Ripping

The second phase of the project evaluated the use of early post-emergent deep ripping as an alternative to traditional pre-seeding deep ripping. This method was explored to address issues such as increased wind erosion from bare and loose soil when deep ripping is completed in the autumn period before seeding.

Four sites were established across the Wheatbelt and Northern Agricultural region of WA to evaluate four timings of deep ripping compared to a control (nil ripping): pre-seeding, 1 week after sowing (1WAS), 3WAS, and 6WAS. Three sites were sown to wheat and one to canola into a moist soil bed to facilitate timely emergence, with each site managed uniformly using district best practice agronomy during each season.

The results indicated that plant establishment and early plant vigour were reduced across all early post-emergent ripping treatments, likely negatively impacting grain yield. Overall, grain yield was increased with the pre-seeding ripping treatment compared to the control, while early post-emergent ripping treatments were similar to the control, and the benefit of deep ripping was not realised. Reduced plant establishment through early post-emergent ripping often led to an increase in weed presence, likely causing management issues in successive crops.

Key Findings and Recommendations

1. **Understand Soil Constraints**: Conduct detailed soil analysis to identify specific issues such as compaction, acidity, salinity, or water repellence. Tailor amelioration practices to address these constraints effectively.
2. **Research and Be Open to New Machines**: Stay informed about the latest advancements in soil management technologies. Experiment with new machines that offer different modes of soil loosening and mixing to find the most suitable equipment for your soil conditions.
3. **Conduct Trials on Your Soil Type**: Before fully committing to any soil amelioration practice, conduct small-scale trials to test different methods and assess their impact on soil health and crop yield. Use empirical data to make informed decisions.
4. **Thoroughly Assess Options**: Evaluate the long-term impact of different amelioration techniques on soil health and crop yield. Consider the cost of implementation, expected benefits, and sustainability of the practice. Collect and analyse data to measure the actual benefits.
5. **Progressive Adoption and Investment**: Adopt soil amelioration practices progressively across your farm. Start with small areas and expand as you gain confidence in the effectiveness and economic viability of the chosen techniques. Invest gradually based on solid evidence of economic return.
6. **Continuous Monitoring and Adaptation**: Regularly assess the impact of your amelioration practices on soil health and crop yield. Make necessary adjustments and improvements based on ongoing observations and data collection.
7. **Collaboration and Knowledge Sharing**: Engage with other growers, researchers, and agricultural experts to stay updated on the latest developments in soil amelioration practices. Participate in field days, workshops, and industry conferences to learn from others and share your findings.
8. **Environmental Considerations**: Ensure that your amelioration techniques do not lead to negative environmental consequences such as soil erosion, loss of biodiversity, or contamination of water sources. Adopt practices that promote sustainable land management.
9. **Economic Analysis and Planning**: Conduct a detailed economic analysis of different amelioration techniques. Develop a comprehensive plan that outlines the steps for implementation, resources required and expected timeline for achieving results. Regularly review and update this plan based on ongoing observations and data collection.

The ‘Ripper Gauge’ project provides valuable insights into the effectiveness and economic viability of various soil amelioration practices across a diverse range of soil types in Western Australia. While deep ripping has shown benefits on deep sands, its application to other soil types presents challenges and requires thorough investigation. The study highlights the importance of understanding soil constraints, conducting trials, and adopting a data-driven approach to soil amelioration. By following the recommendations outlined, growers can make informed decisions that enhance the productivity and sustainability of their farming operations.

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BACKGROUND

2018-2020 – Soil Amelioration vs Soil Type

Strategic tillage practices, or soil amelioration, is a key strategy used by farmers to overcome soil limitations to crop production in Western Australian farming systems. The removal of soil constraints such as compaction and water repellence through strategic tillage practices generally leads to increases in crop production in successive years (Newman et al, 2024). An existing network of demonstration sites established across the port zones of WA demonstrate the effectiveness of soil amelioration on deep sands, however, there are many soil types where the benefit and longevity of soil amelioration practices are unknown.

Another key limitation that threatens the longevity of the benefits associated with soil amelioration is that the soil can re-compact over time following amelioration, often leading to compaction levels higher than before amelioration (Davies et al, 2017). The current solution is usually to repeat the deep ripping process every few years, with the period between deep ripping primarily dependent on the soil type and amount of wheeled traffic on the paddock. Other factors, such as rainfall and environmental conditions, and crop rotation also play a factor. This is a costly and repetitive process that may become unsustainable in the long term as soils become compacted to greater depths with successive tillage treatments and larger/heavier machinery.

Controlled traffic farming (CTF) is a system built on permanent wheel tracks where the crop zone and traffic lanes are permanently separated reducing soil compaction from traffic. The adoption of controlled traffic practices by growers is one tool that can potentially increase the longevity of soil ameliorative practices. However, the potential for controlled traffic practices to increase the longevity of amelioration treatments has only been evaluated on a narrow range of soil types.

This project evaluated and demonstrated the benefit of soil amelioration across a wider range of soil types that are common to the WA grain growing region. Sites will be established across the Kwinana East, Kwinana West, Geraldton, Esperance, and Albany port zones that will fill the gaps in current knowledge of the grain yield response and economic return from the ripping of soil compaction. This project has added value to the existing demonstration site network that has been established by DAW00242, DAW00243, and DAW00244 projects that focus on ripping to remove compaction. As a result of the increased number of demonstration sites, growers will have an expanded awareness of the grain yield response and longevity of soil ripping and controlled traffic practices for the major soil types for the selected port zones in WA.

2021-2022 – Effects of Early Post Emergent Ripping

In Western Australian farming systems deep ripping is commonly completed in the autumn period prior to seeding the annual cropping program. This timing can lead to adverse issues such as increased wind erosion from bare and loose soil. An alternative to pre-seeding deep ripping is to move the timing of ripping to after seeding when strong wind events decline after the break to the season and where the soil is generally wetter and more stable. The completion of deep ripping practices after seeding, early post emergent deep ripping, offers a potential solution to alleviate this issue, simultaneously taking advantage of having plant-based ground cover from the crop to protect the soil from wind events.

Building from the results in the 2018-2020 portion of this project this study will further evaluate the use of deep ripping in the form of early post emergent deep ripping across the 2021 to 2022 seasons, investigating another option for farmers to improve grain yield on soils that suffer from compaction. Four sites will be established and managed uniformly using district best practice agronomy across the Wheatbelt and Northern Agricultural region of WA to evaluate the four timings of deep ripping compared to a control (nil ripping): pre-seeding, 1 weeks after sowing (1WAS), 3WAS, and 6WAS.

PROJECT OBJECTIVES

2018-2020 – Soil Amelioration vs Soil Type

Growers in each port zone will use the demonstration sites to increase knowledge and adoption of deep ripping and controlled traffic farming used for alleviating soil constraints on the main soil types in each port zone and farming systems.

2021-2022 – Effects of Early Post Emergent Ripping

To determine the impact of early post emergent deep ripping on plant growth and grain yield compared to the standard grower practice of pre-seeding ripping across the Wheatbelt and Northern Agricultural region.

METHODOLOGY

2018-2020 – Soil Amelioration vs Soil Type

Twenty demonstration sites were established by nine grower groups in 2018 across the five port zones of the Western Australia agricultural region (Table 1).

Table 1. Western Australian agricultural port zones and associated grower group/s.

Port Zone	Site/s	Associated Grower Group
Geraldton	4	Mingenew-Irwin Group (MIG)
Kwinana West	1	Corrigin Farm Improvement Group (CFIG)
	1	Facey Group (Facey)
	1	Liebe Group (Liebe)
	1	West Midlands Group (WMG)
Kwinana East	2	CFIG
	1	Liebe
	1	Merredin and Districts Farm Improvement Group (MADFIG)
Albany	2	Southern Dirt (Sthn Dirt)
	2	Stirlings to Coast Farmers (StC)
Esperance	4	South East Premium Wheat Growers Association (SEPWA)

A range of soil amelioration methods were evaluated that are currently available and being used by growers to ameliorate a range of soil constraints on soil types across the WA Agricultural region (Table 2). The soil types tested in this project range from loamy sands through to gravel and sand duplexes, forest gravels, and clay soil types. Each site was selected based on the low amount of knowledge available on how the soil type would respond to each soil amelioration practice, within each port zone.

Three standard treatments were tested against a control (no amelioration) at each site, including ripping to 30cm (Rip 30cm), ripping to 60cm (Rip 60cm), and a local solution/combination of methods to address local soil constraints. The availability of equipment to implement treatments at each site was the main factor in determining the actual treatment structure of individual sites.

Each site was established in autumn of 2018 as a demonstration strip trial with a plot size of 100 metres long by the width of the harvest equipment (typically 12 metres). The exception was the Hines Hill site, which was established following a fallow period in spring of 2018. Treatments were applied by the participating grower at each site. Each site was divided into three quadrants per treatment to give 12 quadrants (4 treatments by 3 quadrants) to allow for spatial variability to be incorporated into the statistical analysis at each site.

Following soil amelioration, the amount of soil disturbance was measured by placing a 50cm straight ruler across the rip line so that the rip line corresponded with the 25cm mark on the ruler. A push rod was used to make insertions at 0cm, 12.5cm, 25cm, 37.5cm, and 50cm on the ruler to measure the amount of loose soil between, and within the rip line. This was repeated in each quadrant across each site.

Initial soil strength was measured using a data-logging cone penetrometer when the soil was at field capacity in July of 2018. Five insertions were made in each quadrant in a similar manner as the measurement of soil disturbance.

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Plant establishment was measured by number of plants emerged per metre of crop row. In each treatment a 0.5m ruler was placed between two crop rows and plants were counted in each row, repeated 10 times for each plot. Each treatment (100m) was divided into 3 quadrants (33m) by the width of the treatment, taking 3 measurements of plant establishment per quadrant (n=9). Plants/m2 were calculated by the average for each quadrant. Conversion to plants/m2 was calculated using a conversion factor of 4 for 25 cm spacing and 3.3 for 30 cm spacing.

In season plant growth was measured using Normalised Difference Vegetation Index (NDVI) with a handheld Greenseeker® wand at end of tillering (growth stage GS30) for cereals (approximately mid-July to mid-August). Each treatment (100m) was divided into 3 quadrants (33m) by the width of the treatment, taking one average measurement of NDVI for each quadrant.

Grain yield was measured using the yield monitor at harvest by the grower, or by weigh-bin trailer where no yield monitor measurements were available. The majority of sites were sown to cereal crops in 2018 and a range of crops in subsequent years depending on the crop rotation employed by each host grower.

In-season management such as seeding, spraying, and harvest was completed by the participating grower; crop agronomy at each site was similar to the rest of the paddock in both years.

Rainfall data was collected from the Bureau of Meteorology website using GPS points of the trial sites to determine the closest weather station.

Data was aggregated and analysed using the R statistical program to generate summary statistics for each year as most sites were harvested using weigh trailers following issues with collection of yield data from grower harvesters in the 2018 season.

2021-2022 – Effects of Early Post Emergent Ripping

Four trial sites were located across Five port zones (Geraldton, Kwinana East, Kwinana West, Albany, and Esperance) in the 2021 season. The sites were established on either deep sand or sand over clay duplex soil types that were capable of being ripped to a depth of 60cm and with an identifiable hardpan.

Prior to establishing the trial site, a site characterisation was completed by taking soil samples at 0-10cm and 10-30cm depth and submitting for nutrient analysis and additional samples were taken at 0-5cm for soil water repellence. The presence of high soil strength was confirmed prior to individual sites being established using a data logging cone penetrometer.

At each site the ripping treatments were laid out in a demonstration style design with 100m x 12m plot width, with two replicates (Table 4), and treatments applied as specified in Table 5. The machinery used was provided by the host grower and included the type of deep ripping equipment currently used on farm, including a trailing roller in most cases. Prior to each ripping treatment being imposed, soil moisture was measured at 30cm soil depth, being the midpoint of the ripping depth, although all sites were at field capacity at site establishment.

Following the completion of each ripping treatment, a composite soil sample was taken at 0-5cm depth for soil water repellence to measure changes due to the ripping treatment. Plant establishment (live plants) were measured two weeks after each ripping treatment was imposed, and soil strength was measured in July when the soil was at field capacity.

Grain yield was measured by machine harvest with the grower's harvester using either a weigh bin or harvester yield map. All sites were sown, harvested, and managed with farmer equipment and all cropping inputs for the season were constant across all treatments, with the agronomy package consistent with farmer practice in the local area.

Rainfall data was collected from the Bureau of Meteorology website using GPS points of the trial sites to determine the closest weather station.

Data was aggregated and analysed using the R statistical program to generate summary statistics for all sites and years. For the sites established in the 2018-2020 years there was no replication to enable a robust statistical analysis, while sites established in the 2021-2022 years did have replicated demonstration site treatments.

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TRIAL SITE DESIGN & TREATMENTS

2018-2020 – Soil Amelioration vs Soil Type

Table 2. Definition of treatments used in the Ripper Gauge project. Treatments were grouped into broad categories for analysis.

Amelioration Treatment	Treatment Group	Description
Control	Control	No soil amelioration method applied
Rip 30cm	Ripping	Ripping by straight or angled shank ripper to depth of 30cm, either in the direction of sowing or at a slight angle
Rip 60cm	Ripping	Ripping by straight or angled shank ripper to depth of 60cm, either in the direction of sowing or at a slight angle
Spader	Tillage	Rotary spading to mix the A and B soil horizon to a depth of 30cm
Rip 60cm + Spade	Tillage	Combination of ripping to 30cm depth followed by rotary spading, either in the direction of sowing or at a slight angle
Mouldboard plough	Tillage	Mouldboard ploughing to completely invert the soil to depth of 30-40cm
Rip 60cm + Mouldboard	Tillage	Combination of ripping to 30cm depth followed by mouldboard ploughing, either in the direction of sowing or at a slight angle
Plozza plough	Tillage	Modified one-way plough with large diameter discs that can invert the soil to a depth of 40cm
Rip 60cm + Plozza	Tillage	Combination of ripping to 30cm followed by Plozza plough
One-way Plough	Tillage	Traditional one-way plough that loosens, partially inverts, and mixes the top 10-20cm of soil
Shallow Disc	Tillage	An offset disc plough with two gangs of discs that loosen and mix the soil to a maximum depth of 15cm
Scarifier	Shallow Tillage	Cultivation to loosen and mix soil to a depth of 10cm
Rip 30cm + Inclusion plates	Ripping	Ripping to 30cm depth using a straight shank tine with plates installed to the rear of the tine to hold the soil open to allow for topsoil to fall into the furrow
Rip 60cm + Inclusion plates	Ripping	Ripping to 60cm depth using a straight shank tine with plates installed to the rear of the tine to hold the soil open to allow for topsoil to fall into the furrow
Max Tillage	Maximum tillage	Aggressive tillage using a machine with tines capable of ripping to 30cm and discs that aggressively mix the top 10-20cm of soil.
Morrell Lime	Amendment	Moderate neutralising value subsoil that is spread to address soil acidity in the Eastern Wheatbelt.
Dolomite	Amendment	Soil amendment to address soil acidity with high calcium to magnesium ratio.

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Table 31. The species of crop grown at each site in the 'Ripper Gauge' project for the 2018 -2020 seasons. The Tambellup site commenced in 2019. The Kadathinni and Morawa sites were fallowed in 2020 due to poor seasonal conditions.

Site	2018 Crop	2019 Crop	2020 Crop
Broomehill	Lupins	Wheat	Canola
Cascade	Wheat	Barley	Canola
Coomalbidgup	Wheat	Lupins	Wheat
Dalwallinu	Wheat	Wheat	Barley
Darkan	Canola	Barley	Canola
Gorge Rock	Wheat	Barley	Canola
Hines Hill	Fallow	Canola	Wheat
Kadathinni	Wheat	Lupins	Fallow
Kalannie	Wheat	Wheat Hay	Canola
Kojaneerup	Wheat	Canola	Wheat
Kurrenkutten	Barley	Barley	Barley
Mingenew	Wheat	Wheat	Canola
Moora	Barley	Barley	Canola
Morawa	Wheat	Wheat	Fallow
Neridup	Canola	Barley	Lupins
Salmon Gums	Wheat	Wheat	Wheat
Wadderin	Canola	Wheat	Barley
Tambellup	No Trial	Wheat	Canola
Yealering	Wheat	Wheat	Wheat
Yuna	Wheat	Canola	Canola

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2021-2022 – Effects of Early Post Emergent Ripping

Table 4. Example site layout and treatment structure for each early post emergent ripping site.

Rep 1					Rep 2				
3 weeks after seeding	Control	6 weeks after seeding or GS30	1 week after seeding	Pre-seeding	6 weeks after seeding or GS30	Pre-seeding	1 week after seeding	Control	3 weeks after seeding
Tmt 4	Tmt 1	Tmt 5	Tmt 3	Tmt 2	Tmt 5	Tmt 2	Tmt 3	Tmt 1	Tmt 4

Table 5. Outline of treatments at each site.

Treatment (Tmt) 1	Control - Unripped
Treatment (Tmt) 2	Pre-seeding ripped
Treatment (Tmt) 3	Ripping 1 week after seeding
Treatment (Tmt) 4	Ripping 3 weeks after seeding
Treatment (Tmt) 5	Ripping 6 weeks after seeding, or GS30 (whichever comes first).

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LOCATION

2018-2020 – Soil Amelioration vs Soil Type

Table 6. Compiled location details for sites across 2018 to 2020 seasons.

Soil Group	Soil type	Site Name/Locality	Latitude (decimal degrees)	Longitude (decimal degrees)
Clay	Heavy Grey Clay	Cascade	-33.382425° S	120.943011° E
Duplex	Gravelly Duplex	Broomehill	-33.849594° S	117.717283° E
Duplex	Sandy Gravel over Clay	Coomalbidgup	-33.570733° S	121.421373° E
Duplex	Sand over Gravel	Dalwallinu	-30.240332° S	116.594884° E
Duplex	Sand over Gravel	Kadathinni	-29.640361° S	115.655083° E
Duplex	Sandy Loam over Clay	Salmon Gums	-33.039866° S	121.736452° E
Duplex	Loamy Duplex	Tambellup	-34.004141° S	117.898761° E
Duplex	Sand over Gravel	Wadderin	-31.956750° S	118.480250° E
Duplex	Sandy Loam over Gravel	Yealering	-32.535300° S	117.682430° E
Gravel	Forest Gravel	Darkan	-33.272917° S	116.633152° E
Gravel	Deep Sandy Gravel	Neridup	-33.634446° S	122.053783° E
Loam	Sandy Clay Loam	Gorge Rock	-32.500222° S	117.979500° E
Loam	Sandy Loam	Hines Hill	-31.423100° S	118.062583° E
Loam	Loamy Sand	Kalannie	-30.353119° S	117.069205° E
Loam	Loamy Sand	Mingenew	-29.390767° S	115.456750° E
Loam	Silty Clay Loam	Moora	-30.618100° S	116.030008° E
Loam	Red Sandy Loam	Morawa	-28.856003° S	115.985778° E
Loam	Sandy Loam	Yuna	-28.124861° S	115.080253° E
Sand	White Sandplain	Kojaneerup	-34.511306° S	118.331194° E
Sand	Wodjil Sand	Kurrenkutten	-32.286250° S	118.178444° E

2021-2022 – Effects of Early Post Emergent Ripping

Table 7. Compiled location details for sites across 2021 to 2023 seasons.

Site #	Nearest Town	Latitude (decimal degrees)	Longitude (decimal degrees)
Trial Site #1	Corrigin	32.37767° S	117.74418° E
Trial Site #2	Dandaragan	30.54182° S	115.67324° E
Trial Site #3	Latham	29.75308° S	116.39755° E
Trial Site #4	Mingenew	29.14715° S	115.39053° E

If the research results are applicable to a specific GRDC region/s (e.g. North/South/West) or GRDC agro-ecological zone/s, indicate which in the table below:

Research	Benefiting GRDC region (select up to three)	Benefitting GRDC agro-ecological zone	
	Choose an item. Choose an item. Western Region	☐ Qld Central ☐ NSW NE/Qld SE ☐ NSW Vic Slopes ☐ Tas Grain ☐ SA Midnorth-Lower Yorke Eyre ☒ WA Northern ☒ WA Eastern ☐ WA Mallee	☐ NSW Central ☐ NSW NW/Qld SW ☐ Vic High Rainfall ☐ SA Vic Mallee ☐ SA Vic Bordertown-Wimmera ☒ WA Central ☒ WA Sandplain

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RESULTS

2018-2020 – Soil Amelioration vs Soil Type

Rainfall

Table 8. Compiled annual rainfall (mm) across 2018 to 2020 seasons including comparison to the Long Term Average (LTA) collected from various Bureau of Meteorology (BOM) weather stations.

Site	BOM station	2018	2019	2020	LTA
Broomehill	010643	344	307	322	447
Cascade	012140	303	213	327	403
Coomalbidgup	009922	484	316	417	463
Dalwallinu	008061	382	182	301	352
Darkan	009914	609	396	505	589
Gorge Rock	010603	287	199	257	317
Hines Hill	010151	231	161	276	282
Kadathinni	008121	326	226	343	376
Kalannie	010070	362	227	308	314
Kojaneerup	009754	409	408	499	605
Kurrenkutten	010603	287	199	257	317
Mingenew	008299	363	271	362	354
Moora	008008	435	247	324	428
Morawa	009296	327	191	249	284
Neridup	009739	572	420	566	553
Salmon Gums	012071	201	304	385	354
Tambellup	010643	344	307	322	447
Wadderin	010119	272	212	310	345
Yealering	010912	289	227	260	291
Yuna	008147	291	188	286	341

There was a range of rainfall zones seasonal conditions covered by all sites during the 2018 to 2020 period (Table 8). Rainfall was variable in 2018 between sites, with sites either being near average, above, or below the long-term average for each site. The 2019 and 2020 seasons were generally below average for most sites in this study and the dry conditions prompted a change in crop rotations at some sites. For example, canola at the Kadathinni site in 2020 season was fallowed due to poor establishment from severe wind erosion sustained at the season break along with dry conditions. Additionally, the Kalannie site was cut for hay in 2019 following low rainfall and high weed burden, while dry seasonal conditions meant that the Morawa site was fallowed in the 2020 season.

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Clay-based Soil Types

Plant Establishment

Table 9. Plant counts per square metre of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as clay based. Note: Plant counts not available for the 2018 season.

Site (Soil type)	Year (Crop)	Amelioration method	Plants/m²
Cascade (Heavy Grey Clay)	2019 (Barley)	Control	110
		Max Tillage	110
		Rip 30cm	90
		Rip 60cm	80
	2020 (Canola)	Control	17
		Max Tillage	17
		Rip 30cm	21
		Rip 60cm	25

NDVI

NDVI was not measured at the Cascade site.

Grain Yield

Table 102. Grain yield of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as clay based.

Site (Soil type)	Treatment	Grain Yield (t/ha) 2018	2019	2020
Cascade (Heavy grey clay)	Crop	Wheat	Barley	Canola
	Control	1.9	2	1
	Rip 30cm	2.5	1.9	1
	Rip 60cm	2.4	1.7	0.7

The cascade site was the only clay-based site in the study where deep ripping was compared to maximum tillage and a control treatment. There was a large difference between the two ripping treatments in the 2018 year, but this was not sustained into the future years (Table 10). All soil amelioration treatments gave an inconsistent impact on plant establishment in each year where it was measured (Table 9), with a trend that ripping reduced plant establishment in the 2019 year, but significantly increased plant establishment in the 2020 year (as denoted by lower case letters).

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Gravel Soil Types

Plant Establishment

Table 11. Plant counts/m2 of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a gravel.

Site (Soil type)	Year (Crop)	Amelioration method	Plants/m2
Darkan (Forest Gravel)	2018 (Canola)	Control	16
		Mouldboard	13
		Rip 60cm	19
Neridup (Deep Sandy Gravel)	2019 (Barley)	Control	82
		Max Tillage	70
		Rip 60cm	82
		Rip 60cm + Max Tillage	79
	2020 (Lupins)	Control	43
		Max Tillage	40
		Rip 60cm	39
		Rip 60cm + Max Tillage	41

NDVI

Table 12. NDVI measurements of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a gravel.

Site (Soil type)	Year (Crop)	Amelioration method	NDVI (GS30)
Darkan (Forest Gravel)	2018 (Canola)	Control	0.56
		Mouldboard Plough	0.42
		Rip 60cm	0.69
	2019 (Barley)	Control	0.54
		Mouldboard Plough	0.33
		Rip 60cm	0.48
	2020 (Canola)	Control	0.42
		Mouldboard Plough	0.38
		Rip 60cm	0.41

Grain Yield

Table 133. Grain yield for soil amelioration treatments at each site in the 2018-2020 seasons where the soil was generally described as containing gravel.

Site (Soil type)	Treatment	Grain Yield (t/ha) 2018	2019	2020
Darkan (Forest Gravel)	Crop	Canola	Barley	Canola
	Control	2.6	3.3	1.3
	Mouldboard plough	2	2.9	1.3
	Rip 30cm	2.5	3	1.4
Neridup (Deep Sandy Gravel)	Crop	Canola	Barley	Lupins
	Control	2.3	6.1	2.6
	Max Tillage	3	5.4	2
	Rip 60cm	2.2	5.5	2.2

	Rip 60cm + Max Tillage	1.8	6.7	2.2

There was a clear and consistent trend that the mouldboard plough treatment at the Darkan site (on a forest gravel) had a negative impact on crop growth and production over the 3 years of this study. Plant establishment was significantly affected in 2018 (Table 11) and NDVI for each of the year of study (Table 12). The grain yield benefit for all soil amelioration treatments ranged between -0.7 t/ha and 0.6 t/ha across all sites in this subgroup. The maximum tillage treatment in 2018 led to the highest or equal highest grain yield at the site, but this was not sustained in subsequent seasons. In many cases for the 2020 season, the tillage treatments at each site were similar or lower than the control treatment, indicating little to no long-term benefit of amelioration practices.

Duplex Soil Types

Plant Establishment

Table 14. Plant counts/m2 of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a duplex.

Site (Soil type)	Year (Crop)	Amelioration method	Plants/m2
Coomalbidgup (Sandy Gravel over Clay)	2018 (Wheat)	Control	88
		Max Tillage	176
		Rip 60cm	220
		Rip 60cm + Spader	164
		Spader	192
	2019 (Lupins)	Control	16
		Max Tillage	8
		Rip 60cm	20
		Rip 60cm + Spader	4
		Spader	3
	2020 (Wheat)	Control	84
		Max Tillage	92
		Rip 60cm	96
		Rip 60cm + Spader	92
		Spader	96
Dalwallinu (Sand over Gravel)	2018 (Wheat)	Control	92
		Max Tillage	108
		Rip 60cm	136
		Rip 60cm + Shallow Disc	56
		Shallow Disc	56
	2019 (Wheat)	Control	41
		Max Tillage	33
		Rip 60cm	33
		Rip 60cm + Shallow Disc	39
		Shallow Disc	31
Kadathinni (Sand over Gravel)	2018 (Wheat)	Control	108
		Max Tillage	96
		Plozza Plow	96
		Rip 60cm	48
Salmon Gums	2018 (Wheat)	Control	64

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Site (Soil type)	Year (Crop)	Amelioration method	Plants/m2
(Sandy Loam over Clay)		Rip 30cm	68
		Rip 60cm	80
	2020 (Wheat)	Control	53
		Rip 30cm	52
		Rip 60cm	50
Wadderin (Sand over Gravel)	2018 (Canola)	Control	24
		Rip 30cm	24
		Rip 30cm + Dolomite	24
		Rip 60cm	16
	2019 (Wheat)	Control	103
		Rip 30cm	87
		Rip 30cm + Dolomite	88
		Rip 60cm	92
	2020 (Barley)	Control	78
		Rip 30cm	57
		Rip 30cm + Dolomite	46
		Rip 60cm	77
Yealering (Sandy Loam over Gravel)	2018 (Wheat)	Control	122
		Rip 30cm	123
		Rip 60cm	124
	2019 (Wheat)	Control	129
		Rip 30cm	152
		Rip 60cm	170
	2020 (Wheat)	Control	168
		Rip 30cm	168
		Rip 60cm	188

NDVI

Table 15. NDVI measurements of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a duplex.

Site (Soil type)	Year (Crop)	Amelioration method	NDVI (GS30)
Broomehill (Gravelly Duplex)	2018 (Lupins)	Control	0.56
		Plozza Plow	0.62
		Rip 60cm	0.62
		Rip 60cm + Mouldboard	0.62
		Rip 60cm + Plozza	0.65
	2019 (Wheat)	Control	0.43
		Plozza Plow	0.41
		Rip 60cm	0.38
		Rip 60cm + Mouldboard	0.38
		Rip 60cm + Plozza	0.44
Dalwallinu (Sand over Gravel)	2018 (Wheat)	Control	0.67
		Max Tillage	0.77
		Rip 60cm	0.76

Site (Soil type)	Year (Crop)	Amelioration method	NDVI (GS30)
		Rip 60cm + Shallow Disc	0.74
		Shallow Disc	0.75
Kadathinni (Sand over Gravel)	2019 (Lupins)	Control	0.33
		Max Tillage	0.47
		Plozza Plow	0.48
		Rip 60cm	0.49
Tambellup (Loamy Duplex)	2019 (Wheat)	Control	0.79
		Plozza Plow	0.73
		Rip 60cm	0.72
		Shallow Disc	0.80
Wadderin (Sand over Gravel)	2020 (Barley)	Control	0.33
		Rip 30cm	0.44
		Rip 30cm + Dolomite	0.35
		Rip 60cm	0.30
Yealering (Sandy Loam over Gravel)	2018 (Wheat)	Control	0.51
		Rip 30cm	0.50
		Rip 60cm	0.52
	2019 (Wheat)	Control	0.51
		Rip 30cm	0.45
		Rip 60cm	0.52
	2020 (Wheat)	Control	0.63
		Rip 30cm	0.67
		Rip 60cm	0.65

Grain Yield

Table 164. Grain yield for soil amelioration treatments at each site in the 2018-2020 seasons where the soil type was generally described as a duplex. The Tambellup site commenced in 2019.

Site (Soil type)	Treatment	Grain Yield (t/ha) 2018	2019	2020
Broomehill (Gravelly Duplex)	Crop	Lupins	Wheat	Canola
	Control	1.9	3	2
	Plozza Plow	2.4	2.9	1.9
	Rip 60cm	1.9	3.2	2.1
	Rip 60cm + Mouldboard	2.3	3.6	1.9
	Rip 60cm + Plozza Plow	2.2	3.7	2
Coomalbidgup (Sandy Gravel over Clay)	Crop	Wheat	Lupins	Wheat
	Control	6.1	1.5	3.8
	Max Tillage	6.7	1.3	3.4
	Rip + Spade	6.6	1.3	4.3
	Rip 60cm	6.8	1.3	3.9
Dalwallinu (Sand over Gravel)	Crop	Wheat	Wheat	Barley
	Control	5	1.3	2.4
	Max Tillage	6.1	1.5	2.8
	Shallow Disc	5	1.4	2.3

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	Rip 60cm	5.3	1.6	2.4
	Rip 60cm + Shallow Disc	5.3	1.5	2.3
Kadathinni (Sand over Gravel)	Crop	Wheat	Lupins	Fallow
	Control	2.2	1.2	Fallow
	Max Tillage	2.5	1.4	Fallow
	Plozza Plow	2.3	1.5	Fallow
	Rip 60cm	2.2	1.5	Fallow
Salmon Gums (Sandy Loam over Clay)	Crop	Wheat	Wheat	Wheat
	Control	2.8	1	2
	Rip 30cm	3.3	1.1	1.9
	Rip 60cm	4	1.3	2.3
Tambellup (Loamy Duplex)	Crop	No Trial	Wheat	Canola
	Control	No Trial	6.3	2.5
	Maximum tillage	No Trial	5.7	2.5
	Plozza Plow	No Trial	6.1	2.4
	Shallow disc	No Trial	6.3	2.5
Wadderin (Sand over Gravel)	Crop	Canola	Wheat	Barley
	Control	0.4	0.9	1.5
	Rip 30cm	0.3	1	1.4
	Rip 30cm + Dolomite	0.3	1	1.5
	Rip 60cm	0.2	0.9	1.2
Yealering (Sandy Loam over Gravel)	Crop	Wheat	Wheat	Wheat
	Control	2	2.1	4.4
	Rip 30cm	2.2	2.3	4.4
	Rip 60cm	2.3	1.9	4.4

There were few discernible trends in the data for plant establishment at the duplex soil sites for the 2018-20 seasons. (Table 14). There were also few trends in NDVI present and (Table 15), and little impact of the soil amelioration treatments on grain yield across all sites and years for the duplex soil type (Table 16). The duplex soil type appeared unresponsive to soil amelioration using the treatments in this study.

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Sandy Soil Types

Plant Establishment

Table 17. Plant counts/m² of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a sand.

Site (Soil type)	Year (Crop)	Amelioration method	Plants/m²
Kojaneerup (White Sandplain)	2018 (Wheat)	Control	103
		Rip 30cm	111
		Rip 60cm	108
		Scarifier	123
	2019 (Canola)	Control	27
		Rip 30cm	28
		Rip 60cm	25
		Scarifier	31
Kurrenkutten (Wodjil Sand)	2018 (Barley)	Control	31
		Rip 30cm	33
		Rip 30cm + Shallow Disc	29
		Rip 60cm	29
	2019 (Barley)	Control	30
		Rip 30cm	41
		Rip 30cm + Shallow Disc	36
		Rip 60cm	34
	2020 (Barley)	Control	46
		Rip 30cm	36
		Rip 30cm + Shallow Disc	47
		Rip 60cm	43

NDVI

Table 18. NDVI measurements of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a sand.

Site (Soil type)	Year (Crop)	Amelioration method	NDVI (GS30)
Kojaneerup (White Sandplain)	2018 (Wheat)	Control	0.64
		Rip 30cm	0.63
		Rip 60cm	0.65
	2019 (Canola)	Control	0.57
		Rip 30cm	0.59
		Rip 60cm	0.59
		Scarifier	0.55
Kurrenkutten (Wodjil Sand)	2018 (Barley)	Control	0.28
		Rip 30cm	0.38
		Rip 30cm + One way Plough	0.23
		Rip 30cm + Shallow Disc	0.23
		Rip 60cm	0.33

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Grain Yield

Table 195. Grain Yield of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a sand. nd=Trial site discontinued.

Site (Soil type)	Treatment	Grain Yield (t/ha) 2018	2019	2020
Kojaneerup (White Sandplain)	Crop	Wheat	Canola	Wheat
	Control	6	1.2	nd
	Rip 30cm	6.1	1.4	nd
	Rip 60cm	5.8	1.3	nd
	Shallow Disc	5	1.1	nd
Kurrenkutten (Wodjil Sand)	Crop	Barley	Barley	Barley
	Control	2.9	1.6	1.1
	Rip 30cm	3.4	1.5	1
	Rip 30cm + Shallow Disc	3.6	1.5	0.9
	Rip 60cm	3.6	1.5	1

This study evaluated two sandy soil types that are not normally considered for ripping due to lower fertility or location in the southern region. While there was an increase of up to 0.7 t/ha of grain yield from soil amelioration treatments in 2018 at the Kurrenkutten site, there was little difference in grain yield for subsequent growing seasons. The treatments at the Kojaneerup site were altered in the 2020 season in response to the severe impact of soil water repellence identified by the host farmer and this led to the paddock being spread with subsoil clay. In this instance, clay spreading and ripping to 60cm resulted in a greater yield compared to spreading clay alone (data not presented as treatment structure/sampling was altered).

Loam Soil Types

Plant Establishment

Table 20. Plant counts/m^2 of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a loam.

Site (Soil type)	Year (Crop)	Amelioration method	Plants/m2
Gorge Rock (Sandy Clay Loam)	2018 (Wheat)	Control	200
		One-way Plough	221
		Rip 30cm	196
		Rip 60cm	206
	2019 (Barley)	Control	167
		One-way Plough	213
		Rip 30cm	160
		Rip 60cm	182
	2020 (Canola)	Control	41
		One-way Plough	39
		Rip 30cm	39
		Rip 60cm	37
Kalannie (Loamy Sand)	2019 (Wheat Hay)	Control	74
		Max Tillage	73

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Site (Soil type)	Year (Crop)	Amelioration method	Plants/m2
		Rip 60cm	65
		Shallow Disc	52
	2020 (Canola)	Control	93
		Max Tillage	116
		Rip 60cm	89
		Shallow Disc	88
Mingenew (Loamy Sand)	2018 (Wheat)	Control	47
		Plozza Plow	48
		Rip 60cm	40
		Rip 60cm + Spader	40
		Spader	44
Moora (Silty Clay Loam)	2018 (Barley)	Control	156
		Rip 60cm	175
	2019 (Canola)	Control	23
		Rip 60cm	31
Morawa (Red Sandy Loam)	2018 (Wheat)	Control	62
		Rip 30cm	59
		Rip 60cm	38
Yuna (Sandy Loam)	2018 (Wheat)	Control	32
		Rip 30cm	30
		Rip 30cm + Inclusion Plates	21
		Rip 60cm	26
		Rip 60cm + Inclusion Plates	18

NDVI

Table 21. NDVI measurements of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a loam.

Site (Soil type)	Year (Crop)	Amelioration method	NDVI (GS30)
Gorge Rock (Sandy Clay Loam)	2018 (Wheat)	Control	0.37
		One-way plough	0.39
		Rip 30cm	0.39
		Rip 60cm	0.38
	2019 (Barley)	Control	0.46
		One-way plough	0.44
		Rip 30cm	0.46
		Rip 60cm	0.44
Hines Hill (Sandy Loam)	2019 (Canola)	Control	0.31
		Rip 30cm	0.25
Kalannie (Loamy Sand)	2018 (Wheat)	Control	0.49
		Max Tillage	0.43
		Rip 60cm	0.47
		Shallow Disc	0.48

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Site (Soil type)	Year (Crop)	Amelioration method	NDVI (GS30)
	2019 (Wheat Hay)	Control	0.56
		Max Tillage	0.61
		Rip 60cm	0.65
		Shallow Disc	0.61
	2020 (Canola)	Control	0.66
		Max Tillage	0.68
		Rip 60cm	0.73
		Shallow Disc	0.69
Mingenew (Loamy Sand)	2018 (Wheat)	Control	0.55
		Plozza Plow	0.54
		Rip 60cm	0.56
		Rip 60cm + Spader	0.50
		Spader	0.46
	2019 (Wheat)	Control	0.33
		Plozza Plow	0.31
		Rip 60cm	0.30
		Rip 60cm + Spader	0.32
		Spader	0.33
Moora (Silty Clay Loam)	2018 (Barley)	Control	0.77
		Rip 60cm	0.75
	2019 (Canola)	Control	0.67
		Rip 60cm	0.68
Morawa (Red Sandy Loam)	2018 (Wheat)	Control	0.53
		Rip 60cm	0.55
		Rip 60cm + Shallow Disc	0.52

Grain Yield

Table 226. Grain Yield of soil amelioration treatments at sites in the 2018-2020 seasons where the soil type was generally described as a loam.

Site (Soil type)	Treatment	Grain Yield (t/ha)		
		2018	2019	2020
Gorge Rock (Sandy Clay loam)	Crop	Wheat	Barley	Canola
	Control	2.7	2.9	1.1
	One-way plough	2.5	3.1	1.2
	Rip 30cm	2.9	3.2	1.1
	Rip 60cm	3.3	3.2	1.2
Hines Hill (Sandy Loam)	Crop	Fallow	Canola	Wheat
	Control	-	0.4	1.7
	Rip 25cm	-	0.7	2
	Rip 60 cm	-	0.8	2.1
	Rip 60 cm + Morrell lime	-	0.8	1.9
Kalannie (Loamy Sand)	Crop	Wheat	Hay	Canola
	Control	2.7	-	2

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	Max Tillage	3.6	-	2.4
	Shallow Disc	3	-	2.5
	Rip 30cm	4.2	-	2.2
	Shallow Tillage	2.7	-	2.5
Mingenew (Loamy Sand)	Crop	Wheat	Wheat	Canola
	Control	3.7	1.3	3.2
	Plozza Plough	3.9	1.4	3.2
	Rip 60cm	4.1	1.6	3.1
	Rip 60cm + Spader	4.2	1.4	3.1
	Spader	4.1	1.6	3.4
Moora (Silty Clay Loam)	Crop	Barley	Barley	Canola
	Control	6	6	0.6
	Rip 60cm	6.1	6	0.6
Morawa (Red Sandy Loam)	Crop	Wheat	Wheat	Fallow
	Control	3.7	1.1	-
	Rip 30cm + Inc. Plates	3.5	1.1	-
	Rip 60cm + Inc. Plates	3.5	1.1	-
Yuna (Sandy Loam)	Crop	Wheat	Canola	Canola
	Control	2.2	0.4	0.4
	Rip 30cm	2	0.5	0.5
	Rip 30cm + Inc. Plates	2.2	0.4	0.4
	Rip 60cm	2.8	0.5	0.5
	Rip 60cm + Inc. Plates	2.3	0.4	0.4

There was a trend among the loamy soil types that the benefit of soil amelioration was confined to the first year (Table 22). The exceptions were the Kalannie and Mingenew sites which were classified as a loamy sand and these sites had a benefit to soil amelioration in all study years. There was no impact of soil amelioration on plant establishment in each year (Table 20) and few, but variable results on crop growth (NDVI) during the season (Table 21).

Economic Benefit of Soil Amelioration

The increase or decrease in grain yield from individual soil amelioration treatments relative to the control at each site, was used to calculate the economic benefit to the grower from soil amelioration activities. Each site was uniformly managed within seasons so the variation in grain yield presents an increase or decrease in resource use efficiency for soil amelioration treatments compared to the control. There was a positive economic benefit to soil amelioration activities for 60% of soil amelioration treatments imposed across all sites after the 2020 season, an increase from 46% in the 2019 season (Figure 1). This gave a mean economic benefit of $164/ha where the economic benefit was positive. In contrast, 40% of treatments resulted in a loss, averaging -$154/ha due to cumulative yield penalties associated with the amelioration activity. Additionally, there were only six out of 63 treatments that returned an economic benefit of greater than $300/ha in total from the three production years across all sites (Table 24). In contrast, there were five treatments that resulted in an economic loss greater than -$200/ha over the three years (Table 24). The economic benefit includes the initial cost of soil amelioration treatment as outlined in Table 23.

The highly variable cumulative economic benefit is influenced by the very small increases in grain yield observed for most soil amelioration treatments across all sites in this study, along with a lack of consistent grain yield benefit from any specific treatment. Seasonal conditions (average annual and growing season rainfall) have varied within and between years and sites in this study (Table 8).

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Table 237. Average cost of each soil amelioration treatment used in this study as determined by participating growers in the project.

Method of Amelioration	Cost/ha
Deep ripping	$73
Spading	$90
Plozza ploughing	$64
Mouldboard ploughing	$184
Shallow tillage	$40
Aggressive Tillage	$45
Morrel Lime (inc. spreading)	$80
Gypsum (inc. spreading)	$45
Local Grower solution	Any combination of above

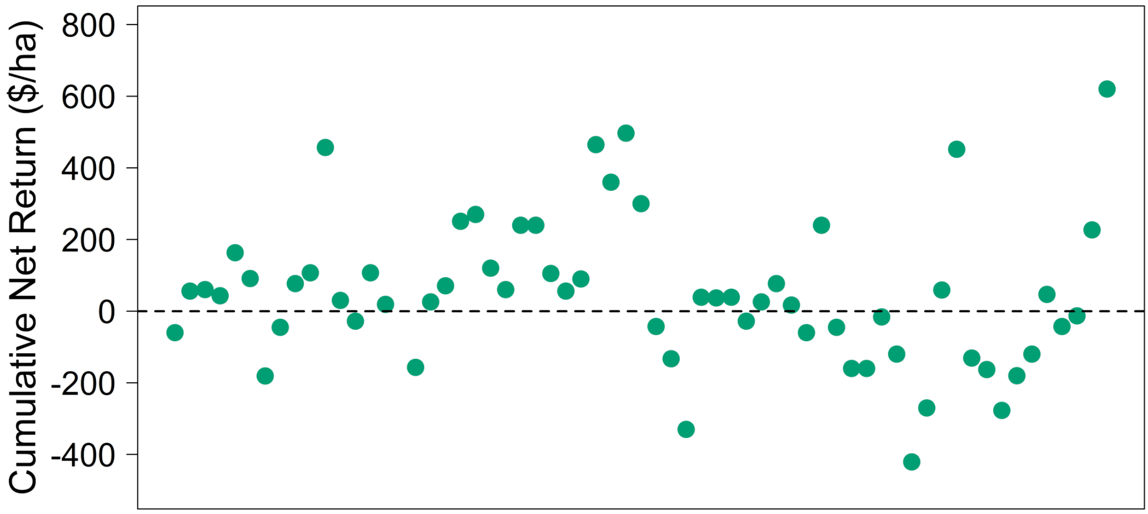

Figure 1. Cumulative (three year) economic benefit or loss for soil amelioration treatments across all Ripper Gauge sites. Data represents the additional financial profit/loss from the change in grain yield of each soil amelioration treatment compared to the control treatment (nil amelioration). Agronomic inputs are held constant at each site. The cost of soil amelioration has been subtracted from the cumulative economic benefit (Table 24).

Table 248. Summary of the five most and least profitable treatments in the Ripper Gauge project across all sites using the cumulative economic benefit which considers the cost of amelioration.

Treatment	Site	Soil Type	Cumulative Economic Value ($/ha)
Rip 60cm + Inc. Plates	Yuna	Sandy Loam	620
Rip 30cm	Kalannie	Loamy Sand	497
Maximum Tillage	Kalannie	Loamy Sand	465
Maximum Tillage	Dalwallinu	Sand over Gravel	457
Rip 60cm	Salmon Gums	Sandy Loam over Clay	452
Rip 60cm + Max Tillage	Neridup	Deep Sandy Gravel	-270
Rip 60cm	Wadderin	Sand over Gravel	-277
Shallow Tillage	Kojaneerup	White Sandplain	-330
Rip 60cm	Neridup	Deep Sandy Gravel	-421
Mouldboard plough	Darkan	Forest Gravel	-656

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Rainfall

Table 25. Compiled annual rainfall (mm) across 2021 to 2022 seasons including comparison to the Long-Term Average (LTA) collected from various Bureau of Meteorology weather stations.

Site	BOM station	2021	2022	2023	LTA
Corrigin	010536	457	445	329	373
Dandaragan	009006	511	526	248	476
Latham	008072	490	357	209	305
Mingenew	008299	469	402	192	354

Crop rotation and ripper configuration at each site

Table 26. Summary of crop types sown in each year and a description of deep ripper used at each site.

Site	2021 Crop	2022 Crop	Ripper configuration
Corrigin	Barley	Canola	600mm with coil packers
Dandaragan	Wheat	Canola	700mm with crumble roller
Latham	Canola	Wheat	600mm, no roller
Mingenew	Wheat	Canola	600mm with tyre roller

There was predominantly cereal sown at each site in the year of deep ripping apart from the Latham site where grower practice was to sow canola following deep ripping (Table 26). Each site was aimed to be ripped to depth of 600-700mm and with a roller of some description to close the soil following ripping. Most ripping equipment was set up for pre-seeding ripping and had more aggressive rollers to reduce clods and level the soil surface. The most aggressive ripper/roller combination was used at the Dandaragan site, and this had a severe impact on crop growth, such that the farm owner chose to discontinue the trial because of the severe damage caused to the crop. In general, there was a decrease in plant numbers following deep ripping (Table 27) due to the translocation of plants during the ripping process. There was a tendency for the deep ripping prior to seeding treatment to increase plant numbers at the Corrigin and Mingenew sites, and differences in grain yield tended to reflect differences in plant numbers. There was a low level of soil water repellence at each site as indicated by the Molarity of Ethanol Droplet (MED) test, except for the Mingenew site which had a moderate level of water repellence (Table 27).

Table 27. In-season measurements taken two weeks after the imposition of the last ripping treatment (6WAS) at each site in this study. Gaps in data are where data is not available. The Dandaragan site was discontinued at the request of the farm owner due to negative impact of early post emergent ripping on crop establishment and growth. The Dandaragan site was discontinued in 2022. Soil Water Repellence Rating = SWRR, Plant Establishment = PE.

Site	Treatment	2021			2022		
		Crop Type	SWRR (MED)	PE (Plants/m^2)	Crop Type	SWRR (MED)	PE (Plants/m^2)
Corrigin	Control	Barley	0	91	Canola	0	nd
	Pre-seeding		0	112		0	nd
	1WAS		0	80		0	nd
	3WAS		0	58		0	nd
	6WAS		0	82		0	nd
Latham	Control	Canola	0	15	Wheat	0	119
	Pre-seeding		0	nd		0	nd
	1WAS		0	12		0	119

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Site	Treatment	2021			2022		
		Crop Type	SWRR (MED)	PE (Plants/m²)	Crop Type	SWRR (MED)	PE (Plants/m²)
	3WAS		0	20		0	119
	6WAS		0	19		0	119
Mingenew	Control	Wheat	0.25	85	Canola	2	35
	Pre-seeding		2	nd		2	nd
	1WAS		2	97		2	31
	3WAS		2	64		2	25
	6WAS		2	80		2	nd
Dandaragan	Control	Wheat	0	nd	Canola	0	nd
	Pre-seeding		0	nd		0	nd
	1WAS		0	nd		0	nd
	3WAS		0	nd		0	nd
	6WAS		0	nd		0	nd

The impact of each ripping practice on soil strength was clearly evident at each site, with all treatments lowering soil strength below the threshold where root growth becomes increasingly limited (i.e. greater than 2500 kPa) as shown in Figure 2 Prior to deep ripping, all sites were above 2500kPa from about 200-250mm soil depth and below. The target ripping depth was 600mm and it appears that this depth has been achieved at all sites and has significantly reduced soil strength down to at least 500mm.

Grain yield for at all sites in both the 2021 and 2022 seasons exhibit either a slight downward trend or no impact at all compared to the Nil (no deep ripping) treatment (Figure 3). The pre-seeding ripping treatment often had the highest grain yield, and this was followed by ripping early after seeding (1WAS). The impact of ripping later in the season was evident on grain yield as it impacted on plant growth which was not able to be compensated by the crop (data not presented). The severity of the impact on crop growth meant that the host grower at the Mingenew and Dandaragan sites opted to discontinue the trial and not implement the 6WAS treatment.

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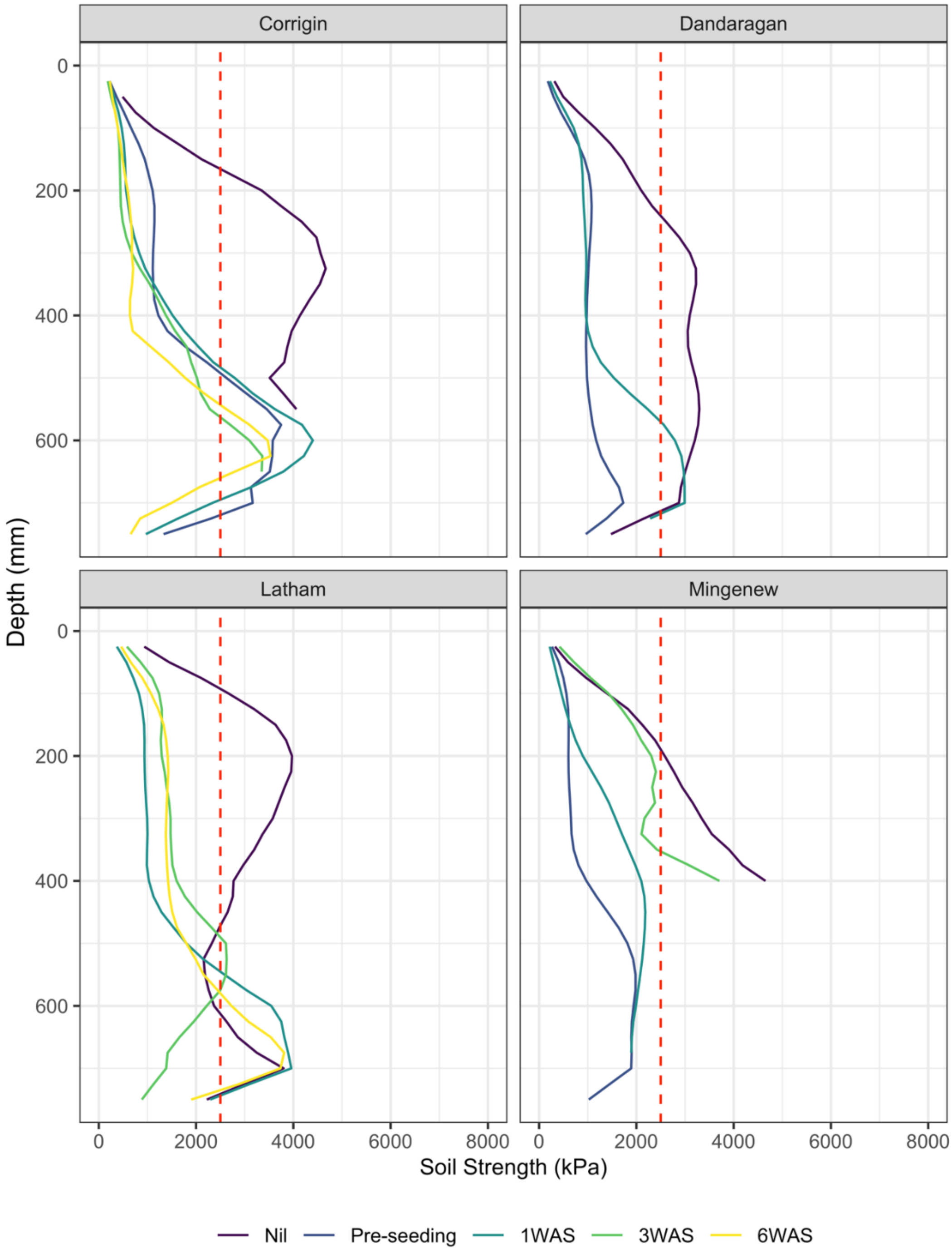

Figure 2. Soil strength for each site where early post-emergent ripping strategies were investigated in 2021-22. Measurements taken in July 2021 at field capacity of soil at each site. Red dotted line indicates where root growth becomes increasingly restricted at soil strength greater than 2500kPa. WAS = Ripping completed 1, 3, 6 weeks after seeding. Note: not all sites had ripping treatments imposed due to host grower hesitation.

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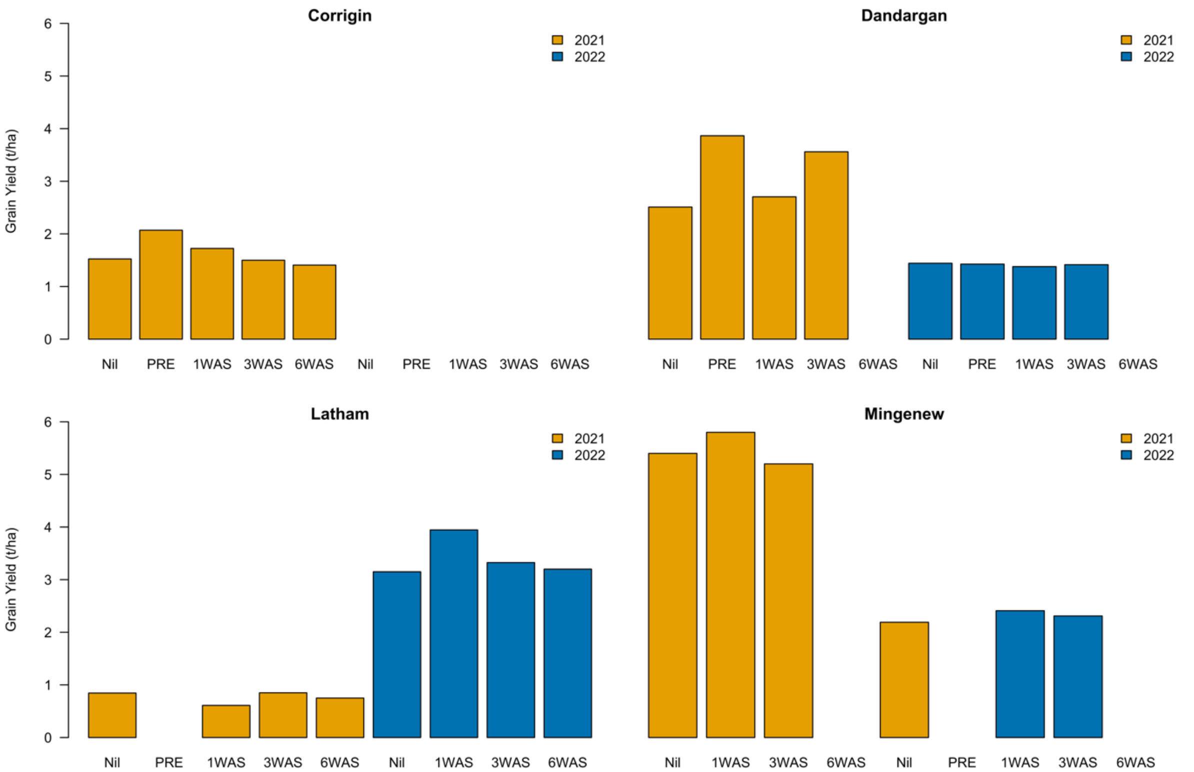

Figure 3. Grain yield for each treatment at each site for 2021. WAS = Weeks After Sowing. Data for the Corrigin site for 2022 not available at time of publication.

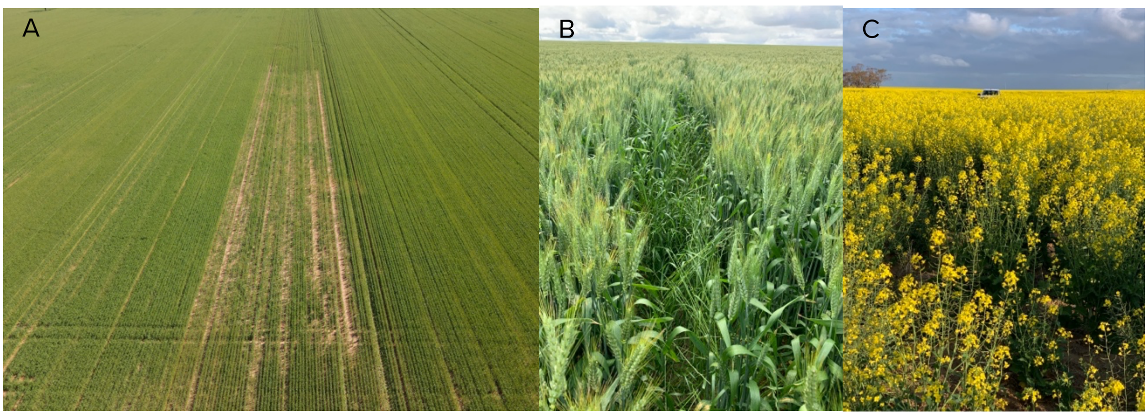

Figure 4. Impact of early post-emergent ripping on plant establishment at the Dandaragan site (1 week after sowing (A), the increase in annual ryegrass in gaps left by the ripper at the Mingenew site (B), and gaps left in canola (foreground) where plant establishment was impacted with post emergent ripping at Latham (C).

The impact of early post emergent ripping at each site had differing effects on crop production (Figure 4). At the Dandaragan site, the aggressiveness of the deep ripper/roller combination had a large and visual impact on plant numbers, and this led to the termination of the site by the farm owner. Where deep ripping was completed at the Mingenew site at a slight angle (5 degrees) to the direction of sowing, it was evident that annual ryegrass had populated the area where short lengths of crop row (~0.5m) had been pulled out by the ripper as it crossed the seeding row. In comparison there were fewer weeds in the rest of the crop. At the Latham site, plant numbers were low where early post emergent ripping was used, and this was reflected in there being many larger areas (~1m^2) where there was no crop growing. Plant establishment was higher at the Corrigin site for the pre-seeding ripping treatment, and

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this is clear in the early vigour of the treatment compared to the control (Figure 5). The reduction in early plant vigour is evident in the early post-emergent ripping treatment at the Corrigin site.

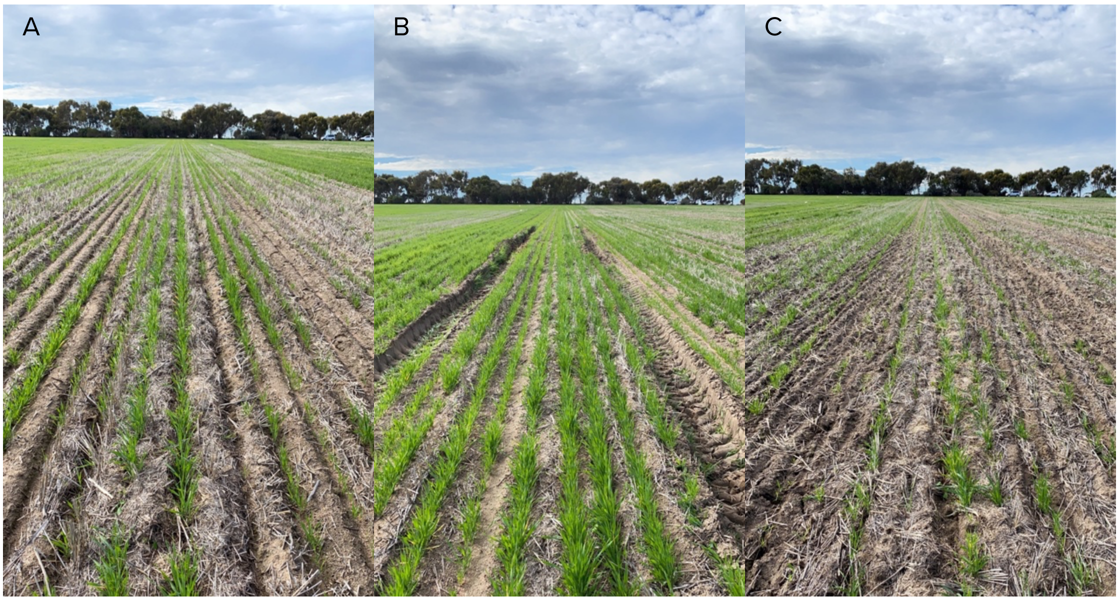

Figure 4. Difference in the success of plant establishment for the control (nil ripping, A), pre-seeding rip (B), and early post emergent ripping (3 weeks after seeding, C) at the Corrigin site. Photos taken 8 weeks after seeding.

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DISCUSSION

2018-2020 – Soil Amelioration vs Soil Type

The results of the 2018-2020 study have shown significant variation in crop response to amelioration between sites, crop types, years, and seasonal conditions. This contrasts with previous work that demonstrated more consistent benefits from ripping the deep sand-based soils in WA, particularly in the north of the grain growing region. The soil types in this study were very broad and encompassed clay, gravel, duplex, loam, and sandy soils that have not been evaluated for deep ripping. Establishing sites in this study presented significant challenges, as these soils are difficult to work with due to the presence of hard-setting layers, rock, or gravel, which limit the ability to effectively penetrate these soils. The impact of these soils on the wear and tear of machinery was not a factor when establishing these trial sites as they were very small in size relative to the area that could potentially benefit from amelioration. This is a factor that will need to be addressed by any grower seeking to ameliorate these other soil types.

There was not a clear or consistent crop production or grain yield advantage to ameliorating many of the soils in this study. There was often a decreasing trend in grain yield in the years following the soil amelioration practice at many sites and this may be due to the presence or activation of other subsoil constraints. The series of years also exhibited a declining trend for rainfall, and this is likely to impact the potential for the benefit to crop production to be realised. However, one of the advantages of soil amelioration is that roots gain increased access to a greater volume of soil as constraints to plant growth are removed. Grain yield would also have been impacted by the choice of crop in the 2020 season; canola, being a break crop, is sensitive to dry seasons and, as such, yield would have been severely impacted. The impact of the dry season on canola grain yield in 2020 was evident in two sites (Morawa and Kadathinni) being fallowed during the season in response to poor canola establishment, growth, and anticipated low grain yield. The data from this study aligns with previous deep ripping work in sandplain soils, where the longevity of deep ripping response is predicted to be 3-5 years, depending on the farming system and machinery employed. The longevity of benefit for each site in this study is likely to be less than three years. Considering that the grain yield response is highly variable from year to year and dependent on interactions with seasonal conditions, it is expected that soil amelioration on many of the ‘other’ soil types across the region is not economically viable.

There is not a strong economic case for adopting soil amelioration practices, particularly deep ripping, across a wider range of ‘other’ soil types. There were a few instances where significant cumulative increases in net return were achieved above $300/ha (equating to a $100/ha/year benefit); however, 40% of treatments resulted in a long-term net loss compared to the control. This threshold was selected as a reasonable return on investment; however, this threshold will vary between growers and businesses depending on their target returns and appetite for risk. Greater definition of what constitutes success is also required to interpret the results of this project. For example, a grower may be satisfied with a $50/ha return per year for a soil amelioration activity if it decreases the variability in grain yield from year to year. Alternatively, growers may have a threshold that needs to be achieved to justify the return on investment from soil amelioration practices. Given the high variability in grain yield between years, it is unlikely that soil amelioration practices on ‘other’ soil types will be widely adopted by growers, as it does not lead to a production advantage or a reduction in production variability (based on the results of this study). Further studies to identify the most appropriate soil amelioration method, or machine, for these soil types may improve the benefit to crop production, however, this study was limited to the application of methods that have been proven on deep sandy soils to other soil types.

The 2018-20 study was based on the use of deep ripping to ameliorate compacted soils, and the results could be limited where there are multiple soil constraints present at each site. For example, the presence of subsoil acidity would still be a severe chemical barrier for root growth and would limit the grain yield benefit from any deep ripping treatment. The inclusion of a grower-led option for ameliorating the soil often involved using multiple amelioration

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methods and/or soil amendments. This indicates that growers are considering the range of soil constraints in these soils and future work should focus on developing custom amelioration solutions for these soils. At some sites, the combination of ripping and soil inversion (mouldboard or Plozza Plow) or soil mixing (spading) were high-yielding treatments, likely indicating an issue with soil water repellence at some sites. The inconsistent grain yield benefit from these treatments indicates that there likely other factors at play, and the decision of what amelioration practice to use on these 'other' soil types is still unclear.

2021-2022 – Effects of Early Post Emergent Ripping

The 2021-22 study has identified that the practice of early post emergent deep ripping does not lead to an increase in grain yield in the year of deep ripping that is commonly expected from the practice of deep ripping. The impact of pre-seeding deep ripping appears to have two benefits in that it tended to increase plant establishment and led to an increase in plant vigour compared to where no ripping had occurred (control treatment). This early vigour likely was a key factor in the higher grain yield for the practice of pre-seeding ripping as even though the soil was loosened with the early post emergent deep ripping, the plant was not able to compensate for the reduction in early plant vigour.

The impact of early post emergent deep ripping was exacerbated by the depth of ripping and the aggressiveness of the roller that follows the ripper. It is now standard practice for growers to aim to deep rip to a depth of 600-700mm to address soil compaction, compared to 300mm when deep ripping was first introduced in the 1980's (Perry, 1986). In conversing with growers who have had prior experience in early post emergent ripping, it was explained that historically, only a depth of 300mm ripping had been used and this was expected to move less dirt and have less impact on plant establishment. Ripping to a depth of 600mm increases the fracture of the topsoil and tends to achieve a greater level of soil disturbance in general (Ucgul et al., 2020). Where ripping to depth is practiced prior to seeding, a heavy or aggressive roller is needed to break down clods that are raised to the surface during ripping. This aggressive roller likely caused a significant amount of damage and was seen flicking up plants and dirt during the ripping process. The constraint of the use of aggressive crumble rollers are that they are often integrated into the structure of the deep ripper, and this limits the applicability of most deep rippers on the market to the post emergent practice. For early post emergent deep ripping to be successful, deep rippers that have low soil disturbance and with a non-aggressive roller are considered ideal in hopes to decrease the impact on crop growth. Early post emergent deep ripping may also be aided by greater accuracy in the placement of seeding and deep ripping rows, with wider row spacing likely to lessen the impact of the ripping process, particularly where inter-row ripping is achieved. This is an area for future study if there are growers capable of undertaking this practice.

Significant management issues have tended to arise from the activities of this project. The reduction in plant establishment across all sites from the deep ripping was in part transitory, in that the impact was most visual in the two weeks following deep ripping. In conversing with growers who have previous experience in early post emergent deep ripping, it was suggested to 'not look at the paddock for a few weeks.' Overall, plant establishment was lower for pre-seeding ripping compared to early post seeding timings despite each treatment looking visually better after two weeks post ripping. Where the direction of ripping and seeding were parallel, the impact of early post emergent deep ripping was to displace and rearrange the plants in the soil and disturb the rows of crop from seeding. This displacement caused a reduction in growth that has the potential for weeds to establish, compete with crop growth in the year of ripping, and cause issues for the future management of the paddock. Where ripping was conducted at a slight angle to the direction of seeding, this resulted in frequent patches where short sections of crop were removed, leaving a gap in the crop row. This resulted in weeds such as annual ryegrass filling this gap and is likely to cause significant management issues in the future.

CONCLUSION

Based on the findings from both studies it is evident that soil amelioration practices, particularly deep ripping, exhibit significant variability in crop response across different sites, timing of application, crop types, and seasonal conditions. While deep ripping has shown consistent benefits in sandplain-based soils, its application to other soil types presents economic and practical challenges. This highlights the necessity of evaluating soil amelioration practices over several years and under various seasonal conditions to make informed decisions.

The economic viability of soil amelioration practices appears to be consistently viable only on the deep sandy soil types. Although there were instances where significant cumulative increases in net return were achieved, with some treatments yielding above $300/ha, 40% of treatments resulted in a long-term net loss compared to the control. This underscores the need for a clearer definition of what constitutes success in soil amelioration. For some growers, a modest return of $50/ha per year might be acceptable if it reduces yield variability. However, given the high variability in grain yield between years, it is unlikely that soil amelioration practices on 'other' soil types will be widely adopted by growers, as they do not consistently reduce variability.

The study also revealed a decreasing trend in grain yield in the years following soil amelioration practices. While the third year was a dry year and likely impacted the expression of the grain yield benefit, the data aligns with previous deep ripping work in sandplain soils, where the longevity of the deep ripping response is predicted to be 3-5 years, depending on the farming system and machinery used. For many sites in this study, the benefit is likely to be less than three years, making soil amelioration on many 'other' soil types economically unviable.

The study also found that early post-emergent deep ripping does not lead to the expected increase in grain yield that is commonly attributed to deep ripping. Pre-seeding deep ripping tends to increase plant establishment and vigour, which are crucial for higher grain yield. However, the aggressive nature of the ripping process can cause significant damage, highlighting the need for less disruptive methods. Future research should focus on refining these techniques and exploring alternative methods to improve soil health and crop yield sustainably. This approach will help ensure that soil amelioration practices are both economically viable and beneficial in the long term.

IMPLICATIONS

Soil Amelioration Practices

The study highlights the variability in grain yield responses to different soil amelioration treatments. This variability underscores the importance of site-specific strategies and long-term assessments. For growers, this means that adopting a one-size-fits-all approach to soil amelioration is unlikely to be effective. Instead, tailored practices that consider the characteristics of the soil type and presence of multiple soil constraints is essential. An indicator that a soil amelioration will give a long-term improvement in crop profitability is the magnitude of response, with an increase in grain yield of greater than 0.5t/ha likely to deliver a return of greater than $300/ha over 3 years, depending on crop rotation. This approach can optimise grain yield and economic returns, ensuring that the chosen methods are both effective and sustainable.

One of the significant limitations of the study is the challenge in establishing sites due to the presence of hard-setting layers, rock, or depth to clay, which limit the ability to ameliorate these soils effectively. This highlights the necessity of evaluating soil amelioration practices over several years and under various seasonal conditions to make informed decisions. The study's findings suggest that while deep ripping can enhance plant establishment and vigour, especially when performed pre-seeding, the benefits are not universally applicable and may not justify the investment for many growers.

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Economic Viability

The economic analysis of the soil amelioration treatments revealed that 60% of the treatments showed a positive cumulative economic benefit after three years, averaging $164/ha. However, 40% of the treatments resulted in a loss, averaging $154/ha. This high variability in economic returns highlights the need for detailed cost-benefit analyses before implementing soil amelioration practices. Growers should consider the initial costs, potential yield benefits, and long-term economic returns when considering adopting soil amelioration on soil types other than sand.

The average costs of soil amelioration treatments used in the study were based on averages from grower feedback and can vary from region to region. The economic viability of each treatment will depend on the specific conditions of the site and the expected yield benefits. The costs associated with the various soil amelioration treatments are significant and vary depending on the method used. For example, mouldboard ploughing is the most expensive treatment at $184/ha, while shallow tillage is the least expensive at $40/ha. These costs must be weighed against the potential benefits to determine the economic viability of each treatment.

The benefits of soil amelioration practices are highly variable and depend on the specific conditions of each site. The study found that 60% of the treatments resulted in a positive economic benefit, with an average cumulative net return of $164/ha over three years. However, the benefits were not consistent across all sites and treatments. For example, the most profitable treatment was ripping to 60cm with inclusion plates at the Yuna site, which resulted in a cumulative economic benefit of $620/ha. In contrast, the least profitable treatment was mouldboard ploughing at the Darkan site, which resulted in a cumulative economic loss of $656/ha.

Controlled Traffic Farming

The adoption of controlled traffic farming (CTF) practices can potentially increase the longevity of soil amelioration benefits by reducing soil compaction from wheel traffic. This integration can enhance the effectiveness of deep ripping and other amelioration methods, providing long-term benefits to growers. However, the potential of CTF to increase the longevity of amelioration treatments was not able to be assessed in this study as there were few farmers who had soil types other than sand and were practising controlled traffic farming. This limitation suggests that while CTF practices may offer benefits, their applicability across a broader range of soil types remains untested.

Early Post Emergent Ripping

The study found that early post-emergent deep ripping negatively affected plant establishment and early vigour, leading to increased weed competition compared to other treatments. This suggests that early post-emergent ripping is not a viable alternative to pre-seeding ripping. However, pre-seeding ripping consistently improved plant establishment, early vigour, and grain yield compared to the control. Therefore, growers should prioritise pre-seeding ripping over post-emergent and non-ripping methods to achieve better agronomic outcomes.

The impact of early post-emergent deep ripping was likely exacerbated by the depth of ripping and the aggressiveness of the roller that follows the ripper. It is now standard practice for growers to aim to deep rip to a depth of 600-700mm to address soil compaction, compared to 300mm when deep ripping was first introduced in the 1980s. In conversing with growers who have had prior experience in early post-emergent ripping, it was explained that historically, only a depth of 300mm ripping had been used, and this was expected to move less dirt and have less impact on plant establishment. Ripping to a depth of 600mm increases the fracture of the topsoil and tends to achieve a greater level of soil disturbance in general. Where ripping to depth is practised prior to seeding, a heavy or aggressive roller is needed to break down clods that are raised to the surface during ripping. This aggressive roller likely caused a significant amount of damage and was seen flicking up plants and dirt during the ripping process. The constraint of the use of aggressive crumble rollers is that they are often integrated into the structure of the deep ripper, limiting the applicability of most deep rippers on the market to the post-emergent practice. For early post-emergent deep ripping to be successful, deep rippers that have low soil disturbance, and a non-aggressive roller are considered ideal in hopes of decreasing the impact on crop growth. Early post-emergent deep ripping may also be aided by greater accuracy in the placement of seeding and deep ripping rows, with wider row spacing likely to lessen the impact of the ripping process, particularly where inter-row ripping is achieved. This is an area for future study if there are growers capable of undertaking this practice.

Management Issues

Significant management issues have tended to arise from this project. The reduction in plant establishment across all sites from ameliorating the soil was in part transitory, in that the impact was most visual in the two weeks following deep ripping or in the year that the amelioration was completed. This suggests that the long-term benefit of soil amelioration on these soil types would need to be highly positive to take a short-term decrease in crop production. However, in both the 2018-20 and 2021-22 studies, the short-term impact on crop growth was not reliably compensated by the increase in grain yield in following years. Growers will need to thoroughly test their preferred options for soil amelioration to ensure that a profitable outcome is achieved. This is likely to increase the time for achieving an increase in crop production but will reduce the likelihood of long-term negative impacts from the incorrect soil amelioration method being used.

RECOMMENDATIONS

Understand the soil constraints

The first step in any soil amelioration practice is to thoroughly understand the soil constraints you are dealing with. The results of the 2018-2020 study have shown significant variation in crop response to amelioration between sites, crop types, years, and seasonal conditions. This variability underscores the importance of conducting a detailed soil analysis to identify the specific issues affecting your soil (such as compaction, acidity, salinity, or water repellence) and determine any spatial variability. Understanding these constraints is crucial because it informs the choice of amelioration techniques and machinery. For instance, if your soil is compacted, deep ripping might be necessary, whereas if acidity is the issue, lime application could be more appropriate. By knowing the exact nature of your soil constraints, you can tailor your amelioration practices to address these issues effectively, thereby optimising crop yield and ensuring sustainable soil health.

Research and be open to new machines or methods of soil amelioration

The agricultural industry is constantly evolving, with new technologies and machinery being developed to improve soil management practices. It is essential to stay informed about the latest advancements and be open to experimenting with new machines that offer different modes of soil loosening and mixing. The study highlighted the challenges of working with various soil types, including clay, gravel, duplex, loam, and sandy soils, which have not been traditionally evaluated for deep ripping. Thorough research on the types of machines available can help you find the most suitable equipment for your specific soil conditions. For example, while traditional deep rippers are effective for breaking up compacted soil, newer machines like rotary spading or Plozza Plowing might offer additional benefits such as better soil mixing or reduced surface disturbance. By keeping an open mind and staying updated on technological advancements, you can enhance the effectiveness of your soil amelioration practices.

Conduct trials on your soils

Before fully committing to any soil amelioration practice, it is advisable to conduct trials on your specific soil type. These trials can help you determine the most suitable amelioration techniques and machinery for your conditions. Start with small-scale trials to test different methods and assess their impact on soil health and crop yield. Monitor the results closely, collecting data on various parameters such as soil structure, moisture retention, nutrient availability, and crop performance. This empirical approach allows you to make informed decisions based on actual field data rather than relying solely on theoretical knowledge or recommendations from other regions. Conducting trials also helps in identifying any potential issues early on, enabling you to make necessary adjustments before scaling up the practice across your entire farm.

Thoroughly assess options

Taking the time to thoroughly assess all available options is crucial for the success of soil amelioration practices. This involves evaluating the long-term impact of different techniques on soil health and crop yield. The study found that there was not a clear or consistent crop production or grain yield advantage to ameliorating many of the soils. There was often a decreasing trend in grain yield in the years following the soil amelioration practice at many sites, which may be due to the presence or activation of other subsoil constraints. Consider factors such as the cost of implementation, the expected benefits, and the sustainability of the practice. Ensure that you collect and analyse data to measure the actual benefits of each amelioration technique. This data-driven approach helps in making informed decisions and avoids the pitfalls of adopting practices that may not be suitable for your specific conditions. For instance, while deep ripping might show immediate benefits in terms of improved root growth and crop yield, its long-term impact on soil structure and health needs to be carefully evaluated. By thoroughly assessing all options, you can choose the most effective and sustainable soil amelioration practices for your farm.

Progressive adoption and investment

Once you have identified the most suitable soil amelioration practices through trials and thorough assessment, it is advisable to adopt these practices progressively across your farm. Start with small areas and gradually expand as you gain confidence in the effectiveness and economic viability of the chosen techniques. This phased approach allows you to manage risks better and make adjustments based on ongoing observations and data collection. As success becomes evident, you can invest more confidently in scaling up the practice. Progressive adoption also provides an opportunity to refine your techniques and machinery, ensuring that they are optimised for your specific conditions. By investing gradually and based on solid evidence of economic return, you can ensure that your soil amelioration practices are both effective and financially sustainable.

Continuous monitoring and adaptation

Soil amelioration is not a one-time activity but an ongoing process that requires continuous monitoring and adaptation. Regularly assess the impact of your amelioration practices on soil health and crop yield. Use this data to make necessary adjustments and improvements. For instance, if you notice that the benefits of deep ripping are diminishing over time, you might need to explore additional practices such as controlled traffic farming to reduce soil compaction from wheel traffic. Similarly, if certain areas of your farm are not responding well to a particular amelioration technique, consider trialling alternative methods. Continuous monitoring and adaptation ensure that your soil amelioration practices remain effective and relevant in the face of changing conditions and new challenges. The best outcome for some soil types and environments is to not conduct physical amelioration and consider other approaches to increasing the bucket size.

Collaboration and knowledge sharing

Collaborating with other growers, researchers, and agricultural experts can provide valuable insights and help you stay updated on the latest developments in soil amelioration practices. Participate in field days, workshops, and industry conferences to learn from the experiences of others and share your own findings. Engaging with the broader agricultural community can also provide access to new technologies, research findings, and practical advice. By fostering a culture of collaboration and knowledge sharing, you can enhance your understanding of soil amelioration practices and contribute to the collective advancement of the industry.

Environmental considerations

While improving crop yield is the primary goal of soil amelioration practices, it is also important to consider the environmental impact of these practices and only conduct these operations when the conditions are right, not to the calendar. Ensure that your amelioration techniques do not lead to negative consequences such as soil erosion, loss of biodiversity, or contamination of water sources. Adopt practices that promote sustainable land management and contribute to the overall health of the ecosystem. For example, integrating cover crops or maintaining vegetation strips can help reduce soil erosion and improve soil organic matter. By considering the environmental impact of your soil amelioration practices, you can contribute to the long-term sustainability of your farming operations and the broader environment.

Economic analysis and planning

Conducting a detailed economic analysis is essential for the successful implementation of soil amelioration practices. The study found that there is not a strong economic case for adopting soil amelioration practices, particularly deep ripping, across a wider range of 'other' soil types. There were a few instances where significant cumulative increases in net return were achieved above $300/ha; however, 40% of treatments resulted in a long-term net loss compared to the control. Consider the costs of different amelioration techniques, the expected benefits, and the potential risks. Develop a comprehensive plan that outlines the steps for implementation, the resources required, and the expected timeline for achieving results. Regularly review and update this plan based on ongoing observations and data collection. By taking a strategic and well-planned approach, you can ensure that your soil amelioration practices are economically viable and aligned with your long-term farming goals.

The successful implementation of soil amelioration practices requires a thorough understanding of soil constraints, careful selection of machinery, and a data-driven approach to assessing and adopting techniques. The 2018-2020 study highlighted the variability in crop response to amelioration between sites, crop types, years, and seasonal conditions, underscoring the need for site-specific strategies. By conducting trials, progressively adopting practices, and continuously monitoring and adapting your approach, you can optimise soil health and crop yield. Collaboration with other growers and experts, consideration of environmental impacts, and detailed economic planning are also crucial for ensuring the sustainability and effectiveness of soil amelioration practices. By following these recommendations, you can make informed decisions that enhance the productivity and sustainability of your farming operations.

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GLOSSARY AND ACRONYMS

Nil acronyms presented.

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