AMENDING SUB-SOIL CONSTRAINTS INCLUDING PH STRATIFICATION, EXCESS SODIUM, CHLORIDE AND SOIL COMPACTION LAYERS

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A trial to assess if deep ripping can aid in mitigating constraints in the 0-30cm zone of the soil profile and help move soil amendments into the sub-soil zone in medium rainfall zones on a clay loam soil type?

Key Findings

- Strategic management in the first year after deep ripping is critical to establish a crop and ensure long term cover. Pre-emergent chemicals need to be selected strategically and sowing depth closely monitored
- Deeper is not always better: If applying lime to ameliorate acidity within the top 0-15 cm's, minimise deep ripping too just below the acidic band. Ripping deeper will result in a dilution of the lime and therefore reduced impact on the acidic band. Alternatively, if ripping below the band increased lime rates will be required.
- The impact of deep ripping and gypsum on leaching salts is a long-term management approach. Results show salts have started to migrate down from the 0-10 cm fraction and into the 10-30 cm layer. More rainfall and potentially further applications of gypsum will be required to continue leaching salts. Monitoring change is highly important to track progress.
- Minimal research has been completed in our growing region with regards to deep ripping, and general "soil fracture" dynamics. Therefore, it is not recommended to rip large areas of land until more research is completed, confirming long-term, cost effective and sustainable benefits.

Location	Melrose, SA
Grower	Andrew Walter
Growing season rainfall	250 - 300 mm
Crop type	Wheat
Soil type	Red clay loam
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UNFS Upper North Farming Systems

Australian Government

Elders

Background

In low to medium rainfall zones soil amendments can take multiple seasons to wash (permeate) through the profile and reach the sub-soil layers, if at all. Consequently, we are beginning to see, and understand the effects of, chemical stratification when analysing local soil profiles. Examples of this is the dramatic change in soil texture, pH or salts, which was observed at this trial site.

Figure 1: Soil profile from trial site – identification of soil constraints in the upper (0-30cm) of the profile

With decades of weathering, clay particles can slowly move down (eluviate) the profile with water movement, over time resulting in a texture contrast profile. In other words, a light soil texture in the top of the profile and a heavier texture throughout the subsoil layers. The area of accumulated clay (illuviated layer) can begin to also accumulate salts. If sodium content is increased past a certain threshold, soil structural issues (compaction) can follow, leading to poor water movement through the clay pan.

At this site, the 'clay pan' is located at approximately 20 cm's, with the accumulation of both chloride and sodium highest in this fraction. A thin band of accumulated clay that's high in moisture (and salts) and low porosity can stop water moving past this layer, imposing yield limitations due to plant rooting depth and moisture availability.

Another emerging issue within this rainfall zone is pH stratification. Even with routine applications of lime (calcium carbonate, utilised to neutralise soil acidity), acid throttles can appear in the Upper North growing environment.

In the Upper North growers can struggle to move lime down the profile, this is due to lime being a low solubility product and in a low/medium rainfall environment. In the region we are beginning to see neutral- alkaline topsoils, now with a crop limiting "acid throttle" below, where the lime has been unable to move to.

This trial assessed how deep ripping, paired with the application of appropriate soil ameliorants can aid in correcting the above constraints.

Rainfall

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2022	103.6	7	1	-	65.8	27.6	4.8	81.8	68.8	15.8	122.6	5
2023	11.6	11.2	5	46.8	57.4	86.8	30.6	33	20.8	30.6	45	46.4

The trial was implemented at the beginning of 2022 planting season, with final soil sampling completed at the end of 2023. Rainfall records are displayed above, with above average rainfall throughout 2022 helping to move amendments throughout the profile.

Trial Design

The trial was established on the 29th of April 2022, prior to any significant rainfall events for the season. Each plot was soil sampled prior to the application of amendments and again two years later in December 2023. Two soil cores were taken and mixed from each plot and split into 0-10, 10-30 and 30-60 cm soil (horizonal and incremental) fractions. The Agrowplow AP91 was used for ripping, which is a 6 m ripper with a tow behind "crumble roller" to smooth the soils surface following ripping. This is a 6-tine configuration which can rip to a total depth of 600 mm depending on soil conditions. In the treatments where soil was 'mixed' inclusion plates (wings behind tines) were used to increase soil disturbance and allow topsoil to drop into lower layers. Soil ameliorants utilised at this site included Penrice quarry lime and gypsum and Peats Soils compost.

The trial site was managed in line with the rest of the paddock for the duration of the trial.

	Un-ripped	40cm rip	60cm rip	40cm mix	60cm mix
Nil					
5t Gypsum					
5t Lime					
20t Compost					
All					

Nil = no amendment applied
All = 5t gypsum + lime + 20t mature compost

RESULTS / BODY

Treatment list:

- 5t Lime – Penrice lime was applied to raise the soil pH.
- 5t Gypsum – Blanchetown gypsum was applied to dissociate sodium from clay particles and increase the soil solutions calcium content, allowing the salt to leach from the profile and the soil structure to improve.
- 20t Peats Soil compost – An application of manure based compost added nutrition as well as organic carbon to help improve soil structure which was disrupted through the ripping process.
- 40 cm – Ripped to 40 cm's
- 40 cm mix – Ripped to 40 cm's with inclusion plates to mix the soil
- 60 cm – Ripped to 60 cm's
- 60 cm mix – Ripped to 60 cm's with inclusion plates to mix the soil

Table 1. Soil condition prior to the beginning of this trial.

Sample depth	pH	Organic Carbon	Soil Texture	CEC	Calcium	Magnesium	Potassium	Sodium	Chloride	EC 1:5
mm	$CaCl^2$	%		cmol/kg	%	%	%	%	mg/kg	dS/m
0-10	5.87	1.33	Silty loam	11	58.5	22	8.6	10.9	1000	0.84
10-30	7.1	0.63	Silty clay loam	16	57.5	28.2	4.1	10.2	610	0.47
30-60	7.62	0.51	Silty loam	23	55.9	28.4	2.3	13.5	1600	1.3

PH STRATIFICATION

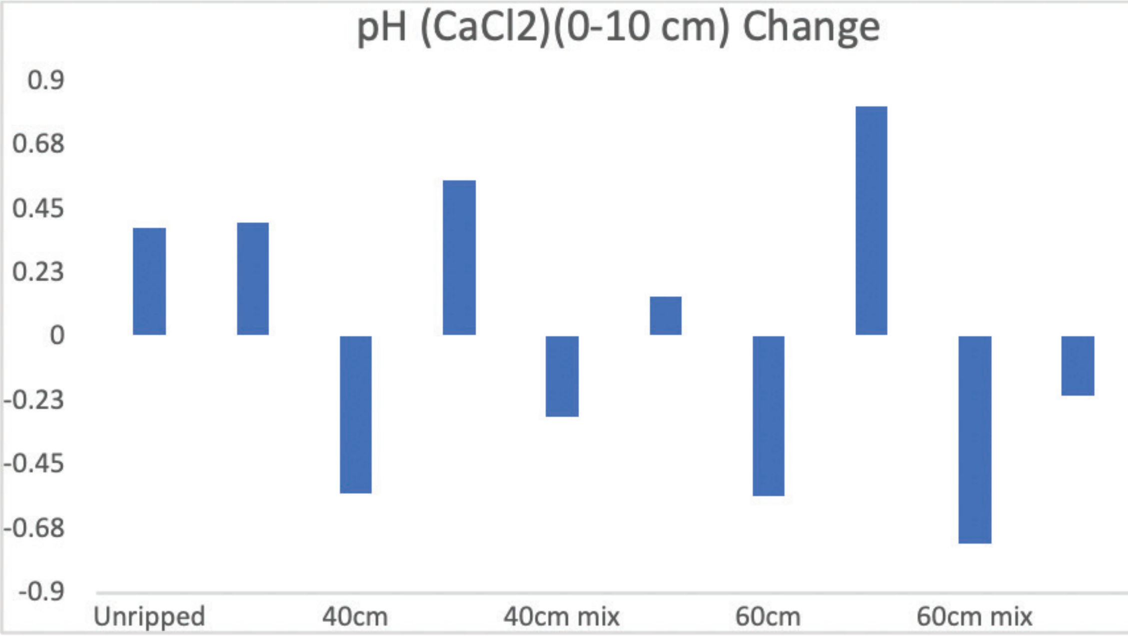

Figure 3: Soil pH Change from April 2022 to December 2023 in the top 0-10 cm fraction of soil

Figure 3 highlights the difference between the initial soil pH analysis, taken in April 2022, and the final soil pH analysis results, taken in December 2023. Therefore, negative values show that pH has reduced since the initial sample and a positive value shows the pH has increased since the initial sampling was done. The aim is to increase the pH at this site from acid condition closer to neutral condition.

When considering the strip where no amendments were applied in the absence of any ripping, the top 0-10 cm fraction increased by 0.4 pH units. This shows the confidence interval between sample timings of about 0.5 units of pH. This is likely due to slightly different placement of soil collection and inputs used between sample dates.

When considering the treatment where 5 t/ha of Penrice lime was applied, pH increased between 0.5 and 0.8 pH units in the top 0-10 cm's in all treatments. For the ripping treatments, all treatments increased in pH by 0.15 and 0.6 units, except for the 60 cm rip where inclusion plates were used to mix the soil. This result has been attributed to a dilution of lime throughout the profile, liming rates were budgeted on addressing acidity in 0-10cm layer, therefore in the deep ripping to 60cm has resulted in a reduced impact in the upper 0-10 cm layer.

Both ripping treatments where inclusion plates were used, pH levels reduced, which was not the intended outcome, once again due to dilution of the lime product.

pH Take Aways

Lime is effective at managing soil acidity especially in the topsoil. When addressing acidity issues below 10cm or needing to disturb soil layers lower in the profile to address other constraints such as compaction, then be aware that 'dilution' of the applied lime can occur. Typically, when lime budgets are created, they are focussed on neutralising the acidity in just the 0-10cm layer. If managing multiple soil constraints, especially if acidity is localised to the topsoil, it may be advantageous to apply lime with a shallow incorporation in year one then follow up with deep ripping (>30cm) in subsequent years.

SALINITY

When reviewing soils tests, salinity is represented as electrical conductivity (EC). Over the trial period, regardless of the treatment, EC reduced in the top 0-10 cm fraction and increased in the 10-30 cm fraction. EC can be further broken down into each salt type. In this scenario the main salts are sodium and chloride, displayed in figures 5 and 6. Throughout the lifespan of this trial, sodium reduced in the 0-10 cm fraction, with variable response in the 10-30 cm fraction. Likewise, chloride consistently reduced in the 0-10 cm fraction and had variable results in the 10-30 cm fraction pending treatment.

When sodium and chloride are present in high levels, they become bound to one another. Sodium chloride is a highly soluble salt type and can be mobile in the soil profile, moving both upward and downward with moisture movement throughout the profile. At this site, the clay pan is preventing water movement down the profile, therefore holding the sodium chloride in the top 0-20 cm fraction. Furthermore, remaining sodium is bound to the clay and organic carbon particles, being held in the profile and unable to leach without intervention (gypsum). Therefore, ripping was used to break through the compaction zone and help move both water and salts down the profile.

When considering ripping treatments, the best response came from the shallow rip (40cm), without inclusion plates. This process was able to break through the compaction layer (clay pan), allowing water movement down the profile, taking with it the salts. Ripping beyond 40cm did not improve salt movement, but instead caused adverse soil structural losses.

Gypsum (calcium sulphate) is utilised as an amendment to aid in accelerating the movement of sodium bound to clay particles down through the soil profile. The calcium in gypsum aids in displacing the sodium attached to clay particles into soil solution, allowing sodium to leach in greater volumes. From this trial it was evident that all gypsum treatments resulted in a positive outcome, moving salts in the 0-10 cm layer to deeper in the profile.

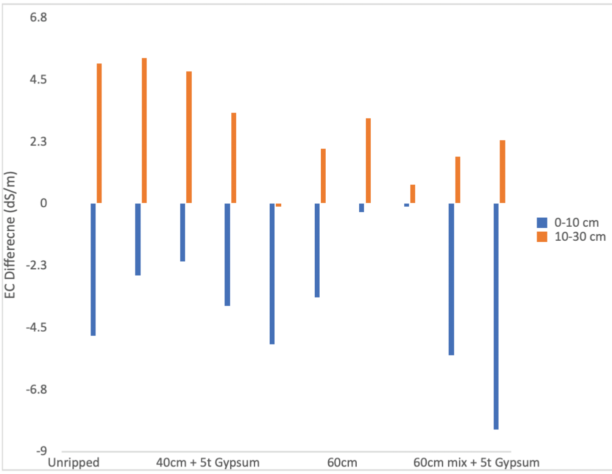

Figure 4:
EC (Salinity) change with treatment and depth

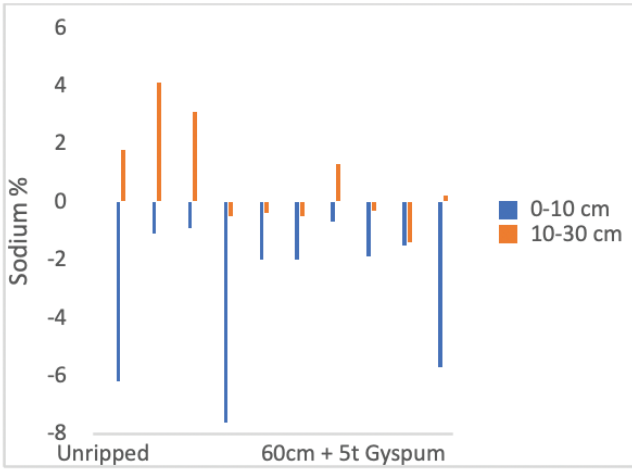

Figure 5:
Exchangeable sodium percentage change

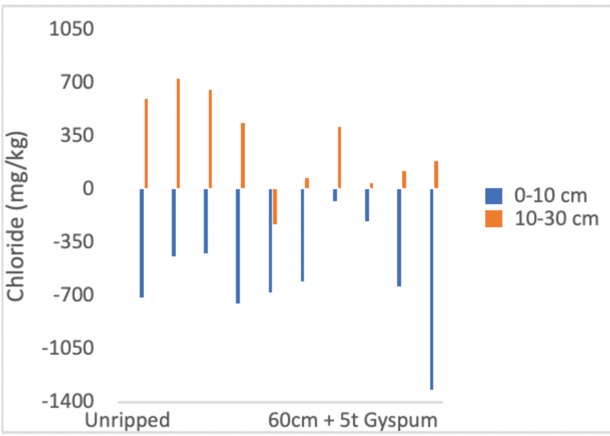

Figure 6:
Chloride changes with treatment and depth

Salinity Take Aways

Deep ripping can disturb the poorly structured (compacted) subsoil allowing for an increased rate of water movement down the profile. This increased rate of water movement allows for the flushing of salts down the profile, rather than arresting at the compacted zone resulting in salt accumulation layers.

When deep ripping occurs, the risk is that the soil, upon wetting, will slump and set back together if the soil structure is poor. This process can be remediated by the application of gypsum to increase the rate of salt leaching and reduce the sodium being left in the upper part of the profile which will result in improved soil structure and reduces the risk of the soil setting back harder than prior to the deep ripping process.

ORGANIC CARBON

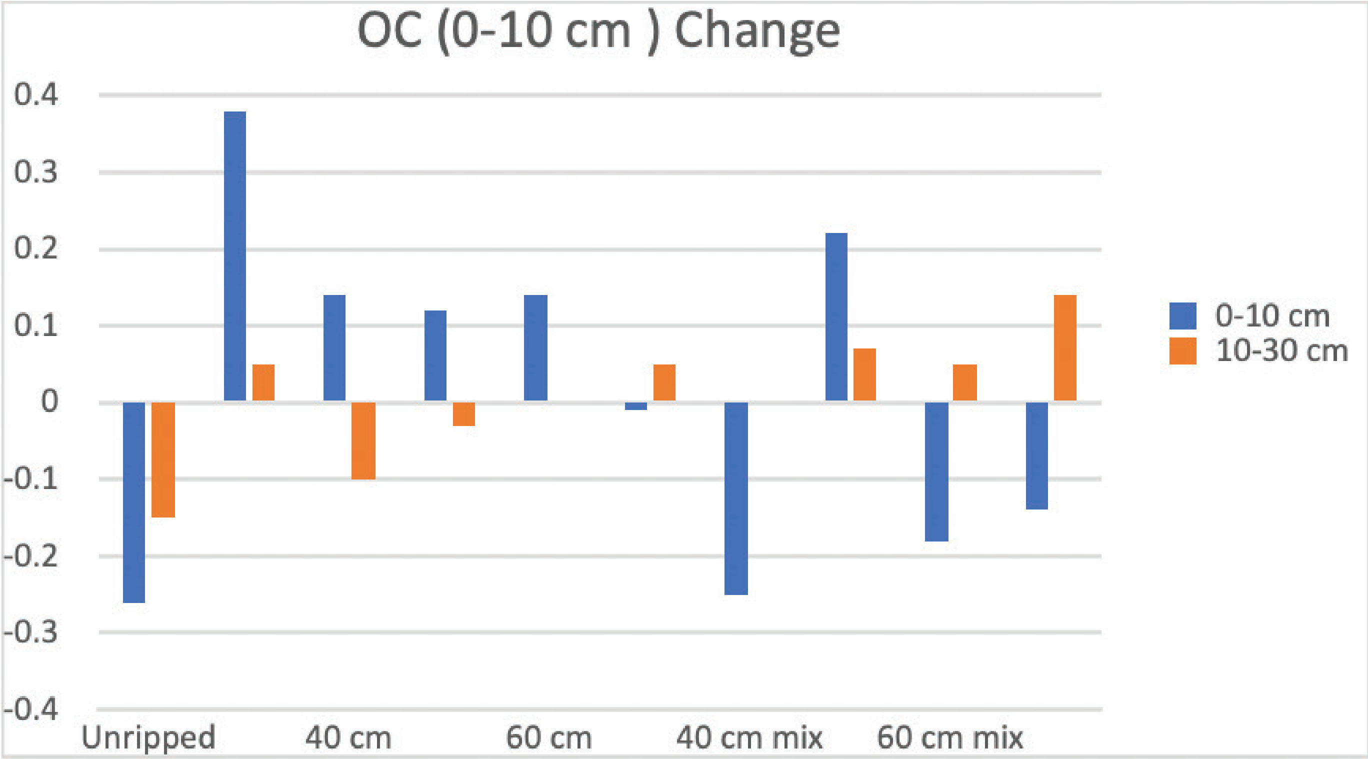

Figure 7. Organic carbon change from April 2022 to December 2023 in the top 0-10 cm fraction of soil

When considering the organic carbon content for each of the treatments, it was found that there was minimal change overall, however a trend toward a reduction in treatments without manure applications and an increase in treatments with manure. In other words, organic carbon is reduced by ripping in the absence of an organic rich amendment such as manure.
The act of ripping a soil mechanically destroys the structural integrity of the profile. Without an adequate concentration of organic carbon, which can act as the soils glue, ripped soil profiles are prone to compaction long term, leaving the productive capacity of ripped soils prone to become less than prior to the ripping activity.
The observed reduction to organic carbon was consistent throughout the profile and is related to an increase in oxygen throughout the profile, increasing the speed microbes within the soil break down the organic carbon, releasing it into the atmosphere.

Organic Carbon Take Aways

It is difficult to show definitive outcomes with regards to soil structure and organic carbon content in a short term trial such as this one. Soil compaction or soil structural formation occurs over a long period and likewise, organic carbon accumulation takes years. However, the results from before and after ripping can highlight that ripping will likely result in loss of organic carbon in the short term and this needs to be responsibly considered and accounted for in any ripping application.

CONCLUSIONS

This project was able to identify there are opportunities in the region for targeted soil amelioration strategies.
There is a potential fit for well thought out, intentional deep ripping and or the utilisation of soil amendments in our growing region short-term. The site will need to be monitored moving forward to ensure a long-term response from the practice.

It was found that incorporation of lime into the acidic fraction was able to speed up amelioration of the acid throttle from the 5-10 cm soil depth. This positive impact was not present in treatments with ripping beyond 30cm and adding inclusion plates was not found to improve results significantly, due to the dilution effect of the applied lime.

A positive impact was observed by deep ripping below the compaction layer on the downward movement of salts, resulting in a lowering of the salinity levels in the topsoil. This was further improved by applying gypsum prior to the ripping.

Overall, it was found that ripping in the top 0-20 cm was most effective on the soil condition from a physical and chemical perspective. Where deep ripping included inclusion plates on this soil the benefits were not as profound; this may have been due to a dilution effect of the applied amendments as well as loss of topsoil to greater, more hostile depths. Results from the physical intervention with deep ripping were further enhanced by applying amendments prior to deep ripping, this is an important finding and with further monitoring the key area of interest will be assessing the variation in longevity of the intervention practices.

ACKNOWLEDGEMENTS

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