Stubble and nutrient management trial to increase soil carbon

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Location: 
Minnipa Agricultural Centre 
Paddock South 2/8
Rainfall 
Av. Annual: 325 mm 
Av. GSR: 241 mm 
2015 Total: 333 mm 
2015 GSR: 258 mm
Yield 
Potential: 3.0 t/ha (W) 
Actual: 2.8 t/ha
Paddock History 
2015: Mace wheat 
2014: CL Grenade wheat 
2013: Mace wheat 
2012: Scout wheat
Soil Type 
Red sandy loam
Plot Size 
12 m x 3 m x 4 reps

Key messages
• Average trial yield was 2.8 t/ha, approximately 1 t/ha below the nitrogen unlimited potential as identified by Yield Prophet® during the season.
• No significant differences in yield were found between stubble treatments (stubble retained, worked or removed) and nutrient treatments (normal practice, normal practice plus additional nutrients to enhance stubble breakdown).
• After three years of trial work, no significant differences in soil carbon were found between the stubble and nutrient treatments.

Why do the trial?
The soil organic matter content of most Australian soils used for crop production is either decreasing or remaining stable. Trials have demonstrated that No-Till stubble retention systems are adding to the partially broken-down particulate organic carbon fraction but are not contributing to the stable humus fraction. Without an increase in soil humus the important functions of soil organic matter (i.e. improved soil water holding capacity, increased nutrient supply (nitrogen and cations), pH buffering capacity and better soil structure) are unlikely to be realised.

What is humus and how can it be increased?
Humus consists of the remains of bacteria and other micro-organisms that consume and break down plant material returned to the soil from a crop or pasture. This plant material consists mainly of carbon (C). For soil microbes to consume this material they also need nitrogen (N), phosphorus (P) and sulphur (S) otherwise they cannot thrive and multiply. Australian soils are inherently low in nutrients and in most soils there is insufficient N, P and S for soil micro-organisms to rapidly break down the plant material returned to the soil. To increase the stable humus fraction of organic carbon in the soil, we need to supply soil microbes with additional N, P and S; this may have to be supplied as extra fertiliser.

How much N, P and S need to be supplied to stubble to form humus?
Dr Clive Kirkby, from CSIRO, has been working on this question and found that:
• In humus 1000 kg of C is balanced with 80 kg N, 20 kg P and 14 kg S.
• Dr Kirkby argues that for soil micro-organisms to breakdown stubble and form humus, we need to add sufficient nutrients (N, P and S) to feed these micro-organisms (Kirkby et al. 2011).
• For micro-organisms to efficiently break down wheat stubble to humus additional nutrients have to be added. Wheat stubble has a low nutrient:C ratio and 1 tonne of cereal stubble needs to be balanced with 5.8 kg N, 2.2 kg P and 0.9 kg S.
In March-April of each year the stubble management treatments: (i) stubble left standing, (ii) stubble worked in with single operation of the seeder before sowing and (iii) stubble removed by raking and burning were imposed.

Nutrient application treatments at seeding were: (i) normal practice for P at sowing and N in crop as per Yield Prophet® and (ii) normal practice PLUS extra nutrients (N, P, S) required to break down the measured wheat stubble from the 2014 crop. Based on the initial 2015 stubble load of 6.8 t/ha, the extra nutrients (39 units N, 15 units P and 6 units S) required to break down the stubble were applied on 16 April with a rainfall event. The extra nutrients (plus treatment) were applied as DAP (18:20:0:0) @ 75 kg/ha, ammonium sulphate (21:0:0:24) @ 25 kg/ha and urea (46:0:0:0) @ 51 kg/ha. Treatments were replicated 4 times.

The trial was sown in drier conditions on 12 May with Mace wheat @ 60 kg/ha and a base fertiliser of DAP (18:20:0:0) @ 50 kg/ha. The trial area was sprayed on 8 May with 1.2 L/ha glyphosate and Cavalier at 100 ml/ha. Pre seeding chemical applications at seeding on 12 May were Roundup Attack @ 1.2 L/ha and Boxer Gold @ 2.5 L/ha. On 27 July, Tigrex was applied at 750 ml/ha and 100 ml/ha Lontrel. Emergence counts, flowering date, grain yield and grain quality were measured.

Crop performance 2015

Emergence counts were taken on 21 May with an average of 163 plants/m² (range of 125 to 207 plants/m²) which was good given the dry start to the season and variability with germination in other trials. The 2015 season was a decile 5 but drier seeding and early seasonal conditions did not allow early plant growth and the season finished quickly with a hot October long weekend. Flowering occurred (GS 65- when 50% of heads have anthers) on 15 September. The trial was harvested on 11 November. There were no differences between treatments in yield. There was a small increase in protein and screenings (P<0.001) for those treatments that received additional nutrients (Table 1).

Yield Prophet was used early in the season (3 July) to predict if extra N fertiliser was required to achieve potential yield given the drier seasonal conditions. Due to the dry conditions an extra 20 kg N/ha was applied on 9 July spread over all treatment plots, and 20 kg/ha was applied again on 3 August with rainfall events.

Soil Carbon 2012 to 2015

At the start of each season additional nutrients were applied to aid in the breakdown of stubble to soil organic matter.

After three years of implementing the stubble and nutrient management strategies, soil C content at Minnipa ranged between 1.1 and 1.3% for the topsoil (0-10 cm) and 0.7 and 0.9% for the subsoil (10-30 cm). There was no difference in SOC content between the 2012 and 2015 measurements (Figure 1).

To measure the change in the amount of soil C over time, the soil mass per unit volume of soil has to be taken into account – in other words the amount of soil C is reported for a defined soil mass

Table 1 Grain yield and quality as affected by stubble treatments and additional nutrients at Minnipa 2015.

<table>
<thead>
<tr>
<th>Stubble treatment</th>
<th>Nutrition treatment</th>
<th>Yield (t/ha)</th>
<th>Protein (%)</th>
<th>Screenings(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stubble removed</td>
<td>normal practice</td>
<td>2.60</td>
<td>10.7</td>
<td>6.1</td>
</tr>
<tr>
<td>Stubble removed</td>
<td>normal practice plus N,P&amp;S</td>
<td>2.90</td>
<td>12.1</td>
<td>10.2</td>
</tr>
<tr>
<td>Stubble standing</td>
<td>normal practice</td>
<td>2.73</td>
<td>10.7</td>
<td>8.7</td>
</tr>
<tr>
<td>Stubble standing</td>
<td>normal practice plus N,P&amp;S</td>
<td>2.84</td>
<td>11.6</td>
<td>8.9</td>
</tr>
<tr>
<td>Stubble worked</td>
<td>normal practice</td>
<td>2.88</td>
<td>10.3</td>
<td>6.6</td>
</tr>
<tr>
<td>Stubble worked</td>
<td>normal practice plus N,P&amp;S</td>
<td>2.97</td>
<td>11.8</td>
<td>11.8</td>
</tr>
<tr>
<td>P value Stubble treatment</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Nutrient treatment</td>
<td>ns</td>
<td>P&lt;0.001</td>
<td>P&lt;0.001</td>
<td></td>
</tr>
</tbody>
</table>
Soil C stocks at Minnipa ranged from 30 to 35 t C/ha (Figure 2). However, there was no difference between soil C stocks for the different stubble and applied nutrient treatments between 2012 and 2015.

What does this mean?
It was expected that the imposed treatments to increase soil organic matter would take several years to become noticeable, especially in low rainfall areas. Even after three good seasons at Minnipa with excellent crop production there were no differences in soil C stocks between the stubble and nutrient supply treatments. The same result applied to the other seven trial sites located in SE Australia. This work shows that increasing soil C stocks is a long-term process, and three years was not long enough to measure significant changes with the practices selected. This is consistent with a recent review indicating the largest gains in soil C stock were seen 5 to 10 years after adoption or change in practice (Sanderman et al. 2009). They also reported that improved management of cropland (e.g. no-till or stubble retention) resulted, on average, in a relative gain in SOC of 0.2-0.3 t C/ha/year compared with conventional management across a range of Australian soils. The Minnipa soil C trial will be re-measured again on the completion of the 2016 season after five years of trial work.

Acknowledgements
Funding for this trial is provided from DAFF and GRDC, and project management through Ag Excellence Alliance and EPARF. Yield Prophet is an on-line modelling service based on APSIM that provides simulated crop growth based on individual paddock information and rainfall, and is registered to BCG.

References
How does changing management practices influence soil carbon stock and other production factors?

Jodie Reseigh, Michael Wurst and Amanda Schapel
Rural Solutions SA, PIRSA

SEARCHING FOR ANSWERS

Location: Elbow Hill
Greg Williams
Rainfall
Av. Annual: 278 mm
Rainfall 2012: 256 mm
Rainfall 2013: 325 mm
Rainfall 2014: 259 mm
Soil Type
Australian soil classification: Calcarosol
South Australian soil classification: A4 Calcareous soil

Location: Cleve
Mark and Andrea Hannemann
Rainfall
Av. Annual: 422 mm
Rainfall 2012: 312 mm
Rainfall 2013: 479 mm
Rainfall 2014: 479 mm
Soil Type
Australian soil classification: Chromosol
South Australian soil classification: D1 Loam over clay on rock

Key messages
- The project established 13 demonstration sites in the Upper North and eastern Eyre Peninsula, SA to investigate the effect of selected management practices on soil organic carbon (SOC).
- Despite the lack of consistent evidence for the effectiveness of different management practices on SOC stocks, selected management practices have led to increases in ground cover and perennial plant numbers.
- It may take many years to see change in SOC stock, let alone significant change.
- In the short-term (2 years) measures of plant productivity (ground cover and perennial plant number) were more sensitive to management change compared to soil carbon (C) stocks and may represent valuable short-term monitoring tools to inform longer-term soil C outcomes.

Why do the trial?
The aim of the trial was to investigate the effect of four different management practices on soil C stock in the Upper North and Eyre Peninsula (EP) of South Australia.

Background
Increasing landholder interest in soil C during 2010/11 (after the introduction of the C tax), in particular how management practices affect soil C; how soil C is measured, plus a range of other questions, led the Upper North Farming Systems (UNFS) group to apply for funding from the Australian Government. The project investigated the effect of four management practices that have been proposed to increase sequestration of C in soils: rotational grazing; management of unviable cropping land; management of degraded land and management for increased perennials.

How was it done?
Twelve landholders (a total of thirteen sites) were identified in the Upper North and on eastern EP (Figure 1) based on their (i) interest in participating in a trial to increase SOC on their property through implementation of one of the four management practices; (ii) commitment to undertake management actions aimed at increasing SOC; (iii) willingness to record and provide details of management actions undertaken; (iv) proven management history (e.g. cropping, grazing, fertiliser application) of their paddocks and farm; and (v) preparedness to share their learnings about management actions aimed at increasing SOC undertaken on their property.

All landholders involved in the trial were mixed farmers, with cereal (predominately wheat and barley) and livestock (sheep, cattle) enterprises. Annual rainfall varied across the study area from 278 to 422 mm (winter dominant).

Demonstration sites were monitored and soil sampled in 2012 prior to the implementation of any change in management, with management practices commencing in 2012/13. Sites were monitored annually for pasture and surface cover, plant biomass, frequency of perennials and the soil was re-sampled in 2014 to monitor soil carbon changes. In total, thirteen demonstration sites were established; ten were located in the Upper North, and three on EP. The discussion below relates specifically to the EP sites.
Rotational grazing - Williams
The Elbow Hill area was settled in the 1880s and was cleared for cropping. Since then the farm and trial paddock have had a history of cropping with both wheat and barley. The cropping regime has varied from cropping and a pasture phase, to continuous cropping in the period 2007-2009. The trial paddock and adjoining land have not been cropped since 2009, due to a combination of poor yields and increasing costs. The paddocks were set stocked for most of the year at generally low stocking densities (~ 1 DSE/ha).

Fences were repaired or replaced in 2013 to make the paddocks stock proof, and central watering points constructed with watering yards consisting of a single trough with high water flows allowing four paddocks to be watered from a single point. Rotational grazing began in May 2013, with sheep grazing at 34 DSE/ha for 5-10 days, followed by up to 120 days rest depending on seasonal conditions.

Degraded land – Hannemann
The local area has been cropped since settlement and prior to 1997, the demonstration site paddock was traditionally cropped for two years followed by a one year self-regenerating pasture. Since 1997, the paddock has been continuously cropped, with stubbles of the previous year’s crop grazed over summer, generally for a period of six weeks at 13 DSE/ha. Crop yields declined and the area close to the creek became waterlogged during winter, due to a rising water table.

In March 2012, gypsum was spread over the upper slopes of the paddock at 2.08 t/ha. The paddock was sprayed in early May 2013, to control a range of annual grasses and broadleaved weeds, and sprayed again following 39 mm of rain in mid-May.

Immediately after spraying perennial pastures were planted, with Lucerne (*Medicago sativa*) sown at 4 kg/ha on the upper slopes (northern side of paddock) and a mix of Tall Wheat grass (*Thinopyrum elongatum*) at 6 kg/ha and Puccinellia (*Puccinellia species*) at 4 kg/ha sown on the lower slopes and low lying areas. Fertiliser was applied with the pasture seed at 100 kg/ha of 27:12. Four rows of forage shrubs were planted in an area between the Lucerne and Tall Wheat grass/ Puccinellia in single rip lines at 5 m intervals. A mix of Oldman saltbush (*Atriplex nummularia*), River saltbush (*Atriplex amnicola*), Silver saltbush (*Atriplex rhagodioides*) and Creeping saltbush (*Atriplex semibaccata*) seedlings were planted in July 2014.

Land managed for increased perennials - Siviour
The local area has a history of regular cropping. Before the current owners purchased the property (2010), the paddock was continuously cropped with wheat for four years. The demonstration site was previously three paddocks with three different rotational histories. From 2010 to 2014 the stubbles and pasture were only occasionally grazed, due to a lack of water in the paddock. Prior to 2010 the area was set stocked all summer but grazing was very sporadic and uneven as the water supply was in an adjacent paddock.

In 2012, the demonstration site was sprayed and ploughed to control woody weeds, including blanket weed and annual saltbush (*Atriplex species*). The demonstration site was again sprayed in January 2013, to control summer weeds. Following good opening rains in May 2013, the demonstration site was sprayed and cultivated with a one way disc and then broadcast with Puccinellia (*Puccinellia species*) at 5 kg/ha and Tall Wheat grass (*Thinopyrum elongatum*) at 10.5 kg/ha in June. Fertiliser was spread at 70 kg/ha of DAP in June 2013. The area was grazed at 1.5 DSE/ha during January and February 2014, and at ~1.9 DSE/ha from March to May 2014.
The implementation of a grazing method (such as rotational grazing) which increases pasture productivity should result in: i) increased organic matter (OM) inputs into the soil; ii) increased trampling of OM by grazing animals which enhances the physical breakdown and incorporation of OM into the soil [1]; iii) reduced erosion; iv) and improvements or maintenance of ground cover. Furthermore, the combination of rotational and perennial species (generally deeper and more extensive root systems than annual species), should lead to increased organic carbon (OC) inputs over the longer term (>10 years) and decrease surface erosion due to greater surface cover through dry months. Additionally, OC decomposition may decrease due to the perennial plants ability to use rainfall that falls outside of the traditional growing season (summer rain).

These results are generally consistent with the theory that rotational grazing increases pasture productivity; however the increases need to be observed over a longer period (> 2 years) as productivity variables vary seasonally and are highly dependent on seasonal conditions. The theoretical increase in SOC following the implementation of rotational grazing was not observed, however other variables measuring pasture productivity: numbers of perennial plants, increased consistent with the theory that rotational grazing increases pasture productivity.

**Degraded land – Mark and Andrea Hannemann**

A decrease in SOC stocks of -4.9 Mg C/ha, from baseline levels was recorded as a result of implementing rotational grazing actions. However increases in ground cover (2.7%) and numbers of perennial plants (1.5 more plants/m²) were observed.

Remediating degraded land through the addition of amendments, and planting of perennial plants has a very high chance of increasing SOC through increased above and below ground biomass [2]. However, it may take a number of years for increases to be realised due to the slow process of remediation. Eventually with increased above ground biomass production, loss of OC from photo-degradation of surface litter will be reduced. Nevertheless, this will be a trade-off as the soil temperature will decrease and soil moisture will increase which will result in increased decomposition of OC by microbial activity.

The results are inconsistent with the theory that retirement of degraded land increases SOC stocks. The observed decrease in SOC stocks, may be attributed to the site being cultivated and sown to pasture which may have resulted in a loss of C and increased decomposition rates [3]. Other variables related to pasture productivity both ground cover and numbers of perennial plants increased.

**Land managed for increased perennials - Bevan and Cindy Siviour**

SOM stocks increased (2.1 Mg C ha-1) but not significantly. Any changes in SOC stock ~ 2.0 Mg C ha-1 are expected within natural variability. A dramatic increase in the number of plants/m² was recorded in 2014 with an increase of 48.1 plants/m² and an increase in ground cover of 15.4%.

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**Table 1 Summary of the impact of management practice on the change (2012-2014) in measured variables. Each site is represented by a symbol: No change, 1 increase, ↓ decrease**

<table>
<thead>
<tr>
<th>Management practice</th>
<th>SOC stock</th>
<th>Erosion risk</th>
<th>Ground cover</th>
<th>Perennial plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotational grazing</td>
<td>↓</td>
<td>↑</td>
<td>↓</td>
<td>↑</td>
</tr>
<tr>
<td>Degraded land</td>
<td>↓</td>
<td>↑</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduction and/or increase perennial plants</td>
<td>↑</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Changes of < 2.0 Mg C/ha are expected within natural variability
The introduction of perennial species to areas that have been retired from cropping, which typically become dominated by annual weed species resulting in large losses in productivity and lower returns of OC to the soil, should result in increases in SOC (at least in the area surrounding the shrubs/plants) as they have greater net primary production (NPP), requiring low nutritional inputs and partitioning more C to their root systems than agricultural plants [4].

The results are consistent with the theory that increasing the number of perennial plants in areas which have been retired from cropping leads to an increase in primary production and also show trends consistent with the theory with respect to increases in soil C.

What does this mean?

Improvements in some plant productivity variables were observed for all management practices, implying an increase in C inputs to the soil, and a reduced risk of C losses from the soil, providing the theoretical potential to increase SOC stocks over time. Trials such as these have an important role in establishing the most likely management practices which will lead to improvements in variables (ground cover, perennial plant number) and ultimately SOC stocks.

Longer-term monitoring (>2 years) is required to measure the SOC changes that may result from rotational grazing, management of unviable or degraded land, and approaches to increase perennials.

Research into the effects of management on SOC stock requires further work. The effects of management change are likely to vary depending on variables including how management change is implemented, soil type and climatic conditions.

Where research on the effects of management change on SOC stock has been undertaken:

i. the effect of rotational grazing on SOC stocks findings are conflicting with some research reporting an increase (e.g. [5] and [6]) and others reporting no significant change in SOC stock (e.g. [7], [8] and [9]), which is consistent with this trial;

ii. retirement of degraded land and the planting of perennial plants in the US increased SOC [2], this trial recorded a decline in SOC attributable to the implementation of management; and

iii. management for increased perennials through the cessation of cultivation and the planting of pasture has a positive effect on SOC stocks (e.g. [7], [8], [9]), whereas this trial observed no change from baseline levels.

The established demonstration sites provide opportunities to determine the value of short-term measures of management change (e.g. ground cover) to inform longer-term impacts on soil C, and to monitor SOC change over the longer term. SOC stock increases take time but the benefits of even small increases of SOC can improve soil health and productivity.

Acknowledgements

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References

Will controlled traffic improve crop production outside the wheel tracks?

Nigel Wilhelm
SARDI, Minnipa Agricultural Centre

Location:
Minnipa Ag Centre
Paddock S7
Rainfall
Av. Annual: 325 mm
Av. GSR: 241 mm
2015 Total: 333 mm
2015 GSR: 258 mm
Yield
Potential: 3.0 t/ha (W)
Actual: 2.7 t/ha
Paddock History
2014: Medic pasture
2013: Medic pasture
Soil Type
Calcareous red sandy loam
Plot Size
50 m x 3 m x 4 reps

Key message
- Heavy trafficking did not reduce the grain yield of wheat in 2015 and crop development appeared faster with some trafficking.

Why do the trial?
Adoption of Controlled Traffic Farming (CTF) in the low rainfall zone (LRZ) of the Southern Region is very low. The GRDC-funded project ‘Application of controlled traffic in the low rainfall zone’ is evaluating whether or not this skepticism is justified. To help LRZ growers answer the questions and uncertainties they face when thinking about CTF adoption, the project is conducting research on four sites (R sites) across dominant soil types and agro-ecological zones in the Southern Region LRZ. These trials focus on the impact of trafficking (by heavy vehicles) on crop production and soil condition as well as monitoring how quickly LRZ soils will “self-repair” if heavy trafficking is stopped. Issues of implementing CTF and managing permanent wheel tracks are being addressed in other components of the project.

This article summarises the first season’s wheat performance after increasing severity of trafficking was imposed on a red calcareous sandy loam at Minnipa Agricultural Centre. Three other trials similar in design and monitoring have also been implemented across the LRZ – on a deep sand at Loxton (SA), a brown loam near Swan Hill (Vic) and on a deep red earth at Lake Cargellico (NSW). All these trials will be maintained for at least the five year life of the project.

How was it done?
The trials were designed and implemented to be the same at all four sites. Each trial consists of five treatments replicated four times:
1. Control (no heavy vehicle trafficking).
2. One pass of a 30 tonne vehicle prior to seeding when soil was dry.
3. One pass of a 30 tonne vehicle prior to seeding when soil was moist.
4. Three passes of a 30 tonne vehicle prior to seeding when soil was moist.
5. Deep ripping (to loosen any historical trafficking).

These passes were conducted with 50% overlap of the load bearing wheels to ensure even coverage and will not be re-imposed.

The trafficking treatments simulate the effect of compaction caused by trafficking of heavy vehicles, with three passes when the soil is moist as an extreme (soil is always softer when wet so compacts more for the same vehicle weight). A deep ripping treatment was included because we cannot be sure if there is still compaction from previous trafficking in our control areas and the ripping was designed to disrupt any of this historical compaction. Trials were located on farms with soils typical for their district and where wheel track patterns for the previous five years (at least) were the same and were identifiable. The trials are being sown and managed with the farmers’ equipment. Treatments were imposed under the wings of the farmer’s seeder so that the whole trial could be seeded and managed without any heavy vehicle trafficking occurring on these treated areas. All plots were cored after the imposition of treatments and are being regularly assessed for soil physical and chemical condition.

At Minnipa, trafficking treatments were imposed in April 2015 with a 20 tonne single axle chaser bin, with the wet passes and deep ripping following 30 mm of rainfall. Deep ripping was imposed under moist conditions with a narrow profile straight leg ripper to 30 cm on 50 cm row spacings. Scepter wheat at 50 kg/ha and with 60 kg/ha of DAP was sown without prior cultivation on 25 May into marginal seeding conditions. The farm’s Horwood Bagshaw precision seeder (knife points) was used and the trial was sown as part of the whole paddock and managed similarly. The trial was laid out so that two treated plots were sown in each pass, one under each wing of the seeder.
Crop performance was monitored at establishment, for early and late dry matter production and at maturity (grain yield, quality and yield components). Soil in every plot was sampled for moisture, fertility and physical condition pre-sowing and will continue to be monitored. Grain harvest was conducted by hand to avoid trafficking from a header on treated plots.

Crops will continue to be sown and managed with farm equipment for the next three years, with rotation options to be the same as the rest of the paddock. Trafficking treatments will not be re-applied.

What happened?

Trafficking on dry soil had little visual impact on the soil but three passes on wet soil depressed the soil surface by at least 5 cm. Deep ripping left the surface more cloddy than the control with the surface raised by at least 10 cm.

Despite the parallelogram design of the Horwood Bagshaw Precision seeder, sowing depth varied markedly between extreme treatments. Three trafficking passes on wet soil reduced sowing depth from 54 mm in the control to only 25 mm due to the tightness in the surface layers. Deep ripping resulted in sowing depth averaging 103 mm because the profile was so loose and the variability in placement was also higher. Seeding depths in the single pass treatments were similar to the control.

Emergence was slower after three passes or deep ripping but similar to the control after single passes. Final plant populations were also similar in the control and single pass treatments (averaging 124 plants/m²) but were reduced to 100 plants/m² after three passes and to only 84 plants/m² after deep ripping (Table 1).

Once plants started to tiller, the crop after a single pass on wet soil appeared the most vigorous and by mid-tillering had produced nearly 50% more biomass per hectare than the control (which averaged 458 kg DM/ha). Growth after a single pass on dry soil or after three passes on wet soil was similar to the control. Plants after deep ripping were fewer and weaker, resulting in 60% less biomass than the control. Nutrient analysis of these whole shoots showed that levels of all essential elements were in the adequate range and similar for all treatments except for deep ripping which had higher calcium, magnesium and manganese levels than the control but lower (but still adequate) zinc.

A single pass on wet soil also appeared to speed the time to flowering while deep ripping delayed it, relative to the control. At a stage when the controls had one third of their heads emerged, the crop after three passes on wet soil had nearly 50% of heads emerged but deep ripping had only 10%. By flowering, shoot biomass was similar in all treatments (at approximately 6,500 kg DM/ha) except after deep ripping, which was 22% less than the control.

Despite the late sowing and dry spring (only 33 mm of rain in September and October) the controls averaged 2.6 t/ha, which was very similar to the yields with all trafficking passes. Only the crop after deep ripping yielded less than the control, at 2.0 t/ha (Table 1). Yield components were very similar for all treatments (Table 1), except grain size was better after deep ripping. All trafficking treatments resulted in very similar crops to the control at maturity. Plants after deep ripping were too few to match the grain yield of the other treatments despite larger grain size. Grain proteins were all high in the trial and similar to the control except for deep ripping which was nearly 2% lower than the control.

Deep ripping did not fully achieve our aim of investigating crop production with compaction completely removed from the top 30 cm of soil because the farm seeder did not adequately compensate for the loosened profile and seeding depth was double the control. This severely reduced establishment and wheat growth throughout the season. The end result was that wheat after deep ripping yielded 600 kg/ha, or 30% lower, than the control. This detrimental impact of deep ripping appeared to be largely due to the reduced plant numbers caused by deep sowing. We expect that in future seasons, the deep ripping treatment will be a more rigorous examination of the impact of removing historical compaction on crop production because the profile will continue to settle with time.

Table 1 Grain yield and yield components of Scepter wheat after trafficking and deep ripping at Minnipa in 2015.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Grain yield (kg/ha)</th>
<th>Establishment (plants/m²)</th>
<th>Heads per plant</th>
<th>No of grains per head (g)</th>
<th>1000 grain weight</th>
<th>Grain protein (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>2602*</td>
<td>124</td>
<td>2.30</td>
<td>43.4</td>
<td>21.8</td>
<td>15.7</td>
</tr>
<tr>
<td>One pass on dry soil</td>
<td>2742</td>
<td>122</td>
<td>2.44</td>
<td>41.6</td>
<td>22.2</td>
<td>15.3</td>
</tr>
<tr>
<td>One pass on wet soil</td>
<td>2548</td>
<td>127</td>
<td>2.37</td>
<td>41.5</td>
<td>20.0</td>
<td>15.9</td>
</tr>
<tr>
<td>Three passes on wet soil</td>
<td>2488</td>
<td>100</td>
<td>2.60</td>
<td>44.2</td>
<td>22.8</td>
<td>16.1</td>
</tr>
<tr>
<td>Deep rip</td>
<td>1976</td>
<td>84</td>
<td>2.10</td>
<td>45.3</td>
<td>25.1</td>
<td>14.0</td>
</tr>
</tbody>
</table>

LSD (P=0.05) 244 16 ns 2.4 2.8 1.0

* Control is the average of 13 plots: extra quadrats were taken from the seeder runs between treated plots for grain yield only
What does this mean?
Consideration of CTF can be divided into two broad components. One is the operational and logistical impacts of conducting all field operations on permanent, unseeded (and hence compacted) wheel tracks with equipment which has matching path and axle widths. There are potentially both positive (e.g. better traction, more timely operations) and negative (e.g. weed nursery and erosion risk) impacts of permanent wheel tracks. This aspect of CTF is being considered by this GRDC funded project but not as part of the four R sites. The R sites are focused on investigating the other major component of CTF which is whether crop production will improve if heavy vehicle traffic is removed from the cropped area of LRZ paddocks, because the heavy vehicles are causing compaction which is detrimental to plant growth. The case in medium and high rainfall zones is that there are clear net benefits from both components and cropping can be expected to be more productive and profitable under a CTF system in these two zones. The case for the LRZ has not yet been made, chiefly because it has not been fully investigated before in this zone.

In this trial, in the first year of crop production following implementation of these trafficking treatments, wheat has produced similar yields to the untrafficked control, despite sowing depth being shallower after the most extreme trafficking which resulted in a lower plant population. These early results suggest that wheat is relatively insensitive to the compaction caused by heavy vehicles on this red calcareous sandy loam in a low rainfall environment, compared to the existing conditions in the paddock. In fact, early growth of wheat was best after one pass on wet soil and development was more rapid after trafficking, suggesting that some extra compaction may have actually benefited wheat growth. This trial will be continued for the next three years at least and we will continue to monitor the impact of trafficking imposed in 2015 on subsequent crop production and soil condition. In future seasons, we are hoping the deep ripping treatment will allow us to assess whether current levels of compaction in the paddock are already restricting crop production.

Harvest data from the other three R sites are still being processed. When all are completed, a comparison will then be made of the impact of trafficking in four typical, but very different low rainfall environments.

Acknowledgements
Thanks to MAC farm staff for the implementation and management of the R site and to Ian Richter and Naomi Scholz for undertaking the monitoring of crop performance and soil condition. GRDC is the major funder of this project, which is managed by the Australian Controlled Traffic Farming Association (project code ACT00004).
New opportunities for soil wetting agents on repellent soils

Stephen Davies¹, Glenn McDonald¹, Geoff Anderson¹, Liam Harte¹, Grey Poulish¹, Richard Devlin² and Rebecca Jenkinson²

¹Department of Agriculture and Food, Western Australia, ²Living Farm

Key messages

• Banding soil wetting agents with the seed, through existing liquid banding systems and with less risk of poor placement, can improve crop establishment on water repellent soils and often has an equivalent effect to placement on the furrow surface.

• Some soil wetting agents are compatible with UAN, fungicides and other liquid applications and can be applied through existing liquid in-furrow banding systems improving their adoptability. This indicates soil wetting agents could be useful as a carrier for liquid nutrients.

• The impact of banded wetters on grain yield can vary with season, soil types and other yield constraints, therefore it is recommended growers trial them on their own farms and soil types.

Why do the trial?

The aim of the trial was to assess the effectiveness of wetting agents when applied in formulations with UAN and when banded with the seed compared to banded on the furrow surface.

Soil wetting agents include in their formulations a penetrant (surfactant) compound that will aid water infiltration into repellent soil but some also have water absorbing compounds (humectants) that help hold and retain soil moisture and sometimes nutrients in the topsoil. Soil wetting agents can be applied as blanket applications through a boom spray but this is costly as rates of 10-50 L/ha are often required and the benefits have been soil type specific and last only 1-2 years. Banding soil wetting agents involves applying them through nozzles usually as a continuous stream on top of the furrow following the press wheels to improve the consistency of soil wetting in the furrow. This is much cheaper as application rates are typically 1-2 L/ha. There is some evidence that banding soil wetters near the seed can also be effective at improving establishment but this requires further research to confirm the impacts. In previous research soil wetters have been shown to improve establishment and yield on water repellent sands (Blackwell et. al. 2014) but the results can often be inconsistent (Davies et. al. 2015). Less research has been undertaken on water repellent loamy gravel soils. These soils contain 20% or more ironstone gravel and typically have a sandy loam matrix in the topsoil, they are often called forest gravels and are found in the south-west medium-high rainfall zone of WA.

How was it done?

In 2015 replicated small plot experiments were established at Meckering, on repellent pale deep sand, and at Kojonup on +/- repellent loamy gravel (Table 1). Commercial soil wetting agents were tested and were applied either on top of the furrow, behind the press wheels (furrow banded) or applied ‘with’ the seed, banded 5-15 mm below the seed. The soil wetters were applied as a continuous stream at a water rate of 90-100 L/ha. Soil water repellence was assessed at each site and the crop was assessed for establishment and grain yield.

What happened?

Rainfall in March and April prior to seeding at both sites (Table 2) meant that there was some soil moisture present at the time the crop was sown but, due to the soil water repellence, the topsoils still had many dry patches. At Meckering rainfall was low throughout May and June and terminal drought was severe with only 8.6 mm in September and less than 2 mm in October (Table 2). October rainfall was also low at the Kojonup site which received only 4 mm (Table 2).
Table 1 Summary of seeding details, soil type, growing season rainfall (GSR Apr-Oct), soil water repellence rating and treatments applied, for five trials over three sites with water repellent soil established in 2015.

<table>
<thead>
<tr>
<th>Soil Type, Location &amp; GSR (mm)</th>
<th>Variety, Rate &amp; Sowing Date</th>
<th>Experiment and Treatments</th>
<th>Soil Water Repellence (0-5 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pale deep sand, Meckering GSR = 184</td>
<td>Mace wheat, 75 kg/ha, 9 May</td>
<td>SOIL WETTERS on SAND 1) Control (nil banding) 2) Water only banded on furrow or with seed 3) Wetter 1 – penetrant banded on furrow or with seed 4) Wetter 2 – penetrant &amp; retainer banded on furrow or with seed 5) Wetter 3 – penetrant &amp; retainer banded on furrow or with seed All wetters banded at 2 L/ha</td>
<td>2.4 Severe</td>
</tr>
<tr>
<td>Loamy (forest) gravel, Kojonup GSR = 251</td>
<td>Hindmarsh barley, 110 kg/ha, 13 &amp; 14 May</td>
<td>SOIL WETTERS on LOAMY GRAVEL 1) Control (nil banding) 2) Water only banded on furrow 3) Wetter 1 – penetrant &amp; retainer banded on furrow at 1 or 2 L/ha 4) Wetter 2 – penetrant banded on furrow at 1 or 2 L/ha 5) Wetter 3 – retainer &amp; penetrant banded on furrow at 1 or 2 L/ha 6) Wetter 4 – penetrant &amp; retainer banded on furrow at 1 or 2 L/ha</td>
<td>4.1 Very Severe</td>
</tr>
<tr>
<td></td>
<td>Hyola 525 RT Canola, 2.5 kg/ha, 5 May</td>
<td>SOIL WETTERS for CANOLA on LOAMY GRAVEL 1) Water only banded on furrow or with seed 2) Wetter 1 banded on furrow or with seed 3) Wetter 1 + UAN banded on furrow or with seed 4) Wetter 2 banded on furrow or with seed 5) Wetter 2 + UAN banded on furrow or with seed All wetters banded at 2 L/ha</td>
<td>3.2 Very Severe</td>
</tr>
</tbody>
</table>

*Molarity of ethanol droplet test uses solutions of different concentrations of ethanol, which acts as a surfactant, reducing the surface tension of the water. The higher the concentration (molarity) of ethanol in the solution needed to get a droplet to enter a repellent soil in 10 seconds the higher the soil water repellence. A rating of 0.2-1.0 represents low water repellence, 1.2-2.2 moderate water repellence, 2.4-3.0 severe water repellence and >3.2 very severe water repellence.

Table 2 Monthly, annual and growing season (GSR; May-October) rainfall for Meckering and Kojonup trial sites, 2015.

<table>
<thead>
<tr>
<th>Site</th>
<th>2015 Monthly Rainfall (mm)</th>
<th>Ann. Rain (mm)</th>
<th>GSR (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Feb</td>
<td>Mar</td>
<td>Apr</td>
</tr>
<tr>
<td>Meckering</td>
<td>7.2</td>
<td>26.4</td>
<td>16.2</td>
</tr>
<tr>
<td>Kojonup</td>
<td>0</td>
<td>50</td>
<td>60.5</td>
</tr>
</tbody>
</table>

*No rainfall was received in January at either site.
### Wetting agent placement and rates

At Kojonup wetting agents were banded on the furrow surface at two application rates of 1 and 2 L/ha onto very severely water repellent loamy gravel. The crop was sown into variable moisture on 13 May 2015, with subsequent rainfall of 8 mm on 19 May 2015 and 3 mm on 31 May 2015. Barley plant numbers were improved by 51-73% (63-90 plants/m²; Table 3). Grain yields were increased by 15-29% (0.53-1.02 t/ha; Table 3). For most of the wetters there was no benefit from using the higher application rate.

Soil wetter placement was assessed on water repellent pale deep sand at Meckering and repellent loamy gravel at Kojonup. At the Meckering site seed banded soil wetters improved wheat establishment by 30-40% (27-36 plants/m²) but soil wetters banded on the furrow did not significantly improve establishment (Table 4). Despite these improvements in establishment, grain yields were not improved by the soil wetting agents and in fact yields were reduced in some instances (Table 4). The site did experience severe terminal drought stress, receiving only 8.6 mm of rainfall in September and 1.4 mm in October on a soil type with low water holding capacity (Table 2). The drought stress may well have been exacerbated by a subsoil acidity constraint with soil pH (CaCl₂) of 4.3 and 4.2 in the 10-20 and 20-30 cm layers, respectively, and possibly by subsoil compaction. In addition to terminal drought the site was frosted and frost damage was evident. Given this, it is not surprising that the greater plant numbers in the wetter treated plots did not end up translating to a yield advantage. The biggest improvement in plant numbers occurred when wetters were banded with the seed, but in these treatments there was a yield decline. This typically occurs when the higher biomass from larger plant numbers results in the crop suffering from more severe terminal drought due to higher demand for water leaving less water for grain fill.

* denotes increase relative to the untreated controls.

### Table 3 Impact of soil wetting agents and the rate of application on barley establishment and grain yield on repellent loamy gravel at Kojonup, 2015.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crop Establishment (plants/m²)</th>
<th>Grain Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wetter @ 1 L/ha</td>
<td>Wetter @ 2 L/ha</td>
</tr>
<tr>
<td>Control (Nil)</td>
<td>123</td>
<td>123</td>
</tr>
<tr>
<td>Water only (Control)</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td>Wetter 1</td>
<td>195*</td>
<td>195*</td>
</tr>
<tr>
<td>Wetter 2</td>
<td>186*</td>
<td>186*</td>
</tr>
<tr>
<td>Wetter 3</td>
<td>213*</td>
<td>213*</td>
</tr>
<tr>
<td>Wetter 4</td>
<td>163</td>
<td>163</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td>63</td>
<td>63</td>
</tr>
</tbody>
</table>

* denotes increase relative to the untreated controls.

### Table 4 Impact of soil wetting agents and their placement, banded either on the furrow surface and or near the seed, on crop establishment and grain yield.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crop Establishment (plants/m²)</th>
<th>Grain Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Furrow</td>
<td>Seed</td>
</tr>
<tr>
<td>Control (Nil)</td>
<td>90</td>
<td>0.9</td>
</tr>
<tr>
<td>Water only (Control)</td>
<td>86</td>
<td>86</td>
</tr>
<tr>
<td>Wetter 1-2 L/ha</td>
<td>103</td>
<td>123*</td>
</tr>
<tr>
<td>Wetter 2-2 L/ha</td>
<td>98</td>
<td>126*</td>
</tr>
<tr>
<td>Wetter 3-2 L/ha</td>
<td>86</td>
<td>117*</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td>13</td>
<td>0.11</td>
</tr>
<tr>
<td>Kojonup, Loamy (forest) gravel – Canola 2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (Nil)</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Water only (Control)</td>
<td>34</td>
<td>35</td>
</tr>
<tr>
<td>Wetter 1-2 L/ha</td>
<td>45</td>
<td>56*</td>
</tr>
<tr>
<td>Wetter 2-2 L/ha</td>
<td>51*</td>
<td>54*</td>
</tr>
<tr>
<td>Wetter 3-2 L/ha</td>
<td>45</td>
<td>44</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td>15</td>
<td>0.22</td>
</tr>
</tbody>
</table>

* denotes a difference from the control treatment.
At the Kojonup site the placement of soil wetters on canola establishment and yield was assessed. Banded wetters improved crop establishment by 18-21 plants/m², an increase of 54-70%. Use of banded soil wetters improved canola yields by 260-510 kg/ha, and a grain yield increase of 9-17% (Table 4). In this experiment banding the soil wetters with the seed significantly (P<0.05) improved the grain yield compared with banding the wetter on the furrow (Table 4).

**Wetting agents in formulation with UAN**

At the Meckering site soil wetter on its own or in formulation with UAN significantly (P<0.05) improved wheat plant numbers by 18-21 plants/m², an increase of 54-70%. Use of banded soil wetters improved canola yields by 260-510 kg/ha, and a grain yield increase of 9-17% (Table 4). In this experiment banding the soil wetters with the seed significantly (P<0.05) improved the grain yield compared with banding the wetter on the furrow (Table 4).

**Table 5 Impact of soil wetting agents and their placement (banded either on top of the furrow or near the seed) on crop establishment and grain yield. Soil wetting agents were applied either on their own or in formulations with UAN.**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Crop Establishment (plants/m²)</th>
<th>Grain Yield (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Furrow</td>
<td>Seed</td>
</tr>
<tr>
<td><strong>Meckering, Pale Deep Sand – Wheat 2015</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (nil)</td>
<td>102</td>
<td>133*</td>
</tr>
<tr>
<td>UAN</td>
<td>126</td>
<td>183*</td>
</tr>
<tr>
<td>Wetter - 2 L/ha</td>
<td>140*</td>
<td>166*</td>
</tr>
<tr>
<td>UAN + Wetter - 2 L/ha</td>
<td>144*</td>
<td>166*</td>
</tr>
<tr>
<td>UAN + Wetter - 4 L/ha</td>
<td>174*</td>
<td>192*</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td>29</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Kojonup, Loamy (forest) gravel – Canola 2015</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water only (Control)</td>
<td>161</td>
<td>173</td>
</tr>
<tr>
<td>UAN</td>
<td>173</td>
<td>143</td>
</tr>
<tr>
<td>Wetter 1</td>
<td>192</td>
<td>188</td>
</tr>
<tr>
<td>UAN + Wetter 1</td>
<td>189</td>
<td>165</td>
</tr>
<tr>
<td>Wetter 2</td>
<td>209</td>
<td>212</td>
</tr>
<tr>
<td>UAN + Wetter 2</td>
<td>212</td>
<td>178</td>
</tr>
<tr>
<td>LSD (P=0.05)</td>
<td>ns</td>
<td>0.29</td>
</tr>
</tbody>
</table>

* denotes a difference with 90 or 95% confidence; ns denotes no significant differences.

At the Kojonup site the placement of soil wetters on canola establishment and yield was assessed. Banded wetters improved crop establishment by 18-21 plants/m², an increase of 54-70%. Use of banded soil wetters improved canola yields by 260-510 kg/ha, and a grain yield increase of 9-17% (Table 4). In this experiment banding the soil wetters with the seed significantly (P<0.05) improved the grain yield compared with banding the wetter on the furrow (Table 4).

In contrast to the crop response at the Meckering site, soil wetters on their own or in formulation with UAN did not significantly increase plant numbers. However, there was a trend towards higher plant numbers when the soil wetter was banded with the seed compared to when it is applied on the top of the furrow (Table 4). In general, wetter treatments banded with the seed had higher plant numbers and biomass. Yield responses of 8-36% have been measured in response to banded wetters on yellow deep sand at Binnu and pale deep sands near Badgingarra in moderate-low rainfall seasons (Blackwell et al. 2014). It is possible that frost or heat stress reduced the number of viable grains and this impact was bigger for the wetter treatments which had earlier and more consistent establishment and development.

In other studies banded soil wetters have resulted in yield improvements on deeper sands (Blackwell et al. 2014), and in general yield usually is improved as a result of higher plant numbers and biomass. Yield responses of 8-36% have been measured in response to banded wetters on yellow deep sand at Binnu and pale deep sands near Badgingarra in moderate-low rainfall seasons (Blackwell et al. 2014; Davies et al. 2015). Soil wetting agents with water retention compounds have been shown to have benefits over penetrant only wetters in seasons which have leaching rains (Blackwell et al. 2014).
In contrast crop yield responses on the repellent loamy gravels have been impressive and more consistent than those on deep sand. Canola yield increases have ranged from 0.3-0.5 t/ha and barley yield increases from 0.3-1.0 t/ha. In another experiment in 2015 near Kojonup on this soil type in which a broader range of treatment options was assessed, banded soil wetters increased barley yield by 0.7 t/ha for furrow banded and 1.0 t/ha for seed banded (Davies et. al. 2016). The cost of banding wetters typically ranges from $6-12/ha, and in these studies the yield response of barley on loamy gravel to the 1.0 L/ha rate was equivalent to that achieved at double the rate, 2 L/ha, so cost of the treatment is low relative to the potential yield benefit.

The results of these experiments indicate some useful developments in the use of soil wetting agents:

• Banding soil wetters with the seed can effectively increase plant numbers on repellent soils but should be used with caution on pale deep sands with poor water holding capacity and greater overriding soils constraints such as aluminium toxicity and compaction. Amelioration of these constraints may improve the reliability of the response to soil wetting agents;

• Some soil wetters are compatible with UAN and other liquid nutrients making their testing and adoption easier using existing liquid systems on seeders;

• Soil wetters can give large and quite consistent yield responses on loamy forest gravels in WA for both canola and cereals.

As a result of these findings ongoing research will focus on:

• Residual benefits of soil wetters, particularly on water repellent loamy gravels, and impact on a cropping rotation using longer term trials;

• Benefit of soil wetters on nutrient uptake and effectiveness when used in formulations with liquid fertilisers;

• Placement of banded soil wetter in relation to the seed row – how close does it need to be to the seed to be effective and how do the wetters improve soil wetting of the seed zone;

• Use of soil wetters in combination with lime and deep ripping on repellent soils with the aim of realising a greater yield benefit from the use of soil wetters when other soil constraints are also treated.

References

Acknowledgements
Thanks to GRDC and DAFWA for funding the soil water repellence project: DAW00244 ‘Delivering enhanced agronomic strategies for improved crop performance on water repellent soils in WA’. This project is part of the GRDC’s Soil Constraints West Initiative. We acknowledge the support of SouthernDIRT grower group, Tim Boyes (AgVivo consulting), Matt Sherriff (SACOA), Wayne Foot (SST), and John Hawkesford (Chemsol). We acknowledge and thank the host growers, their families and staff: Jono Clifton, Kojonup and Darren Morrell, Meckering. Thanks to Liam Ryan and Paul Blackwell (DAFWA) for peer review.
Overcoming subsoil constraints to increase soil carbon on Eyre Peninsula soils

Brett Masters and David Davenport
Rural Solutions SA, Port Lincoln

Key messages

• Subsoil constraints can be addressed through application of appropriate soil modification and ameliorants.
• Results to date have varied.
• Biomass responses to treatments do not always translate to increased yields.

Why do the trial?

• To identify how soil organic carbon (SOC) levels can be increased on Eyre Peninsula soils with low SOC levels.
• To determine if treatments to increase SOC also deliver yield increases relative to soil constraints, limiting delivering improved productivity and offsetting carbon dioxide emissions to the atmosphere.
• To improve amelioration techniques - deep ripping on poorly structured soils and the addition of clay to sandy soils, have delivered inconsistent results on Eyre Peninsula (EPFS Summary 1999, p72, EPFS Summary 2000, p105, EPFS Summary 2005, p129, EPFS Summary 2010, p154, EPFS Summary 2011, p166, EPFS Summary 2014, p207).

How was it done?

Four replicated trial sites and three demonstration site were established in 2014 (Table 1). Trials were monitored throughout the 2014 season with data collected on plant emergence, spring dry matter and crop yield (EPFS Summary 2014, p201). Results from 2014 were mixed, however clear yield benefits were recorded with the addition and deep incorporation of clay and organic matter at Terry Young’s Ungarra site. The addition of organic matter also provided a biomass response on the sodic soil at Phillis’, however there was no yield benefit at harvest. This is consistent with other trials where increased dry matter production did not necessarily lead to a yield benefit, particularly where there is a dry finish to the season. These trials were further monitored during the 2015 season.

What happened?

Good rains and mild conditions in April created ideal conditions for sowing and crop germination at all sites. Sites were sown and managed by the landholder as part of the larger paddock. Young’s was the only site with significant differences in crop emergence between treatments. Plant densities were much higher than the control on plots that had a soil ameliorant (clay or organic matter) added (P<0.05). Crop germination was better on clay + spade + organic matter plots compared to unincorporated clay and spade + organic matter plots with no clay (Figure 1).

Regular rainfall events kept the soil profile damp with no evidence of waterlogging. Following dry matter cuts taken in September, rainfall was sporadic with below average rainfall recorded at all sites in September and October. Trials were harvested using SARDI small plot harvesters in December.

Beinke Biomass data was highly variable with poorer growth on the 10 t/ha surface applied gypsum treatment. Whilst the dry matter levels were lower in the 10 t/ha gypsum treatments than the nil gypsum or 5 t/ha gypsum treatments, the differences were not significant and were not any better than the control. There were no differences in grain yields (P>0.5).
Table 1 Summary of replicated trial sites in 2014.

<table>
<thead>
<tr>
<th>Co-operator / Location</th>
<th>Soil type</th>
<th>2015 Crop</th>
<th>Measurements</th>
<th>Treatments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beinke, (FB) Crossville</td>
<td>Alkaline red brown earth</td>
<td>Barley</td>
<td>Plant emergence, Dry matter, Crop yield</td>
<td>Untreated, surface applied gypsum (5 and 10 t/ha), deep ripping, deep ripping + gypsum (10 t/ha), deep ripping + 10 t/ha gypsum + 10 t/ha organic matter (pea straw).</td>
</tr>
<tr>
<td>Phillis, (JP) Ungarra</td>
<td>Alkaline red brown earth</td>
<td>Lentils</td>
<td>Plant emergence, Dry matter, Root DNA, Crop yield</td>
<td>Untreated, surface applied gypsum (5 and 10 t/ha), deep mixing, deep mixing + 10 t/ha gypsum + 10 t/ha organic matter (vetch hay).</td>
</tr>
<tr>
<td>Young, (TY) Ungarra</td>
<td>Neutral sand over clay</td>
<td>Wheat</td>
<td>Plant emergence, Dry matter, Root DNA, Crop yield</td>
<td>Untreated; spaded; shallow clay (250 t/ha clay); deep incorporated clay, deep incorporated organic matter (10 t/ha vetch hay); deep incorporated clay + organic matter (10 t/ha vetch hay).</td>
</tr>
<tr>
<td>Holman, (JH) Cockaleechie</td>
<td>Acidic loamy Ironstone</td>
<td>Canola</td>
<td>Plant emergence, Dry matter, Crop yield</td>
<td>Untreated, surface lime (3 t/ha), deep ripping, deep ripping + lime, deep ripping + lime + organic matter (10 t/ha lupin chaff).</td>
</tr>
</tbody>
</table>

Figure 1 July wheat plant density at Young site, Ungarra in 2015.

Table 2 October lentil biomass, Phillis site, Ungarra.

<table>
<thead>
<tr>
<th></th>
<th>Mean biomass (t/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surface gypsum (10 t/ha)</td>
<td>1.73a</td>
</tr>
<tr>
<td>Surface gypsum (5 t/ha)</td>
<td>2.25ab</td>
</tr>
<tr>
<td>Control</td>
<td>2.60abc</td>
</tr>
<tr>
<td>Rip + gypsum (10 t/ha)</td>
<td>3.44cd</td>
</tr>
<tr>
<td>Rip + gypsum (10 t/ha) + organic matter (10 t/ha)</td>
<td>3.77d</td>
</tr>
<tr>
<td><strong>LSD (P=0.05)</strong></td>
<td>0.951</td>
</tr>
</tbody>
</table>
There was biomass benefit from ripping gypsum into the soil. However, the only yield benefit was found by ripping in 10 t/ha of gypsum compared to the same amount surface applied gypsum treatments but no difference compared to the control. The ripping + gypsum + organic matter treatment was greater (P<0.004) than the control (Table 2).

**Phillis**

However, the higher biomass did not lead to an increase in yield, with ripping + gypsum being the only treatment to have significantly higher grain yields (Figure 2).

**Young**

The addition of organic matter delivered increases in biomass production compared to those treatments without organic matter (Figure 3).
Figure 4 Wheat yield at Young’s site, Ungarra in 2015.

Holman
The biomass data collected was highly variable with none of the treatments performing better than the untreated control (P > 0.5). There was also no significant grain yield response to the treatments imposed at this site.

What does this mean?
There have been a number of factors that impacted on results this season. Seasonal rainfall – “ideal” growing conditions at Beinke’s and Holman’s to the middle of spring may have reduced the impact of subsoil constraints. The dry finish and hot days in early October may have had a greater impact on treatments with higher biomass and also on flowering wheat and lentil crops at Ungarra.

After two seasons it would appear that the treatments applied to the Beinke and Holman sites are yet to deliver major production increases. Biomass increases from some treatments (e.g. ripping + gypsum + organic matter) have been observed at the Phillis site but have yet been able to deliver significant yield increases. Results from the Young site support earlier work which has shown that while clay incorporation into sandy soils can deliver yield increases, further increases can be realised by incorporating clay and organic matter into the bleached, sandy subsoil horizons. There was also a benefit from ripping with gypsum applications compared to surface applied gypsum at Phillis’.

Soil analysis is currently being conducted on the sites to identify changes to soil characteristics. Further monitoring of these sites will occur to further investigate;
- How long before responses from soil applied ameliorants can be expected?
- How long the potential gains may last?
- What are the implications for soil carbon?
- What are the costs/benefits of these treatment options?
- Are there adjustments to current treatments that may provide better outcomes?

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