Natural Resources
Eyre Peninsula

MANAGING SUBSOIL CONSTRAINTS FOR IMPROVED PRODUCTIVITY AND RESILIENCE.

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With funding and support from the Driver River Catchment Group and the Eyre Peninsula Natural Resources Management Board.

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Government of South Australia
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Soil SMART

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CONTENTS

1. Soil Physical Properties (Field Analysis)

1.1 Soil Texture

The texture of a soil describes the percentage of sand, silt and clay present (Figure 1).
The percentage of clay in the soil can be estimated by making a ribbon of the wet soil and measuring the length.
Refer to NSW DPI handout: Methodology for conducting field texture analysis.

Soil texture affects the water holding capacity of the soil and the amount of plant available water. Sand holds little water, but gives it up to plants easily, whereas clay holds a lot of water but it can be more difficult for plants to extract.

Figure 1. Soil texture triangle (Australian Soil Fertility Manual-Third Edition)

1.2 Structure

- The way soil particles are arranged together and interconnected.
- Well-structured soils enable better infiltration of rainfall, drainage and root growth.
- Poorly structured (i.e. sodic soils) soils can be subject to waterlogging, erosion and compaction.

1.2.1 Dispersion and Slaking

Refers to how well clays hold together when they are wet. To test for dispersion or slaking, place a large crumb of clay (about the size of a marble) in a saucer of distilled water or clean rainwater. (Tap water contains chemicals which may prevent dispersion or slaking.) Do not shake or stir.

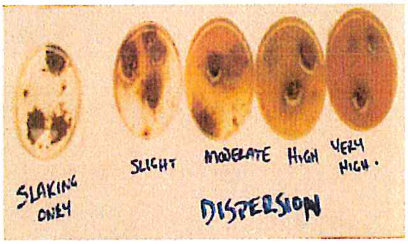

Figure 2. Field testing for dispersion (Emerson dispersion test).

Slaking clay will slump and fall apart in the water, forming a small blob of mud on the saucer, but the water will remain clear. If soils are sodic or strongly sodic and disperse, an application of gypsum (Calcium sulphate) may be used to ameliorate sodicity. Slaking soils however generally do not respond to gypsum applications, soil structure can be improved by reducing the mechanical disturbance and increasing soil organic carbon

1.2.2 Hard setting and Surface Sealing

Hard setting soil can be caused by either lack of organic matter, sodicity, or compaction. A simple test to measure soil strength is to insert a 300mm length of 2.4mm brazing rod (flattened at each end) into the soil. If it can be inserted with open palm, strength is less than 1Mpa and root growth is unimpeded. If the rod can be inserted using a coin to protect the palm, strength is between 1 and 3 MPa, and root growth is likely to be partly restricted. Above 3Mpa, root growth ceases. This test is highly moisture dependent, so should be done when root growth is critical (e.g. at emergence, initiation of tillering)

1.3 Cation Exchange Capacity

- Capacity of the soil to attract, hold and exchange positively charged cations
- Measure of the negative charge of the soil
- Total number of sites that cations can bind to.
- High CEC – reduced leaching of nutrients. This is generally in heavier textured/clay soils.

The CEC will vary depending on a number of factors but broad ranges of what you would expect in different soils are (Table 1):

Sands	1-4
Sandy loams	4-10
Loams	10-15
Clay loams	15-20
Clays	20-60

These figures must be taken with caution as soils such as calcareous or sodic soils will show higher CEC's than other similarly textured soils. Also different methods of measuring CEC can lead to different results which is particularly important when using tests developed in other countries which may not be designed for Australian soils.

1.4 *Water Repellence*

Water repellent or "non-wetting sands" result from waxy residues from the breakdown of plant material coating sand particles. This reduces water infiltration and can impact on crop germination, decreasing yield and increasing wind erosion risk.

A quick field method of assessing water repellence is the water/ethanol absorption test (M.E.D test). Drops of rainwater and ethanol are applied to a soil sample. Methylated spirits at a concentration of 24 ml to 200ml of water can be substituted for ethanol.

Table 2. Categories of water repellence

Non repellent	Water absorbed in less than 10 seconds
Repellent	Water takes more than 10 seconds to be absorbed. Ethanol/ methylated spirits absorbed in less than 10 seconds
Strongly repellent	Ethanol/ methylated spirits takes longer than 10 seconds to be absorbed

Clay spreading and delving have been effective in managing water repellence. Clay particles can have up to 10,000 times the surface area of sand particles. Thus by mixing clay into the sand, surface area is increased and water is absorbed more quickly.

2. Chemical Properties (Laboratory Analysis)

2.1 *Organic Carbon %*

Organic carbon provides binding sites for crop nutrients, increases water holding capacity and mineralises nitrogen for crop use. Compounds released by breakdown of organic residues are also the "glues" which are important in soil aggregation, which improves soil structure, water infiltration and decreases wind erosion risk. Stubble retention and reduced tillage is important in contributing organic matter to the soil for increased soil organic carbon levels, soil structure and reduced soil erosion risk.

Table 3. Desirable Organic Carbon (Walkley Black) levels for different soil textures

Texture	Low	Moderate	High
Sand	<0.5	0.5 - 1.0	>1.0
Sandy loam	<0.7	0.7 - 1.4	>1.4
Loam	<0.9	0.9 - 1.8	>1.8
Clay loam/clay	<1.2	1.2 - 2.0	>2.0

2.2 *pH*

The pH of a soil tells you whether it is acid or alkaline and will give you an indication of nutrient availability. The scale runs from 1-14, where 1-6 is acid, 7 is neutral, and 8-14 are alkaline. Most crops will grow well in the pH range 5.5-8.5.

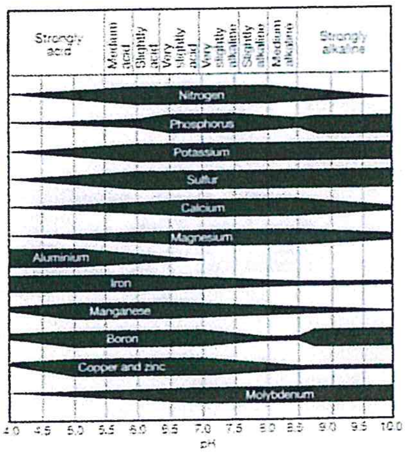

Figure 3. Influence of pH on nutrient availablity (Source: Australian Soil Fertility Manual- Third Edition)

A soil with pH above 8 is alkaline and may have low availability of Phosphorous, Zinc, Manganese and Copper. The presence of calcium carbonate will give pH readings up to about 8.5. If pH is higher than 8.5 then other salts such as sodium must be present as well. Sodium is often associated with boron, so clays with a very high pH can be high in lime, salinity and boron.

Soils with pH less than 5.5 are acidic, may have low available levels of Magnesium, Copper and Zinc and may be high in toxic elements such as Aluminium.

A home pH test kit is accurate to about 0.5 pH units. They are available in most hardware or garden stores

2.3 *Carbonates (Fizz Test)*

Carbonates such as calcium carbonate (lime, calcrete) and calcium magnesium carbonate (dolomite) can affect soil pH and can reduce the availability ("tie up") of nutrients such as Phosphorus, and Manganese, restricting plant root growth. You can tell if your soil contains carbonates by adding a weak acid solution to the soil (1 part hydrochloric acid (commercial grade between 28-38 % w/v) to 9 parts distilled water) If carbonates are present the soil will fizz.

Table 4. Acid reaction and relationship with carbonate %

Reaction	Strength of Effervescence	Approx. % carbonate
Nil	none	less than 0.5
Slight	audible	0.5 to 1.5
Moderate	audible and slightly visible	1.5 to 8
High	easily visible	1.5 to 8
Very High	strong visible fizz, bubbles jump up	more than 8

The fizz test easily shows the presence of carbonates, but the estimation of actual carbonate content is not precise, a soil test is needed to determine the exact amount of carbonate present. ***Acid is dangerous! Take care and follow all safety instructions!***

3. Interpreting soil test results (0-10cm)

Results that you obtain can be used to help identify the most appropriate fertiliser products and rates to use on the crop for the coming season. Paddock history and your knowledge and experience of the capability of your soils should also be taken into consideration when deciding on fertiliser rates. If the potential of your soil is limiting due to factors other than nutrition, no amount of fertiliser will lift the yield beyond that potential.

Refer to Interpretation of Comprehensive Soil test guide for information on specific nutrients. It is strongly recommended that soil test results should be discussed with your agronomic consultant when making decisions based on test results.

3.1 Colwell Phosphorus, Potassium and Sulphur

Colwell phosphorus figures are a guide only. Actual phosphorus requirements will be based on crop yield, stocking rate, production targets as well as soil phosphorus status. On sandy soils adequate levels can be considerably lower or difficult to establish if on leaching sandy soils. On highly calcareous soils Colwell P is considered less accurate due to high levels of P fixation than non-calcareous soils.

Table 5. Critical values for major nutrients in dryland agricultural production

	High	Adequate	Marginal	Low	Very low
Phosphorus (Colwell) *mg/kg*					
Non-calcareous	>45	30-45	20-30	10-20	<10
Calcareous	>45	35-45	25-35	15-25	<15
Pastures	>45	25-45	18-25	10-18	<10
Extractable Potassium *mg/kg*					
Permanent pasture and dryland cropping	>250	120-250	80-120	<80	
Extractable Sulphur *mg/kg*					
Permanent pasture and dryland cropping		>10	5-10	<5	

3.2 Phosphorus Buffering Index (PBI)

When applied as granular fertiliser P dissolves rapidly and is then subject to a range of processes including combining with other soil elements (such as iron and aluminium), adsorption to clay and organic carbon particles and leaching. PBI supports Colwell P analysis by providing a measure of "tie up" and leaching potential.

Higher PBI levels (greater than 150-200) indicate a stronger potential for "tie up" and a significant proportion of P applied will be unavailable to plants. A very low PBI (below 40) indicates that there may be potential for phosphorus to leach (these soils generally have low Colwell P levels as well).

3.3 Extractable trace elements (mg/kg)

Soil test interpretation is difficult as critical concentrations vary between soil types and plants. Availability also varies through the season. Provided the growth status of the plant is not significantly constrained by other factors e.g. low rainfall plant tissue analysis can be useful in determining trace element deficiencies. It is probably the only method available for calcareous soils but for other soil types a combination of soil and tissue testing is recommended. Availability of trace elements will vary depending on a range of factors including:

- Amount of carbonate present - manganese and iron are less available in high pH calcareous soils, resulting in low values.
- Soil texture - generally "adequate" levels are lower in sandy soils than loams and clays.
- Soil moisture – dry conditions can result in less movement of nutrients into the plant.
- Soil or nutritional constraints that limit root growth

Marginal levels of trace elements can result in deficiencies occurring in drier conditions – particularly noted for manganese and copper.

Table 6. Critical values for trace elements for broad acre dryland agriculture production

Trace element	Low	Adequate
Ext. Copper	< 0.5 mg/kg	1-2 mg/kg
Ext. Zinc	<0.7 mg/kg	1.2 -2 mg/kg
Ext. Manganese	<10 mg/kg	<20 mg/kg

4. "Nasties" (Toxicities)

4.1 Salinity

There are two forms of salinity commonly referred to in dryland agriculture in South Australia. These are;

- Dryland Salinity or "Water table induced salinity" – this type of salinity is induced by rising ground water tables, often the result of the clearance of deep rooted perennial vegetation. Management of this type of salinity involves either using water before it reaches the water table (through revegetation or high water use perennial pastures) or lower the ground water table at the discharge point through improved drainage.
- Dry Saline Land or "Magnesia patch" – is the presence of historical salts in the soil profile. These salts move up and down the soil profile depending on rainfall (leaching) and evaporation (capillary rise or "wicking"). Symptoms of dry saline land are generally more noticeable in drying years where the wetting/leaching front is not as deep.

Salinity can be measured using a salinity meter and a soil-water mixture of 1 part soil to 5 parts water. The electrical conductivity (EC) of the 1:5 soil/water suspension is measured (dS/m). The reading is then multiplied by a texture based conversion factor to give an estimate of electrical conductivity (ECe).

Table 7. ECe values and their effect on plant growth (Source: Tonkin 2009)

ECe (mS/cm)	Assessment
0-2	Low salinity
2-4	May affect sensitive crops
4-8	Yields of many crops affected
8-16	Only tolerant crops yield well
16-32	Salt tolerant species only
32+	Too salty for plant growth

4.2 Boron

Boron toxicity can occur in dryland cereals where boron levels exceed 15 mg/kg (ppm) and in sensitive crops when exceeding 5 mg/kg. High boron levels usually occur with carbonate and high soil salinity and can be an indicator of the historic wetting front. For cereal crops the most reliable indicator for boron toxicity is analysis of the grain (Hughes et al 2000).

4.3 Aluminium

High levels of soil extractable aluminium are closely related to soil pH. In soils where significant amounts of aluminium are present aluminium toxicity becomes an issue when soil pH ($CaCl_2$) is less than 5.0. Where extractable aluminium is >4 mg/kg, sensitive plants will be affected.

4.4 Chloride

High levels of chloride are an indicator of salinity. Generally plant damage can occur where chloride levels are in the range 120 mg/kg for sands to 300 mg/kg for clays.

5. DRIVER RIVER CATCHEMENT GROUP – DEEP RIPPING DEMONSTRATION SITES

5.1 Project Background and Aim

Research in Western Australia has shown that deep ripping ploughs with adjustable inclusion plates have been very effective in addressing some subsoil constraints, where previously no appropriate technology existed. Corey Yeates through discussion with local landholders in his role as Regional Landcare Facilitator (Eastern Eyre Region) during 2017 identified a number priority land management issues affecting agricultural lands on eastern Eyre which require further discussion and action. Amongst which were a number of key soil constraints that were of concern to landholders in the district including;

- Depth of productive soil layers - issues with productions on shallow soils and deep sands.
- Increasing soil organic carbon levels
- Addressing sodic soils and;
- Managing non-wetting sands (NWS)

The Driver River Catchment Group were approached with a proposal to partner in a project utilising the EPNRM Board's Yeomans plough to enable landholders in the district to establish a number of low cost demonstrations which implemented interventions including deep ripping with and without inclusion plates and soil ameliorants on a small scale to gauge their effectiveness and the feasibility of implementing these strategies on a broader scale.

5.2 *Target soil types, constraints and management interventions.*

Key soil types, target soil constraints and suggested management interventions are summarised in the table 8 below.

Table 8. Key soil types and management interventions to overcome production constraints

Soils types	Management Interventions/Possible Treatments	Desired Outcome
Sodic Soils	- Control - Ripper only - Ripper with inclusion plates - Ripper with inclusion and gypsum and/or organic matter - Ripper with inclusion plates and organic matter - Ripper with inclusion and gypsum and organic matter	Improve drainage, improve crop/pasture establishment and improve biological activity.
Sandy soils/non wetting sand	- Control - Ripper only - Ripper with inclusion plates - Ripper with inclusion and gypsum and/or organic matter - Ripper with inclusion plates and organic matter - Ripper with inclusion and gypsum and organic matter	Reduce wind erosion potential, improve moisture holding capacity, and improve biological activity.
Red and grey calcareous soils (no rocks)	- Control - Ripper only - Ripper with inclusion plates - Ripper with inclusion and gypsum and/or organic matter - Ripper with inclusion plates and organic matter - Ripper with inclusion and gypsum and organic matter	Increase organic matter and improve biological activity.
Soils with acidic subsurface layers	- Control - Ripper only - Ripper with inclusion plates - Ripper with inclusion and lime and/or organic matter - Ripper with inclusion and gypsum and organic matter	Improve soil pH in subsurface layers, reduce aluminium toxicity, Increase fertiliser efficiency and improve biological activity.
Soils with hard pans	- Control - Ripper only - Ripper with inclusion plates - Ripper with inclusion and gypsum and/or organic matter - Ripper with inclusion plates and organic matter - Ripper with inclusion and gypsum and organic matter	Reduce hard pans and improve water infiltration and root growth.

5.3 *Site establishment and monitoring overview.*

Eight sites were identified in the in the Wharminda, Lock, Tuckey, Darke Peak and Cleve districts, with initial site characterisations undertaken in March 2018 and management intervention implemented in April/May 2018. The sites were sown by landholders and managed per the remainder of the paddock. Site inspections were undertaken in May 2018. Extremely dry conditions resulted in late sowing on most sites and staggered germination. Extended dry conditions meant that the site at Murlong was not sown in 2018. Above average August rainfall boosted crop growth on the sandier sites Darke Peak, Tuckey, Wharminda and Gum Flat sites, however the heavier textured soils at Darke Peak and Cleve suffered moisture stress. Production responses to the management interventions varied considerably with some sites showing large productions increases and other having no noticeable difference between treatments.

Dry matter cuts and harvest cuts were taken at selected sites where crop growth indicated some response from the management intervention during the 2018 growing season. Grain yields were extrapolated from hand cuts which tend to be higher than when harvesting with a mechanical harvester, however the data will still reflect the percentage change in production compared to the untreated controls. Descriptions of the management interventions and responses are detailed in the site summaries below.

5.4 SITE SUMMARIES

5.4.1 ASHLEY BUTTERFIELD

SOIL TYPE AND KEY CONSTRAINT: Low dune/swale. Sand over clay with infertile bleached A2 horizon. Site located on flattened top of low dune which has been clayspread with shallow incorporation.

PLOT SIZE: 12.5 x 100 m **PLOT ORIENTATION:** West – East

Table 9. Site plan – BUTTERFIELD

PLOT	TREATMENT
1. SOUTH	RIP ONLY
2. MIDDLE	CONTROL
3. NORTH	RIP+IP

Figure 4. Plot 2. Control on Butterfield site

Figure 5. Plot 3. Ripped with inclusion plates. Slightly better growth but patchy germination.

There appeared to be some differences in germination and growth at crop establishment with even germination on the control (perhaps as a result of the previous clay spreading), the ripped plots had patchy germination due to the soil disturbance. There was no discernible growth difference between treatments in spring or at harvest. This is possibly due to the drier season where crop germination seemed to have a large influence in overall crop production as was observed at other sites (where large differences in crop biomass and grain yield were measured) but not at this site due to historical clay application.

5.4.2 MATT BEINKE

SOIL TYPE AND KEY CONSTRAINT: Duplex sand on clay with very low fertility bleached A2 horizon to poorly structured yellow sandy clay loam/light clay B horizon at 30-40 cm. Low dunes and swales. Poor crop emergence on tops of dunes and poor growth in swale.

PLOT SIZE: 12.5 x 100 m **PLOT ORIENTATION:** West – East

This site was sown in May and did not have follow up rain until August. Issues with soil moisture and seeding depth resulted in staggered germination and growth (Some plants were in head while others were just emerging). The site also suffered wind erosion during this period and had a high ryegrass weed burden. However despite these challenges the plots which were ripped (with or without inclusion plates) had much higher plant numbers with more even crop emergence.

Table 10. Site plan and production data -BEINKE

SITE	PLOT #	DESCRIPTION	DM (t/ha)	GRAIN YIELD (t/ha)
BEINKE	1. SOUTH	RIP ONLY	N/A	1.1
BEINKE	2	RIP+INCLUSION PLATES	5.0	3.9
BEINKE	3. MIDDLE	CONTROL	0.9	1.1
BEINKE	4	RIP+INCLUSION PLATES	N/A	3.8
BEINKE	5. NORTH	RIP ONLY	N/A	N/A

Figure 6. Plot 3. Control at Beinke site.

Figure 7. Plot 4 – Ripped with inclusion plates has resulted in better crop germination and growth.

Production data (Table 10) shows large increases in the biomass and grain yield on the ripped with inclusion plate plots compared to the control.

5.4.3 BRAD WAKE

SOIL TYPE AND KEY CONSTRAINT: Shallow neutral loamy sand. Hard setting, poorly structured mottled clay at depths below 10 cm.

PLOT SIZE: 12.5 x 30 m **PLOT ORIENTATION:** North East – South West

Table 11. Site plan and production data - WAKE

SITE	PLOT #	DESCRIPTION	DM (t/ha)
WAKE	1. EAST	RIP ONLY	3.6
WAKE	2. MIDDLE	CONTROL	3.8
WAKE	3. WEST	RIP WITH INCLUSION PLATES + GYPSUM (2.5 t/ha in front of ripper)	4.3

The site had variable results. The site was not rolled or worked back prior to seeding and crop germination was affected by clay bought to the surface by ripping. There were some small visual differences between the control and the ripped treatments early in the season with the ripped treatments appearing to be slightly taller with more even growth than the control (Table 11). However dry conditions on a shallow clay soil resulted in a thin crop with few tillers and these early differences did not appear to continue to crop maturity. The site did not received sufficient rainfall during the season to dissolve the applied gypsum (requires approximately 100 mm rainfall to dissolve 1 t/ha of gypsum) and large responses were not expected in the first year.

Figure 8. Plot 3. Ripping + gypsum.

5.4.4 MATT DUNN

SOIL TYPE AND KEY CONSTRAINT: Gently undulating site on low sandy rise. Sandy topsoil to 25 cm (A1 horizon to 10 cm with shallow infertile bleached A2) over poorly structured mottled yellow B horizon clay (columnar structure sodic domes) at 25-30 cm.

PLOT SIZE: 12.0 x 42 m **PLOT ORIENTATION:** North – South

Table 12. Site plan and production data - DUNN

SITE	PLOT #	TREATMENT DESCRIPTION	DM (t/ha)	GRAIN YIELD (t/ha)
DUNN	1 EAST	RIP + INCLUSION PLATES	2.8	4.2
DUNN	2	RIP WITH INCLUSION PLATES + GYPSUM	2.3	4.8
DUNN	3	CONTROL	2.5	2.6
DUNN	4	RIP ONLY	1.2	3.8
DUNN	5	SURFACE APPLIED GYPSUM (2.5 t/ha) RIPPED WITH INCLUSION PLATES	3.5	6.2
DUNN	6. WEST	SURFACE APPLIED GYPSUM (2.5 t/ha)	1.2	3.2

The ripping treatments appeared to impact on crop germination, with less even growth than the unripped plots. However the ripped + inclusion plate treatments produced higher spring biomass than the unripped plots (control and surface applied gypsum) or ripping without inclusion plates (Table 12). The inclusion plates brought more clay to the surface which might have resulted in more even germination and higher plant numbers. These increases in spring biomass converted to higher grain yields

Figure 9. Plot 3 – Control plot patchy germination due to surface water repellence.

Figure 10. Plot 2. Rip + Inclusion plates with gypsum placed in rip lines.

5.4.5 JOHN FLAVELL

SOIL TYPE AND KEY CONSTRAINT: Coarse acidic sand with bleached A2 horizon to well-structured red clay between 25 and 40 cm below surface. Field pH 5.25 in the 0-10 cm layer and 5.75 in the 10-20 cm layer. Top of the B horizon field pH 6.0 with pH increasing at depth.

PLOT SIZE: 12.5 x 30 m **PLOT ORIENTATION:** East- West

Table 13. Site plan and production data - FLAVELL

SITE	PLOT #	DESCRIPTION	DM (t/ha)	GRAIN YIELD (t/ha)
FLAVELL	1. SOUTH	RIP + INCLUSION PLATE	7.4	4.5
FLAVELL	2	CONTROL	4.7	4.2
FLAVELL	3	SURFACE LIME (2 T/ha) + RIP + IP + OM (5 t/ha in front of ripping tyne)	7.3	6.6
FLAVELL	4	SURFACE LIME (2 T/ha) + RIP + IP	6.7	4.5
FLAVELL	5. NORTH	SURFACE LIME (2 T/ha)	3.1	3.5

There were large crop production responses to the ripping treatments compared to the untreated control at this site (Table 13).


Figure 11. Plot 1. Rip + Inclusion plates

Figure 12. Plot 3. Rip + Inclusion plates+lime+organic matter

Applying lime at the surface and then ripping with inclusion plates gave a large response that just ripping with inclusion plates and where organic matter pellets were ripped in the response was larger again. It was not expected that there would be increased production on the surface lime treatments compared to the control as it takes time for the acid nuetralisation reactions to take place and the variety of wheat used (Mace - a variety with parent lines originating in WA) has some acid tolerance. Yield results largely reflected these early growth differences.

5.4.6 PAUL BAMMAN

SOIL TYPE AND KEY CONSTRAINT: Extremely shallow sand (A horizon to 5 cm at sample point) over very poorly structured (blocky) clay. Previous ripping brought up clay bricks. B horizon from 5 cm (rock encountered at 50 cm when sampling).

PLOT SIZE: 12.5 x 30 m **PLOT ORIENTATION:** East-West

Table 14. Site plan and production data - BAMMAN

SITE	PLOT #	DESCRIPTION	DM (t/ha)
BAMMANN	1. SOUTH	RIP ONLY (SUPER GRUBBER)	2.7
BAMMANN	2	RIP+INCLUSION PLATES	2.8
BAMMANN	3	CONTROL	3.2
BAMMANN	4. NORTH	RIP + IP + OM (5 t/ha in front of ripping tyne)	0.8

This site had a shallow sandy A horizon over a poorly structured sodic B horizon with increase carbonate percentage at depth. The sandy A horizon is highly compacted. Ripping (with and without inclusion plates) bought large amounts of calcareous clay and carbonate rubble to the surface. The site was not further treated (rolled or worked back) post ripping and germination was very poor. There was also concerns at this site that the high levels of carbonate, the amount of clay brought to the surface and the dry conditions at crop emergence might have caused some herbicide residue damage at crop establishment on the ripped plot. The much lower spring biomass production on the plot were organic matter was applied was surprising with alleopathic properties (possibly phytotoxic) in the type of organic matter pellets used (pea straw) cited as a possible reason for poor crop performance on this plot (Figure 15). Very dry conditions throughout the season resulted in poor and patchy crop growth with the site suffering significant moisture stress and as such harvest cuts were not taken at this site.

Figure 13. Plot 3. Control

Figure 14. Plot 4. Rip + inclusion plates + organic matter pellets (note poorer growth compared to the control)

Figure 15. Note poor crop growth where high levels of organic pellet residues.

5.4.7 PETER PRIME

SOIL TYPE AND KEY CONSTRAINT: Gently sloping site which was clayspread more than 10 years ago with approximately 250 t/ha of clay, which was unincorporated. The spread clay remains in thick band at soil surface and has some evidence of surface sealing. Original A1 layer is still visible below this surface clay layer. Highly bleached A2 horizon to clay at 55 cm.

PLOT SIZE: 12.5 x 100 m **PLOT ORIENTATION:** East- West

Table 15. Site plan and production data - PRIME

SITE	PLOT #	DESCRIPTION	DM (t/ha)	GRAIN YIELD (t/ha)
PRIME	1 SOUTH	RIP ONLY	2.3	3.7
PRIME	2 CENTRE	CONTROL	1.4	2.5
PRIME	3 NORTH	RIP+IP	2.4	4.3

There appeared to be better germination and plant growth of the ripped only plot compacted to the clay only control with ripping and inclusion plates seeming to provide further crop growth benefits (Table 15 and figure 16 and 17). These early difference in crop germination were mirrored with increased biomass and grain yield on the ripped + inclusion plate plot.

Figure 16. Prime plot 1. Rip only

Figure 17. Prime plot 3. Rip + inclusion plates.

5.4.8 CRAIG WHEARE

SOIL TYPE AND KEY CONSTRAINT: Deep sand over clay (Clayey B horizon at depths greater than 40 cm) with infertile bleached A2 horizon.

PLOT SIZE: 12.0 x 100 m **PLOT ORIENTATION:** East- West

Table 16. Site plan – WHEARE, MURLONG

PLOT	TREATMENT
1. NORTH	RIP+IP
2.	RIP ONLY
3.	CONTROL
4	RIP+IP
5.	RIP ONLY
6. SOUTH	CONTROL

Although management interventions were implemented at the site in April continued dry conditions to the end of July meant that the grower did not sow the paddock. The site was inspected in May but there was little pasture germination on the site at this stage. There appeared to be some better plant growth along the rip lines later in the season. However this was largely low value species such as capeweed and wild turnip.

5.5 *Summary and Conclusions*

The results showed some good responses on sandy textured sites, particularly those where non-wetting was still a major issue. The very dry conditions as crop establishment resulted in poor germination and moisture stress at many of the sites particularly the heavier textured soils at Bamman's and Wakes. In a dry season where clayspreading had already overcome the water repellence at Butterfields there did not appear to be any benefit from the ripping. At a number of the sites the production data appeared to show that ripping with inclusion plates was better than ripping alone. It is difficult to quantify if this is due to better soil mixing or a greater area of physical disturbance. It also appeared that OM provided an added benefit at Flavell's but resulted in decreased production at Bamman's perhaps due to alleopathic impacts from the type of organic matter used (possibly in conjunction with the highly calcareous clay material brought to the surface by ripping on a very shallow sand over clay).

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