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Combatting non-wetting soils

A tour of on-farm research in Western Australia - 2014

Acknowledgements

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Cover Photo

Trevor Syme at his Bolgart property.

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Combatting non-wetting soils

Tour of on-farm research in Western Australia - 2014

This book outlines some of the options that Western Australian farmers have adopted to manage non-wetting soils on their properties. The top three research, development and extension priorities for the Grains Research and Development Corporation's (GRDC) Western Region are frost, weeds and non-wetting soils. GRDC has committed significant investment in these priorities on behalf of growers.

GRDC invested in the Regional Cropping Solutions Network (RCSN) in 2011 with the primary aim to identify local research, development and extension priorities. There are five RCSN's across the Western Region, which have been divided on a port zone basis with two in Kwinana (Kwinana East and Kwinana West). The RCSN consists of a mix of over 70 growers and industry professionals who meet formally twice per year to discuss research, development and extension priorities.

Non-wetting has been identified by the RCSN's as having a significant impact on productivity. The RCSN members have recognised that non-wetting is limiting yield and it is increasing in extent and/or severity across many of the grain growing regions of WA.

In particular, Kwinana West and Albany Port Zone RCSNs are keen to increase farmer knowledge on methods to address non-wetting soils, and want to see extension of these methods to farmers in WA. To help achieve this, two non-wetting bus tours, and this booklet were initiated.

For further information on the GRDC's RCSNs please feel free to contact one of the following:

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Soil water repellence in WA

Soil water repellence occurs when hydrophobic (water repelling) plant-derived waxes and substances released by fungal hyphae coat the soil particles in the topsoil to such an extent that water does not readily or rapidly infiltrate the soil.

These compounds are a component of the particulate organic matter so they are associated with the organically stained topsoil. Sandy surfaced soils with low clay content, typically less than 5 per cent clay are most commonly affected as they have reduced soil surface area and are more readily coated by the hydrophobic compounds. Soils with 5-10 per cent clay can be affected by water repellence depending on the amount and type of organic matter.

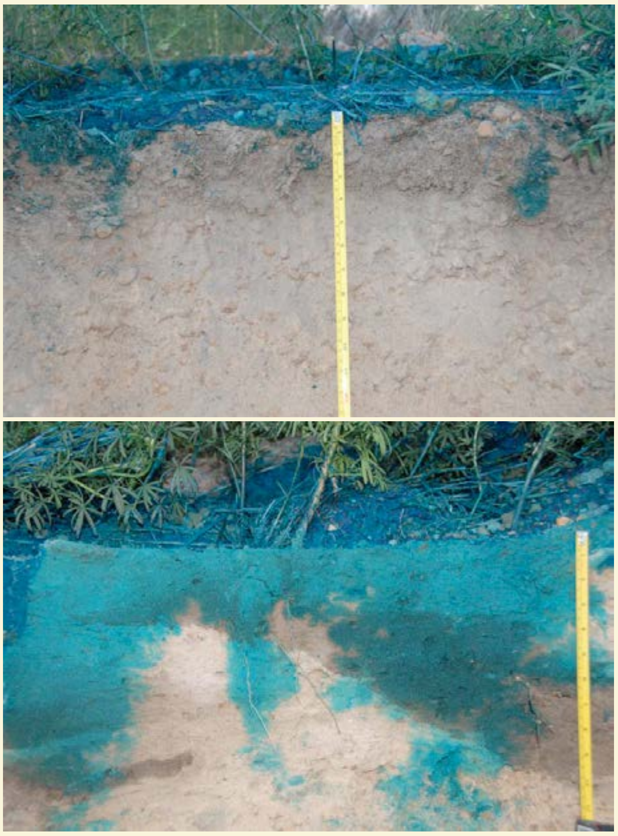

Figure 1. Infiltration of water containing blue dye in an untreated water repellent sandy gravel (top) with restricted limited infiltration down preferred pathways compared with infiltration on the same soil that has ameliorated by inversion with a mouldboard plough burying the repellent soil (bottom) (Davies DAFWA, Bolgart 2012).

In Western Australia nearly 3.3M hectares of agricultural soils are at high risk of soil water repellence with a further 6.9M hectares at moderate risk. Estimates by the WA Department of Agriculture and Food suggest the opportunity cost from lost production due to water repellence in WA is of the order of $250-330M per annum.

Soil water repellence results in poor and variable water infiltration and often incomplete wetting of soils. Water will tend to enter the soil via preferred pathways while other parts of the soil will remain persistently dry, often referred to as 'dry patch'. As a result in cropping and pasture systems water repellence typically has the following negative consequences:

- patchy and delayed crop, pasture and weed emergence (Fig. 2);
- reduced crop and pasture productivity;
- staggered (non-synchronous) plant development (Fig. 3);
- inefficient use of soil water and nutrients;
- poor weed control due to staggered germination and poor herbicide efficacy;
- increased leaching of solutes to depth due to preferential flow;
- increased water erosion risk due to increased lateral flow;
- increased wind erosion risk due to poor soil cover;
- concentration of pesticides and other solutes by lateral flow and splash;
- carry-over of un-germinated seeds; fertiliser and inactivated pesticides in isolated dry soil patches.

Figure 2. Poor and patchy establishment of wheat (top) lupins (bottom) sown with narrow knife points (Davies DAFWA, Nabawa 2010 and Badgingarra 2011).

There is however some possible advantages that can arise from water repellence including:

- reduced moisture evaporation as the dry repellent topsoils acts as an effective soil mulch;
- increased water harvesting from repellent soil ridges which can be used to concentrate water from small rainfall events in the furrow increasing the effectiveness of crop water use.

Typically the negative consequences of water repellence outweigh the benefits, although more mild water repellence in drier, lower yielding and short-season environments may be of greater benefit due to the possibility of more efficient water use through the mechanisms described above.

Figure 3. Delayed wheat emergence in a water repellent sand with recently emerged wheat (left foreground) alongside wheat that is grain filling (left background) and wheat excavated from 1m of row in a repellent sand showing contrasting stages of crop development (Davies DAFWA, Moora and Badgingarra 2013).

Industry surveys indicate that many growers with water repellent soils believe the problem is getting worse and those growers in severely affected areas rate it as one of their biggest productivity and soil constraints. Water repellence is readily diagnosed by: poor crop establishment often seen as large and frequent gaps in the crop row; staggered crop emergence and the presence of significant patches of dry soil shortly after significant rainfall events. Expression of water repellence in this way is quite visual and increased expression of water repellence is not necessarily because the water repellence is getting worse but rather can be a consequence of:

- drier autumns with reduced size and frequency of opening season rains (Fig. 4);
- increased concentration of soil organic matter at the soil surface with widespread, long term practice of minimum tillage;
- increased frequency of dry and early seeding before repellent soils have had time to wet up;
- widespread use of narrow knife points for seeding which allow dry repellent topsoil to readily flow around the point and into the furrow concentrating it with the seed and fertiliser;
- mechanical working and disturbance of dry soil when seeding which may increase the expression of repellence.

Managing water repellent soils

Management strategies for water repellent soils can be classified into three categories: mitigation, amelioration and avoidance.

Mitigation options manage the soil water repellence to allow crop and pasture production in the repellent soil. Amelioration options remove or treat the repellence to make the soil wettable. Avoidance involves removing the affected areas from annual production and applying an alternative land use, usually involving sowing to perennial forage species.

Amelioration techniques include claying, deep cultivation using tools such as rotary spaders, or one-off soil inversion using mouldboard ploughs. These tend to be expensive, but can have substantial and long-lasting impacts on productivity. The expense of these strategies increases the economic risk, and they also carry significant environmental risks if not implemented correctly.

The mitigation strategies include furrow seeding, wetting agents, no-till with stubble retention, on-row seeding, and stimulating the natural microbial degradation of waxy compounds. These are much cheaper than the amelioration strategies, but often have a much smaller, and sometimes inconsistent, impact on crop production. Because of their small cost, mitigation strategies can be applied over large areas, and can usually be applied with positive economic outcomes. For any given farm, the best options or mix of strategies to manage water repellence will depend on the severity and extent of the problem. Small patches of water repellence might best be ameliorated, but large areas are best treated initially with mitigation strategies with subsequent amelioration of areas where large responses are likely or other constraints, such as weeds, subsoil acidity or compaction, also need to be addressed.

Soil water repellence in the south

In the southern area nearly 2.2M ha or 20 per cent of agricultural soils are at high risk of water repellence. A further 3.7M ha of agricultural soils are at moderate risk.

The soils most affected are the sandy duplex soils sandy and loamy or sandy forest gravels. Water repellent soils can be found throughout much of the region with large areas around Esperance and Albany, the Great Southern and Lakes area (Fig. 5). Water repellence is also common in the south-west high rainfall zone associated with gravel soils.

Depth of sand over clay in the duplex soils varies from shallow, with less than 30cm of sand over clay to deep duplexes where there is 30-80cm of sand over clay. In the shallow duplex soils slower infiltration of water into the clay B horizon often means water perches on the B horizon and the repellent sandy A horizon 'wets-up' from underneath.

Water repellence in the deeper duplex soils has typically been managed through the use of furrow sowing or by clay spreading or clay delving, provided the clay is within 50-60cm of the surface. More recently deep cultivation

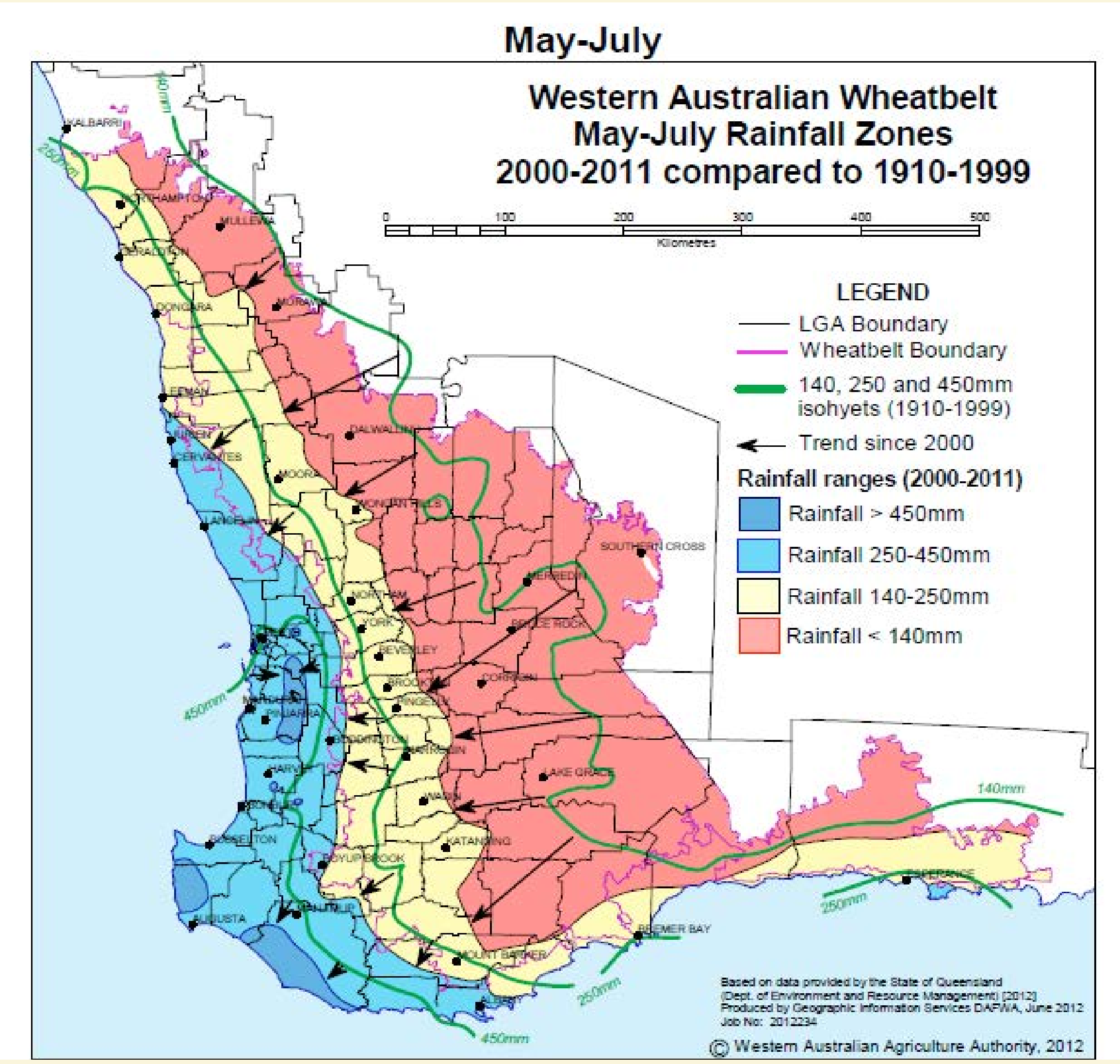

Figure 4. Map showing the shift in average May-July rainfall isohyets from 1910-1999 compared with 2000-2011 which corresponds to break-of season rainfall for sowing of broadacre winter crops. Source: Based on data provided by the State of Queensland (Department of Environment and Resource Management) 2012. Produced by: Geographic Information Services, Department of Agriculture and Food Western Australia, June 2012. (Job. No. 2012234)

techniques including soil inversion and rotary spading have been used with mixed success. The finer low-clay content sands of the south coast are particularly susceptible to erosion and where the duplex soils are shallow soil inversion can bring up too much clay resulting in surface sealing. Use of minimum and zero till soil disturbance systems which cause the least disruption of the water infiltration pathways along remnant and residual roots have also been successfully demonstrated. These residual root zones may also be habitats for microbes which can break down the waxes and hydrophobic compounds that cause repellence although their impact is likely to be greater in soils with higher clay content and in wetter environments. Improved furrow sowing techniques that use winged points, sometimes in combination with paired or ribbon row seeding, may also provide some benefit by helping grade the repellent soil out of the furrow and reducing the flow of repellent soil into the base of the furrow. For the repellent sandy and loamy forest gravels management has commonly involved furrow sowing and use of soil wetting agents. Deep soil cultivation has been shown to reduce repellence on these soils but impacts on crop establishment and productivity have been variable.

Soil water repellence in the north

In the northern area 1.1M ha, about 14 per cent, of agricultural soils are at high risk of soil water repellence. A further 3.2M ha of agricultural soils are at moderate risk.

The most affected soils in this region are the pale and coloured deep sands, sand gravels and some sandy duplex soils. Deep sandy earths can also be water repellent but it tends be more mild-moderate in severity as these soils have sandy topsoils but the clay content in the soil gradually increases with depth. The most affected areas are in the western part of the zone (Fig. 5) in the high to

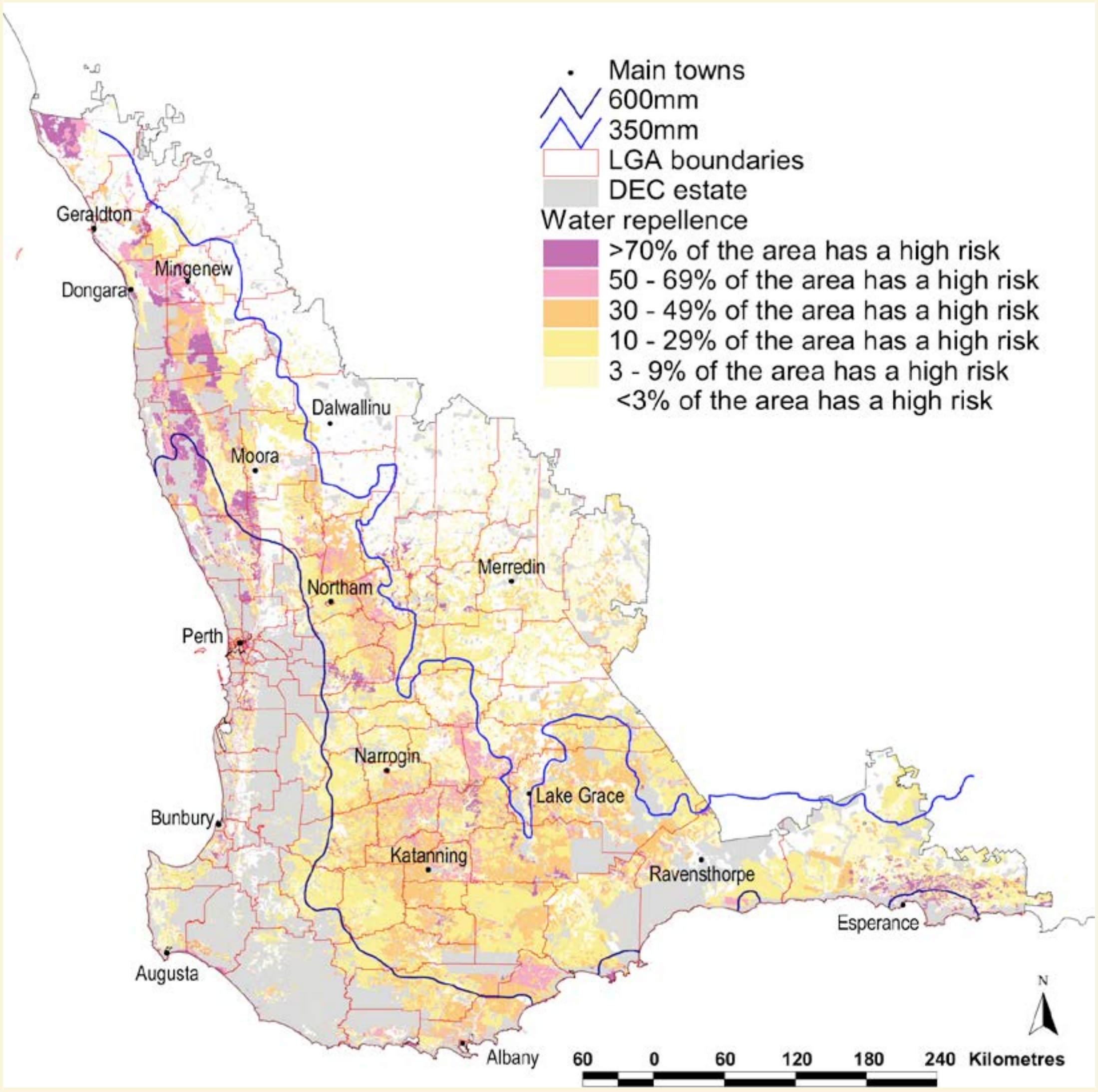

Figure 5. Map showing areas at high risk of soil water repellence in the south-west agricultural area of Western Australia, derived from the DAFWA soil-landscape map unit database (accessed November 2008; van Gool et. al. 2008).

medium rainfall areas where the deep low clay content sands are the dominate soil type.

Water repellence in the deep sands has typically been managed through the use of furrow sowing, although it has recently been found that furrow sowing with narrow knife points is not always effective, particularly when dry seeding. This appears to be a result of dry repellent soil flowing around the knife point and into the base of the furrow with the seed and fertiliser and is more prevalent when dry seeding although there is also recent evidence that dry working of repellent soil can increase the expression and severity of repellence.

There has been successful use of banded wetting agents by a limited number of growers in the region which helps improve establishment, particularly when dry seeding and the benefits of using winged and paired row seeding systems has also been demonstrated.

More recently one-off deep cultivation, through either complete soil inversion with a mouldboard plough or deep mixing using rotary spaders has been successfully used on these soils to overcome water repellence.

Clay spreading is also undertaken and has added benefits of helping control wind erosion, typically subsoil application rates have been reduced with growers typically applying between 100-150 t subsoil/ha which generally contains 30-40 per cent clay. Some growers are spreading the clay with heavy duty multi-spreaders and incorporating it with scarifiers and/or offset discs although spaders are used to incorporate the clay-rich subsoil if higher rates are applied.

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Developing strategies to manage water repellent soils

Soil water repellence is relatively easy to diagnose but because numerous soil types can be affected and there are many possible management options deciding how best to address the problem can be difficult.

Deciding on a water repellence management strategy in cropping systems will be determined by many factors including: the severity of the water repellence, soil types affected, how much of the farm is affected, impact of other constraints and whether repellence occurs in discrete patches or larger more widespread areas.

In general, there are four stages involved in developing a strategy for managing repellent soils:

STAGE 1: Diagnosis and assessment of soil water repellence

STAGE 2: Determine soil types, assess soil profiles and determine other constraints

STAGE 3: Assess and where needed improve furrow sowing technique

STAGE 4: Assess and undertake appropriate soil amelioration

STAGE 1: Diagnosis and assessment of soil water repellence

A number of indicators can be used including simple visual assessment and observation techniques or collection and assessment of soil samples to determine the severity of soil water repellence.

Typical visual symptoms include monitoring crop establishment across a range of seasons and assessing the patchiness of the crop and size of gaps in the crop rows (Table 1; Fig. 2).

Figure 1: Water ponding on water repellent sand (left) and sandy gravel (right) after rainfall. (Photos S. Davies and D. Bakker, DAFWA)

Figure 2: Images showing the impact of mild (top), moderate (centre) and severe (bottom) soil water repellence on wheat establishment. Note the size of the gaps in the crop rows.

Observations can also be made of water entry and occurrence of dry soil following significant rainfall or after watering a patch of sol with a watering can or gentle spray from a firefighter. Visual symptoms are only a qualitative and indicative assessment of water repellence but are helpful because they are the best way of determining the expression of the constraint.

Quantitative methods include water droplet penetration time which is simply a measure of the amount of time it takes for a water droplet to enter the soil. This is done under controlled conditions with soil that is air dry and has been passed through a 2mm sieve.

Temperature can affect the reading so typically it is done with the soil at a temperature of 15-25°C. If water droplet penetration time is assessed in the field the soil needs to be dry and the top 5-10mm of soil needs to be scraped away and repellence assessed below this. The most severe water repellence typically occurs at 2-5 cm and high temperatures at the soil surface, particularly over summer, can reduce the repellence in the top 10-15 mm.

Table 1 is an indicative guide as to the symptoms and water droplet penetration time for various ratings of water repellence.

Severity of water repellence	Typical visual symptoms	Water droplet penetration time (seconds)
Mild	Establishment impacts in dry seasons only and with early dry sowing. Small lengths crop row missing, typically less thazn 50 cm of row. Water entry generally good but small dry patches can be found after small rainfall events.	10-60s
Moderate	Establishment impacts in many seasons but less pronounced or non-existent in seasons with a wet break and consistent follow-up rains. Water ponds on surface after rain for up to 5 minutes. Moderate lengths crop row missing, up to 100 cm row.	60-240s
Severe	Establishment impacts in all seasons, very poor establishment in most seasons, large gaps in crop rows, with gaps up to 100 cm or more of row common. Water ponds on the surface after rain for up to 10 minutes or more. Large patches of poor crop establishment and growth.	>240s
Very severe	Establishment very poor in all seasons, sparse crop establishment. Large patches of missing crop and poor emergence, very sparse crop. Water ponds on the surface after rain for more than 10 minutes.	>240s

Table 1: Summary of visual symptoms and soil tests used at assess the severity of water repellence. Visual symptoms are indicative only.

STAGE 2: Determine soil types, assess soil profiles and determine other constraints

Water repellence typically affects sandplain soils with low (<5%) clay content in the topsoil.

To accurately assess the soil type it is necessary to assess the soil to a depth of at least 80 cm, if possible, to determine if there are significant changes in texture. Changes in soil texture with depth can be gradual (e.g. sandy earths) or abrupt (duplex soils).

Table 2 shows the major soil types affected by water repellence and includes a brief description of them, typical water repellence severity and an indication of which water repellence management options may be suitable for them. It is recommended that growers get further detail and professional advice before determining which management practice may suit their soil type, landscape and circumstances.

Soil type	Soil description	Typical severity of repellence	Typical options to manage repellence on soil type	Factors to consider
Pale or coloured deep sand	Sandy-textured soil to depth with low <5% clay content throughout. Colour can range from white or grey through to yellow, brown and red.	Severe – Very Severe	Improved furrow sowing Banded wetters Rotary spading Soil inversion Clay spreading or delving Alternative land-use	Yield potential of soil Subsoil acidity Erosion risk Poor water holding Nutrient leaching Weed burden
Deep sandy earth	Sandy at the surface, clay content gradually increases with depth to a sandy loam or loam texture within 80 cm, typically with 15-20% clay at depth.	Mild – Moderate Less severe due to higher soil clay content.	Improved furrow sowing Banded wetters Rotary spading Soil inversion On-row & low disturbance seeding	Weed burden Subsoil compaction Subsoil acidity Erosion risk
Deep sandy duplex	Sandy textured topsoil with <5% clay over a texture contrast layer (typically clay) between 30-80 cm.	Moderate – Severe	Improved furrow sowing Banded wetters Rotary spading Soil inversion On-row & low disturbance seeding Clay spreading or delving Alternative land-use	Weed burden Subsoil compaction Subsoil acidity Erosion risk
Shallow sandy duplex	Sandy textured topsoil with <5% clay over a texture contrast layer (typically clay) between 3 to <30 cm.	Mild – Moderate Less severe because soils can wet up from below.	Improved furrow sowing Banded wetters Rotary spading On-row & low disturbance seeding	Waterlogging Properties of clay subsoil including pH, sodicity, salinity Erosion risk
Sandy gravels	More than 20% gravel in a layer at least 20 cm thick within the top 15 cm and with a sandy matrix.	Mild – Very Severe	Improved furrow sowing Banded wetters Soil inversion Disc ploughing Rock grinding On-row & low disturbance seeding	Weed burden Subsoil acidity Cultivation not viable if gravel is cemented.
Loamy (forest) gravels	More than 20% gravel in a layer at least 20 cm thick within the top 15 cm and with a loamy matrix.	Mild – Severe	Improved furrow sowing Banded wetters Blanket wetters Disc ploughing (shallower cultivation) On-row & low disturbance seeding	Soil acidity High P fixing

Other soil and agronomic constraints need to be assessed as it can impact on which management practices may be preferred or possibly shouldn't be adopted.

Table 2: Summary of visual symptoms and soil tests used at assess the severity of water repellence. Visual symptoms are indicative only.

Soil or agronomic constraint	Diagnosis	Management options	Management implications
Subsoil acidity	Soil test in 10 cm increments to at least 40 cm, analyse pH in CaCl2, possible measure aluminium.	Rotary spading Soil inversion Disc ploughing Delving or claying (alkaline subsoil)	Lime incorporation Acidic subsoil brought to surface and poor mixing through profile with mouldboard.
Subsoil compaction	Use soil probe in wet soil to 'feel' hardpans to a depth of 50 cm or more; visual observation of hard pans and restricted root growth; responses to deep ripped test strips.	Deep ripping Rotary spading Soil inversion Delving	Working depth may not completely remove hardpan. Re-compaction risk is very high. Controlled traffic.
Clay layers within top 80 cm	Use auger or spade to assess depth to clay and observe clay structure. Analyse clay for pH, sodicity, salinity and nutrients (K, S, Ca and B).	Spading Delving Improved furrow sowing	Inversion of shallow clay (in top 40 cm) can cause surface sealing problems. Toxic and dispersive subsoils.
Soil P profile	Soil test in 10 cm increments to a depth of 40 cm, analyse for P and P fixing.	Disc ploughing Rotary spading Soil inversion Liming	Inversion may bring low P soil to the surface. Cultivation and liming can improve P availability.
Poor water and nutrient retention	Assess texture to depth of 80 cm or more. Samples can have particle size analysis to measure clay content and CEC. Deep sands in medium to high rainfall areas are prone to leaching.	Claying or delving Banded wetters Soil inversion Rotary spading Deep ripping	Increased clay content from claying improves water and nutrient holding. Use of wetters with nutrient and water retention compounds in the formulation can help. Placement of a layer of organic matter at depth through soil inversion can improve water and nutrient use efficiency and help crops survive mid-season drought. Removing compaction can improve root growth into the subsoil and nutrient access.
Herbicide resistant weeds	Surviving radish and ryegrass plants despite effective herbicide applications; weed seed samples can be tested.	Soil inversion Rotary spading Paired rows Narrow row spacing Higher seeding rates Blanket wetters	Spading helps control radish but can promote grass germination. Improved furrow sowing techniques can increase crop competition. Blanket wetters can help early weed germination.

Table 3: Summary of soil and agronomic constraints that need to be accounted for when assessing water repellent soils and considering possible management options.

STAGE 3: Assess and where needed improve furrow sowing technique

Furrow sowing effectiveness can be assessed using the following indicators:

1) Narrow steep rake angle knife points are a higher risk.
2) Dry soil in furrows and wet inter-row ridges after significant rainfall.
3) Significant gaps in the crop row in areas of moderate to severe repellence.
4) Ungerminated seed and undissolved fertiliser granules in the furrow late in the season.

Furrow sowing efficacy can be improved by using: winged points or boots, paired (twin) row seeding boots; ribbon seeding; sowing close to the previous year's crop row and banded wetting agents with knife points especially when dry sowing. Yield benefits can be about 5-20% (typically a $40-115/ha income benefit with typical prices) and costs can be less than $10/ha.

When applied over a large area of repellent soil use of improved furrow sowing and mitigation techniques can significantly improve whole farm profit with minimal risk. Unless the area of the farm affected by water repellence is relatively small it is generally more profitable to first adopt improved furrow sowing techniques. Progressive amelioration can then be undertaken over time in areas where responses are likely to be high and sustained.

STAGE 4: Assess and undertake appropriate amelioration

Water repellence amelioration techniques, such as soil inversion, rotary spading and claying, are slow and expensive to implement.

For this reason amelioration should be targeted at areas that have good yield potential once the repellence constraint is overcome and are likely to have large yield responses.

Highly repellent soils that still have reasonable water and nutrient holding capacity can be good candidates for amelioration. Soil amelioration often has the potential to overcome a number of constraints which can increase the size and longevity of the benefits.

The need to apply other soil amendments, such as lime, gypsum or nutrients, should be assessed prior to undertaking amelioration. The size and longevity of the benefits will be maximised if compaction is removed as part of the amelioration process and re-compaction is minimised through use of controlled traffic.

Amelioration techniques should, if possible, first be tested over smaller areas to assess responsiveness and possible problems over several seasons. Testing the strategies first also enables growers to assess practical implication issues that may arise, such as how best to successfully seed and manage crops on soft cultivated soils.

Amelioration options can include clay spreading, clay delving, one-off disc ploughing, one-off soil inversion with mouldboard or square ploughs and one-off deep cultivation with rotary spaders.

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A tour of on-farm research in Western Australia - 2014

Improving the effectiveness of furrow sowing on repellent soils

Furrow sowing was an important development for water repellent soils, with the repellent ridges helping to harvest water into the furrow where the seed was sown improving water infiltration and crop establishment.

Grower experience and research, however, has shown that furrow sowing with narrow knife points could fail in water repellent soils because dry repellent topsoil flows around the knife point and into the seed slot.

This problem results in poor crop establishment with gaps in the crop row and the furrows remaining dry after significant rainfall. The problem is made worse by dry-sowing and seasons with small and infrequent season opening rainfall events.

Numerous options exist (Table 1) to help improve the effectiveness of furrow sowing. These include changing the timing of seeding, sowing rate and placement of the seed through to making changes to the seeding system or additions in the form of soil wetting agents.

Delayed wet seeding and higher seeding rates

Depending on what proportion of the farm is affected by water repellence, one option may be to leave seeding the water repellent areas or paddocks to the end of the cropping program.

This means that in many seasons the repellent soils will have more time to wet up and it may also provide an opportunity for weed germination and use of a knockdown herbicide prior to seeding. Delaying seeding can reduce yield potential but in repellent soils improved establishment (Image 1) and weed control may more than make up for this. For farms where water repellence affects most paddocks this strategy may not be viable.

Using higher seeding rates may also be an advantage. Wheat establishment in 2014 after a good start to the season on repellent sandy gravel at Wickepin increased from 98 to 162 plants/m^2 when the seeding rate was doubled from 60 to 120kg/ha. While seeding efficiency can decrease with higher seeding rates this may be further improved when higher seeding rates are combined with paired row or ribbon row seeding systems.

Image 1. Impact on canola establishment of wet seeding (left) after 25mm of rain overnight compared with dry seeding (right) the day before on highly repellent pale deep sand, Badgingarra 2011.

Improved Furrow Sowing Option	Mechanism	Implications
Delay seeding and wet sow	Soil has time to wet up Less dry soil to flow into furrows	Opportunity for weed control Reduced yield potential Delay seeding program
Higher seeding rates	More seed through more soil	Increased cost Reduced seeding efficiency
Winged points or boots	Increased grading of repellent topsoil Reduced flow of repellent topsoil into seed zone	Larger furrows and ridges Increased disturbance Pre-emergent herbicide graded into ridges Stubble handling issues?
Paired rows, ribbon seeding or narrow row spacing	Seed distributed through more soil including preferential wet areas Capacity to sow seed onto undisturbed or firmed soil (under paired-row wings)	Improved weed competition
On-row seeding	Place seed near remnant root from previous crops that act as pathways to aid water entry	Requires accurate steering. Possible stubble handling and disease issues. Build-up of fertile zones associated with the crop row. Activity of microbes that degrade water repellence likely to be higher on old rows. Old rows often have shallow depressions that help harvest water. Exceptions have been observed.
Zero and minimal disturbance	Maintain residual roots that act as infiltration pathways into repellent topsoil.	Can be difficult to build up significant root mass in severely repellent soil or drier areas. Stubble handling issues.
Banded soil wetting agents applied at seeding	Improve wetting of furrow base Effective wetting from smaller rainfall events	Reduced soil water retention unless water holding humectant included in formulation. No weed germination benefit.
Blanket wetting agents applied pre-seeding	Improved water infiltration into soil surface.	May improve weed germination and subsequent control. Can be expensive at the rates sometimes needed to get a significant benefit.

Table 1: Summary of options to improve the effectiveness of furrow sowing.

Image 2. Impact on canola establishment of seeding on the previous year's crop row (left) compared with seeding on the inter-row (right) on repellent loamy gravel (Photo: Derk Bakker, 2012).

Winged points or boots and paired-row or ribbon seeding

Winged seeding points or boots can do a better job of grading the repellent soil out of the furrow and directing the flow of topsoil into the ridge.

For 7 field trial comparisons on repellent sands or sandy gravels winged points have given an overall yield advantage of 140kg/ha compared with knife points across a range of crop types.

Use of winged seeding boots with paired or twin rows further improves the response with an average yield increase of about 400kg/ha compared to knife points. Twin row sowing increases the amount of crop row in a given area and this would likely increase the chance of seed ending up in or near preferential wet areas. A similar benefit is likely to occur with ribbon seeding.

Zero-till, minimal disturbance and on-row seeding

Research by Margaret Roper and Phil Ward (CSIRO) has shown that residual root systems from the previous year's crop, if left relatively undisturbed, can act as preferred pathways for water entry into repellent topsoil.

For example, volumetric soil moisture of unsown (i.e. undisturbed) water repellent yellow sand at Binnu after 53mm of rain over the preceding 4 days was 4.2 per cent on the previous season's wheat rows compared with 1.5 per cent in the inter-row.

This can be taken advantage of by sowing onto or right alongside the previous year's crop row (Image 2).

In water repellent sand at Binnu, lupin establishment was increased from 6 to 20 plants/m^2 by using a banded wetting agent when sown between the previous year's crop row but increased to 36 plants/m^2 when sown on the previous year's crop row both with and without wetting agent.

Soil wetting agents

Banded soil wetting agents can be applied to the base of the furrow, behind the press wheels.

Used in this way only small volumes of soil wetting agent are required, typically 1-2 L/ha, thereby reducing the cost. The advantage of this method is it utilises the water harvesting effect of the repellent ridges then can help improve the evenness of wetting along the entire length of the furrow.

The method is particularly useful for improving establishment when dry seeding and an average yield increase of 230kg/ha has been achieved across a range of crop types on repellent sand or gravel.

Soil wetting agents that contain water and nutrient retention chemistry in addition to a penetrant that helps water enter repellent soil can give growth and yield advantages even when establishment is not significantly improved.

Blanket application of soil wetting agents is attractive because it is easily applied and may help weed germination and subsequent control as well as improving crop establishment. T

he disadvantage is at the rates used 10-40L/ha the costs can be quite high, about $50-$200/ha, although some products may give two years of benefit.

The current range of blanket applied wetters appear to work better on some soils than others being more effective on repellent loamy gravels and less effective on sands.

Where they do work blanket wetters are suited to being selectively applied to highly repellent patches or parts of paddocks, particularly if they have a high weed seed burden.

Conclusion

Improving the effectiveness of furrow sowing can be a very cost-effective and profitable strategy to improve crop establishment and productivity on water repellent soils.

While these approaches may not give yield increases as large as those that may be achieved through amelioration using one-off inversion, spading or claying the cost to implement is much lower and benefits can be accrued over larger areas.

It is recommended that growers wanting to better manage their repellent soils first explore their options to improve the effectiveness of furrow sowing and getting these benefits before then progressively ameliorating those areas where it is profitable to do so over time.

Acknowledgements: Research funded by DAFWA, CSIRO and GRDC through the "Delivering agronomic strategies for water repellent soils in WA – DAW00204" and "Novel solutions for managing non-wetting soils" research projects.

Combining management strategies to beat water repellence at Badgingarra

ANDREW, GINA, MIKE AND SARA KENNY	
"RUBICON", BADGINGARRA	
Area:	4400 ha
Annual rainfall:	500 mm (300 in the growing season)
Soil types:	sand, duplex gravel, loam
Livestock:	5200 ewe breeders and 100 cows
Cropping:	2300 ha (1/3 canola, 1/3 barley, 1/3 wheat and some lupins)

HISTORY

- 1959 – Mike and Sara moved to Badgingarra and cleared the original family farm. Until 15 years ago, 90 per cent of the farm was grazed. Then slowly, they increased the cropping component of the business.
- 2003-2013 – the Kenny's doubled their property size.
- 2006-2008 – they clayed 300 ha using a contractor.
- 2010 – Andrew ran a 20 ha mouldboard plough trial on the property with DAFWA
- 2011 – Purchased a mouldboard plough and ameliorated around 450 ha and did a winged, paired-row seeding system trial.
- 2012 – Seeded entire cropping program using winged, paired-row seeder. The family also purchased a second mouldboard plough.

Badgingarra farmer, Andrew Kenny suspects that the area he farms, which is around 200 km north of Perth and 50 km inland from Cervantes, has always had non-wetting soils. But he says that increased cropping practices, combined with a reduction in rainfall, have exacerbated the issue in recent years.

Claying the non-wetting soils, combined with improved sowing systems and mouldboard ploughing have lifted yields by around 30 per cent on some areas of the farm.

In 2006 the Kenny's employed a contractor to spread clay on around 400 ha, in a mainly mosaic pattern, along the bottom of valleys where some of the worst non-wetting sandy areas of the property were.

Soon after, the family realised that some of their gravelly/ sands were also non-wetting (especially in the drier years).

They then had a spate of drier years which resulted in tight finances and so they were forced to completely stop the claying program in 2008.

"We found that the claying did fix the non-wetting problems and the soils looked heaps better, but in drier seasons, the clayed soils were more prone to spring drought and so quite often they didn't yield that well." Andrew said.

"We also found that claying was also expensive ($800/ha), difficult to do at the right time (beholden to contractors and the season), and the crops were prone to spring drought.

Because the process of claying was so expensive, Andrew felt that with the tightening finances, there needed to be a cheaper way of fixing the increasing problem.

He had always wondered how much extra nutrient holding capacity claying can give, so in 2010, after visiting some mouldboard trials, the Kenny's ran 20 ha of commercial trials on the property with the Department of Agriculture and Food's (DAFWA's), Steve Davies. That was another dry year, but the trials showed some good results. At the end of that year, they realised that they needed to purchase a mouldboard plough so that they wouldn't need to rely on a contractor.

He said that Steve Davies's trial work on the property gave him the confidence to go ahead and increase the mouldboard program.

"So I went halves with my brother-in -law and we did 450 ha in 2012 and so far we have found that this is a much cheaper way of overcoming water repellence and it has also been good for our non-wetting gravels.

On a good year, their best country can yield up to five tonne crops, but the issues of non-wetting are also starting to occur even on this country.

Andrew has found that by mouldboarding, the increases in yield have at times been just as good on his good country, if not better, than the poorer country.

"Weed resistance isn't so much of a problem for us here since we haven't been cropping for as long as other areas, but the increased weed-kill has no-doubt also been a great spin-off with the mould boarding that we have done. There is no-doubt that radish and ryegrass are still an increasing issue for us and we can now also get canola to fit better into the rotation which has been a help."

In fact the mouldboard has increased yields by so much, that at the end of 2013, the family purchased another plough, so that both properties now have one.

"I'm hoping that the benefits of the ploughing will last 10 years. It costs around $150 per hectare, which includes stump picking and levelling, depreciation, fuel and labour ($115 for the actual mouldboard operation and extra for preparation of the site).

"We have been getting around 1 tonne to the hectare bonus. Some of the poorer soils jump from one tonne to two tonne. As the soil type quality improves, we have tended to still have the one tonne improvement, so we might go from three tonne to four tonne."

They ameliorate around two hectares per hour with the six furrow mouldboard plough which allows for a lot smoother paddock. So far the family has mouldboard ploughed around 600 ha and clayed a further 300 ha.

The Kennys also use a paired-row seeding system and depending on the season, will try to undertake more mouldboard ploughing after seeding.

The winged-boot paired-row seeding system was first trialled by the Kennys in 2011. It costs around $10/ha and gave better results for crop establishment and soil moisture-holding ability than their knife-point seeder. A parallel linkage Morris Contour Drill with winged-boot was purchased at the end of 2011 and used for the entire cropping program in 2012.

Economic analysis of the Kenny's farm program, funded by GRDC, was carried out by the DAFWA water repellence project in 2012. This showed the new seeding system combined with the mouldboard ploughing had increased profits by around $131,700 for the Kennys so far.

"I am only new to this, so I still have heaps to learn. No doubt in 5 years-time we will be facing different challenges again – but I think the future is exciting," Andrew said.

KEY LESSONS LEARNT

- Rolling is crucial otherwise it is too light and fluffy to get machinery through.
- Don't plant canola for two years after.
- It is better to have a good understanding of your pH to know whether to lime beforehand (they are lucky that they are only 60 km from a lime pit).
- It can be difficult to get labour as mouldboarding is done at a busy time of year and seeding and mould boarding add another level of stress. Gumtree can be useful and Andrew employed some people who were fantastic and knew more about mouldboarding than he did when he first started

TRIAL RESULTS SUMMARY

This demonstration site is on severely repellent pale deep sand that had a history of blue lupins. A trial area of mouldboard ploughing was initially established in 2010. In 2012 more mouldboard ploughing and clay-spreading treatments were implemented at the site. Clay-rich subsoil (~30% clay) was spread at a rate of ~150 t/ha using a multi-spreader.

The one-off 2010 mouldboard ploughing treatment has resulted in yield increases of 1.0 t/ha or more for the past 4 seasons (Fig. 1). The measured yield increases were partly a result of overcoming the water repellence by soil inversion and improving crop establishment. Barley establishment was improved by ~50% (40 more plants/m^2) in 2010, lupin establishment increased by 300% (33 more plants/m^2) in 2011 and barley establishment by 75% (75 more plants/m^2) in 2012.

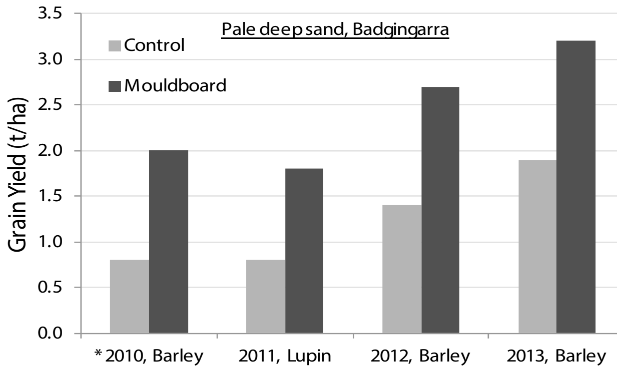

Figure 1. Grain yield (t/ha) in untreated and mouldboard ploughed treatments over 4 seasons for severely repellent pale deep sand at Badgingarra. *2010 was the year the mouldboard ploughing (soil inversion) was done and sown to a barley cover crop.

Improved nutrient access and enhanced crop root growth in the 10-40 cm layer and, in the first few seasons at least, a soil loosening (deep ripping effect), could all contribute to the measured yield improvements.

Soil moisture measurements at this site have shown that the buried topsoil can hold more moisture in the 10-40 cm layer than the pale, low clay content (<5% clay) sand (Fig. 2).

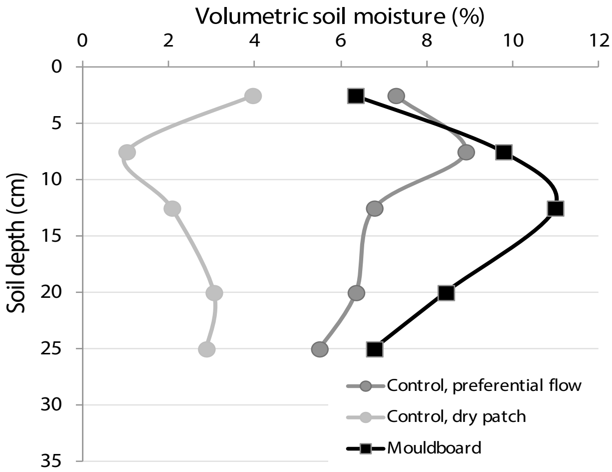

Figure 2. Volumetric soil moisture (%) in severely water repellent pale deep sand at Badgingarra, Western Australia, measured 5 July 2011 for untreated (control) soil in either dry patch areas or preferential flow areas compared with mouldboard ploughed soil that was consistently wet.

There is no evidence that productivity benefits from mouldboard ploughing in 2010 is starting to decline as the yield increase in 2013 was still greater for the 2010 mouldboard ploughing than the more recent 2012 mouldboard ploughing (Fig. 3). Clay spreading increased yield by 200 kg/ha and addition of clay-rich subsoil either on top of 2010 ploughed soil or prior to the 2012 ploughing has tended to reduce the yield benefit (Fig. 3). Where clay has been applied to the surface better incorporation is likely to increase the benefits.

Image 1, below: Top image shows barley establishment in 2012 in untreated soil (left) and soil that had a one-off inversion in 2010 (right). Below image shows one-off inversion of repellent deep sand with a 6-furrow Gregoire-Besson mouldboard plough in late-May 2013 at Andrew Kenny's, Badgingarra.

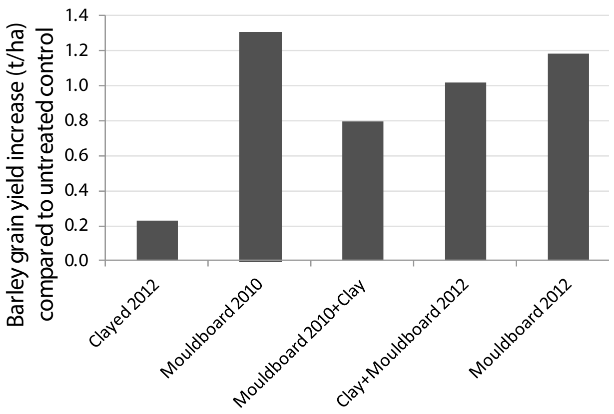

Figure 3. Barley grain yield (t/ha) response across a range of amelioration treatments compared with untreated control strips at Badgingarra in 2013. Note all clay spreading treatments were applied in 2012.

Whole plant hand cuts were also taken in 2013 to get an estimate of the change in whole shoot biomass. Claying increased shoot biomass by 1.5 t/ha; 2010 mouldboard ploughing by 2.2 t/ha and 2012 mouldboard ploughing by 1.9 t/ha (data not shown). This additional above ground biomass would be matched by increases in root biomass and represents increased return of carbon and nutrients back into the soil as the stubble breaks down over time and also improved soil cover over summer.

Seeder Demo Comparison

An on-farm seeder demonstration site was conducted at Kenny's in 2011 consisting of an un-replicated strip trial with a seeder with winged points and paired rows being tested alongside the growers' normal knife point seeder.

The same air cart, seed, seeding rate (90 kg/ha) and fertiliser was used for each seeder. Soil at the site consisted of a sandy gravel with areas of pale deep sands in the lower parts of the landscape. In relatively small patches of strong and obvious water repellence paired measurements were used to determine differences in crop establishment and soil moisture content.

Two areas of severely repellent sandy gravel and one area of moderately repellent pale deep sand were monitored and assessed. An overall yield difference between the two seeder types was determined using 600m long header harvest cuts and a weigh trailer.

A second on-farm comparison was also conducted on a neighbouring farm comparing the same winged point-paired row seeder and another knife point seeder belonging to a local grower.

At this site the knife point seeder was seeding at 85kg/ha while the winged point-paired row seeder was seeding at 100kg/ha. The same fertiliser types and application rates was used. The soil at this site was mostly yellow deep sand – with mild to moderate water repellence. Crop yield was determined using 4 replicate paired plot harvester cuts.

In general for the bulk of the paddock in the wetter 2011 season there was little obvious difference in establishment between the knife point and winged point with paired rows seeder. However there were a several water repellent patches where establishment was poor for the knife point seeder but was much improved for the winged point-paired row seeder.

Plant counts in these areas revealed that establishment was increased by more than 50% from <100 plants/m^2 to >150 plants/m^2 through use of the winged point-paired row system in both the sandy gravel and pale deep sand soil types (Fig. 4).

The paired row seeder effectively has 50% more seeding row so the chances of seed ending up in wet soil and germinating are increased.

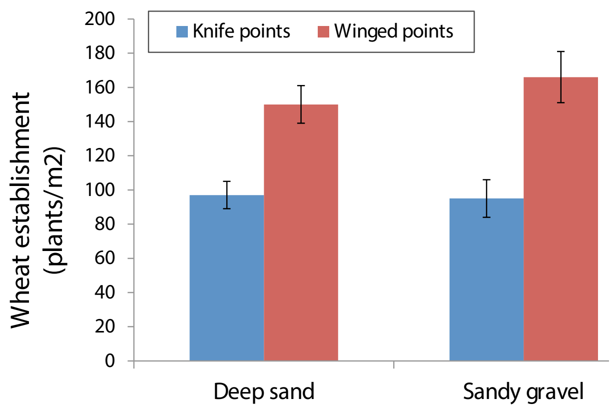

Figure 4. Wheat establishment for a knife point versus winged point-paired row seeder comparison on moderately repellent pale deep sand and severely repellent sandy gravel at Badgingarra in 2011.

A one-off post-emergence measure of soil water content in the severely repellent sandy gravel revealed higher water contents in the furrow where the winged point and paired row system had been used compared to the knife point system (Fig. 5).

In the knife points system the furrow was drier (2.2%) than the ridge (4.8%) with water content less than half what was measured in the ridge (Fig. 5).

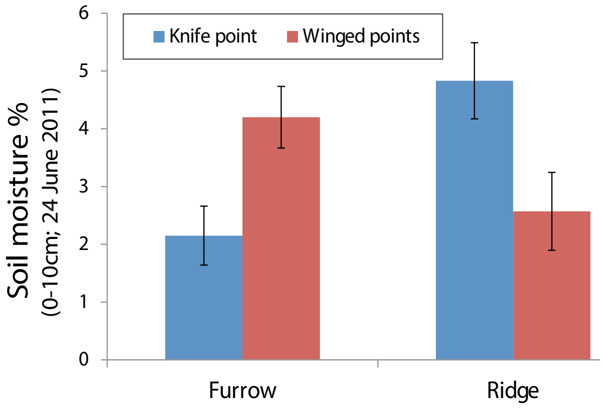

Figure 5. Volumetric soil water in the furrows and ridges for a knife point versus winged point-paired row seeder comparison in severely water repellent sandy gravel, measured once on 24 June 2011 at Badgingarra.

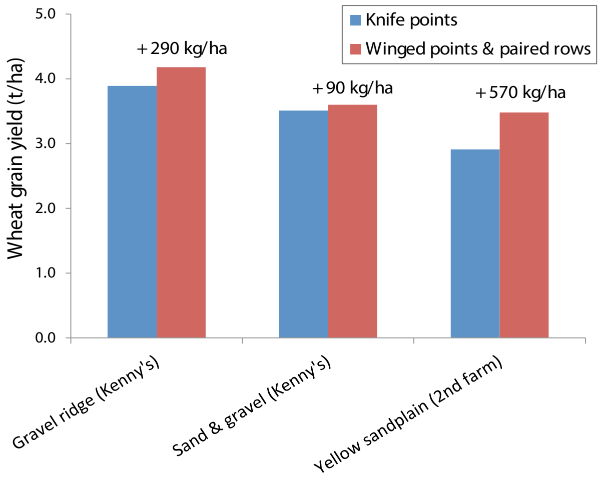

Figure 6. Wheat grain yield for a knife point versus winged point-paired row seeder comparison on moderately repellent pale deep sand, severely repellent sandy gravel and mildly repellent yellow deep sandplain at Badgingarra in 2011. Values show the yield increases in kg/ha from using the paired-row seeder compared with the knife point seeder.

It was observed that weed populations in these water repellent patches were significantly less for the winged point-paired row seeder system compared with the knife point system due to better competition. Yield differences with the header cuts were smaller, with an average yield gain of 290kg/ha in favour of the winged point-paired row seeder on the gravel ridge and 90kg/ha in the swale where there was a lot more pale deep sand areas (Fig. 6).

Acknowledgements: Thanks to Andrew and Gina Kenny, family and staff for trial establishment, support, harvest data and allowing access to the site. Thanks for your patience! Research funded by DAFWA and GRDC through the "Delivering agronomic strategies for water repellent soils in WA – DAW00204" project and supported by the West Midlands Group.

Spading improves yellow sands and gravels at Three Springs

CHAD EVA

THREE SPRINGS

Chad's Three Springs property includes a range of sands, from poor pale deep sand, through to good yellow sand with higher clay content. Water repellence is a problem that seems to have become worse over time.

Rotary Spading as been carried out on the farm since 2010 and the 110 ha spaded that year is till performing well. He finds that spading works best on yellow sand and loose gravel soils.

Some paddocks used to perform so poorly, they were not worth cropping, but since spading they are now productive, yielding 1.5 – 2.0t/ha. The biggest challenge is the soil is very soft after spading, so traction and getting bogged going up hills is an issue with a large air seeder.

Chad uses a rock-roller over spaded country to help re-firm the soil surface. Care needs to be taken not to re-compact the soil too much however as this can reduce the benefits of the deep cultivation. Chad believes it would be good to match the sprayer and airseeder tracks to reduce the compaction and number of wheel track ruts that develop on spaded sand.

Typically Chad finds that the spader brings up enough clay for the soil surface to seal after rain which can help protect the soil from wind erosion but can hinder crop emergence if it seals prior to emergence and if there is little rain in the short-term to soften the crust as the crop emerges. To overcome this Chad has a tracked tractor to provide better traction and avoid bogging problems.

Chad has achieved good couch control by using a high rate of glyphosate followed by spading. In 2014 Chad sold his spader as he had done most of the country suited to it. He has now purchased a Grizzly deep digger and had delving plates made up for the tynes with the aim of delving up clay on some of his duplex soils and increasing root access into the subsoil.

Mouldboard ploughing gives weed control at Mingenew

STUART SMART	
MINGENEW	
Area:	22,000 ha
Annual rainfall:	300-350mm
Soil types:	Yellow sandplain mixed with clay, gravel, deep white sand, weak yellow sand with less clay.
Cropping:	14,000 ha

Mouldboard ploughing has not only helped overcome non-wetting soils for Mingenew farmer, Stuart Smart, but also proved an effective non-chemical weed control.

The ploughing has increased yield by up to 0.4 tonnes per hectare in spot trials on Stuart's property, as well as controlling up to 95 per cent of weeds in the first year of use.

The Smarts have gone from soil that wouldn't accept water at all, to fully wet through the profile as a result of the mouldboarding. Weed management has been the biggest saving, and where once Stuart paid around $120 per hectare for chemical with no effective control, he now pays $70-90 for mouldboard ploughing, with control of 95 per cent in the first year.

Non-wetting soils have always been a problem in the farming area. Stuart believes that some of the sands are naturally repellent, while crops such as lupins can leave behind a waxy residue which compounds the problem. In the past Stuart combatted this by sowing following rain and adopting a no-till farming system. However, the problem persisted and a new approach was needed.

They began mouldboard ploughing in 2009 using a 14-furrow plough with the aim being to completely invert the soil. Over the years he has refined the system and this year had two ploughs running around the clock for selected paddocks.

The point of mouldboard ploughing is to invert all of the non-wetting soil and any weed seed, placing between 6 to 8 inches of clean sand over the top.

Now if they get 5mm of rain, the soil is wet from the top through to its maximum point of extension and their weed control has improved dramatically. Ryegrass is the main problem weed, with increasing herbicide resistance meaning non-chemical treatments are essential to reduce weed populations.

Wind erosion is definitely an issue and a constant threat. Their soils are light and a significant wind event shortly after ploughing can really blow it across the paddock. Another factor is that their soil is extremely soft, so you can't seed it with conventional machinery. Stuart has had to develop a system using a lightweight seeder pulled by a track machine to reduce the load.

They seed on a three metre tramline to match their sprayers, effectively keeping machinery operating along the same line and reducing soil compaction.

Spading more than doubles yields at Coorow

MICHAEL AND JULIA O'CALLAGHAN	
TREEVIEW FARM, COOROW	
Area:	5700 ha (cropped) Lease 2000 ha of that
Annual rainfall:	380 mm
Soil types:	mostly variable deep sands, 400 ha of limestone clay and 700 ha of heavy red soil
Cropping:	lupin/wheat/ and canola/wheat rotations on one farm and canola/wheat/wheat on the other farm.

HISTORY

- 1964: Michael's parents, Bevan and Mary-Anne, purchased the home farm (prior to that they had been in Coorow since 1930 and operated a machinery dealership).
- 1999: After boarding school and then working on mines, Michael returned to the farm full time. A succession plan was undertaken in 2000 and Michael took over the farm soon after.
- 2005: Clayed some land, but it seemed like an expensive operation for what they could achieve. Incorporating clay was also an issue.
- 2009: Michael was inspired after he went on a farmer tour to look at mouldboard ploughing being done by a farmer; Tony Harding at West Arrino.
- 2010: Employed a contractor to do some spading work on the property.
- 2011: Purchased a spader.

Michael O'Callaghan says that non-wetting soils have always been an issue for farmers in the Coorow area. "The difference is that we now realise how much of a problem it was and continues to be", Michael says.

In the 1980's, there were around 4000 sheep grazing the property's sand plain soils. Soil erosion was an issue and that combined with decreasing prices and the nasty chemicals and headaches involved with getting shearers was enough to turn Michael slowly into 100 per cent cropping.

Since then, he has been trying to find the best rotations to suit his environment and he has also been setting up variable rate zones on each farm and at this stage he has around 11 zones to work with yield mapping and variable rates.

Spading has been done on the property since 2011 and ideally Michael would like to see a system of a spader with delving rippers on the front and spading on the back. This would bring up the clay and soften the soil at the same time as assisting with the spading operation by providing less wear and tear.

The spader has a suspension mechanism to avoid rocks – it is set up so that the spader is lifted up if it hits something hard.

Trials with the Liebe Group in 2010 supported by the GRDC and DAFWA showed that yields at least doubled after spading was done in the first and second year after on the property. This meant the cost of spading was returned in the first year.

"The thing we don't know is how long the effect lasts for – it could be 2 years and it could be 5 or even 10 or 20 years," Michael said.

Michael says that if he compared the benefits of mouldboarding to spading, he thinks that mouldboarding is good for weed control, but not if you have acid soil below the surface.

"If your aim is to incorporate lime, then spading seems to be the better option," he said.

"Spading can also be done earlier and doesn't leave the soil exposed to erosion as much as mouldboarding also.

"With mouldboarding, you really have to know what you are doing otherwise you can leave the paddock in a real mess, whereas spading is easier to implement.

He said seeding into spaded or mouldboarded country was not easy and it didn't take much to get the depths wrong. For that reason, hydraulic tynes were essential

and seeding needed to be very shallow. Chemical use also needed to be done with some consideration.

It was imperative to seed as soon as possible after the ground had been worked – and even more important after mouldboarding, to avoid a hard crust developing.

The spader, made by the Dutch company IMANTS, is 4.5m wide with 60 spades. Spades mix the soil to a depth of 300–350 mm. The spader is pulled by a 250 horse power tractor with PTO drive and operates at 7–9km/hr.

"I am very happy with the way the machine incorporates the soil; personally I think it is the best on the market.

Michael had the spading arm and spading shovel hard-faced at a cost of $50 for each spade by a local welding company. This has doubled the life of them, which has been well worth it since they cost between $100 and $150 per spade.

The packing finger harrow worked really well and Michael felt this was better than press wheels.

KEY LESSONS LEARNT

- The process of spading is very slow.
- Spading creates another headache at an already busy time of year.
- Avoid rocky areas and select your soil.
- The process is great for incorporating lime.
- It is better to spade 200 ha properly than 400 ha and not do such things as liming, etc.
- Seasons vary and this makes a huge difference to such things as wear and tear of the machine.
- Economically, spading is very worthwhile, but it is still unknown how long the benefits will last, but in the short term it definitely fixes un-wettable soil and dramatically increases yield on the right soils.
- Spading into paddocks with thick stubble is ideal because some of the biomass may remain on the surface and protect against wind erosion. Michael begins planning the spading 12 months in advance by planting a high biomass crop with a bulky stubble residue that can protect the soil after spading.
- Watch seeding depth, fluffy soil makes it easy to sow too deep
- Apply lime before spading.
- Use a knockdown before spading.
- Try to only spade in daylight hours so fewer mistakes are made.
- Finishing off in the paddock is harder with mouldboarding.
- Watch seeding depth, fluffy soil makes it easy to sow too deep
- Apply lime before spading.
- Use a knockdown before spading.
- Try to only spade in daylight hours so fewer mistakes are made.
- Finishing off in the paddock is harder with mouldboarding.

Image 1: Wheat establishment and growth on a severely repellent pale deep sand in response to one-off rotary spading (left) and untreated (right), O'Callaghan's, Coorow 2011.

TRIAL RESULTS SUMMARY

A number of on-farm rotary spader demonstration trials have been assessed on O'Callaghan's farm from 2010 onwards by the Liebe group and DAFWA with support through several GRDC projects. The trials were conducted on different sandplain soil types as strip trials comparing one-off rotary spaded areas with paired comparisons to neighbouring untreated areas in the same paddock.

Deep one-off cultivation with a rotary spader can be particularly helpful on deep sandy earths as the clay content of these soils increases with depth and spading can increase the clay content of the topsoil (Table 1). Increasing the clay content of the topsoil to 5 per cent or more is equivalent to clay spreading and incorporation and is likely to overcome the water repellence problem for more than 10 years. Many of the more severely affected deep sands however do not have a significant increase in clay content with depth so the amelioration of repellence by deep cultivation is likely to be shorter-lived though the benefits may still last many years.

Trials at O'Callaghan's clearly demonstrate large benefits from one-off rotary spading in the first year (Fig. 1). Yield increases in the first year have been of the order of 500kg/ha or more (Fig. 1) and have tended to be greater in strongly repellent soils (Image 1).

The yield response is partly a consequence of reduced water repellence, a deep ripping effect by reducing soil strength and a cultivation effect which mineralises nitrogen.

In some cases the drier seasonal conditions have limited the size of the potential response. Growing season rainfall was 170 mm for 2010 and 2012; 324 mm in 2011 and 243 mm in 2013.

Treatment	Water Droplet Penetration Time (Seconds)	Particle Size Analysis (0-10cm)			
		% Clay	% Fine Sand	% Coarse Sand	% Silt
Untreated	182s = Moderate	4.6	10.2	83.2	2.0
Spaded	5s = Nil	6.2	13.9	78.6	1.3

Table 1: Soil particle size and water repellence analysis conducted on untreated and rotary spaded deep yellow loamy sand from O'Callaghan's, Coorow 2010. Water droplet penetration times were measured under standard laboratory conditions for 0-5cm soil samples.

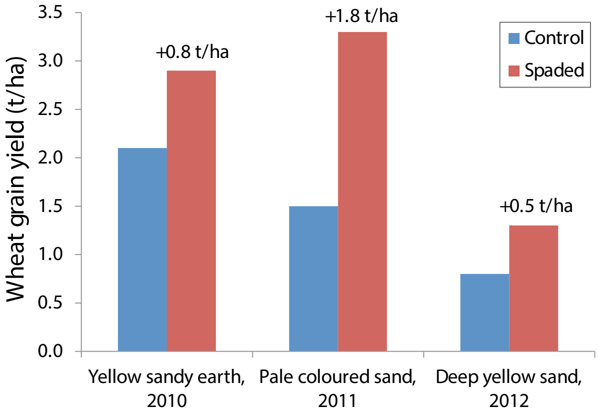

Figure 1: Wheat grain yield on untreated and in the first year after one-off rotary spading of water repellent sandplain soils on O'Callaghan farm, Coorow.

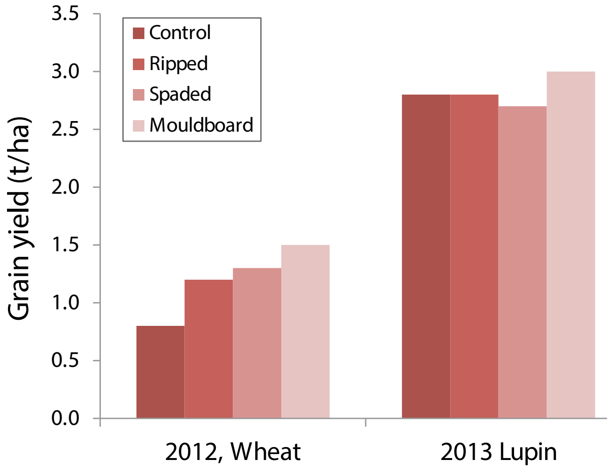

Figure 2: Impact of one-off deep ripping, rotary spading, and mouldboard ploughing conducted in 2012 compared to an untreated control on grain yield of wheat (2012, first year) and lupin (2013, second year) at O'Callaghan's, Coorow.

An on-farm demonstration site comparing one-off deep ripping, rotary spading and mouldboard ploughing was established by Michael and the Liebe group in 2012 (Fig. 2). In 2012 the trial was sown on 10 June in a season with only 170mm of growing season rainfall so yields were low (Fig. 2). In the first year deep ripping gave a 400kg/ha (50 per cent) yield increase, spading a 500kg/ha (63 per cent) response and mouldboard ploughing a 700kg/ha (88 per cent) response (Fig. 2). Growing season rainfall was higher in 2013 and there was no response to amelioration treatments in lupins (Fig. 2).

Longevity of responses to soil amelioration using one-off rotary spading is still unclear. Other research shows the benefits of one-off spading lasting for up to five years in some trials while in other experiments the benefits appear to have dissipated after about three years. Lupin responses have tended to be more variable. In cases where large lupin responses have been achieved this will have contributed to overall benefits in soil fertility but in many trials lupin responses have been lower and generally cereals give more consistent responses over time.

Acknowledgements: Thanks to Michael and Julia O'Callaghan and the Liebe Group for access to trials and support. Research supported by DAFWA and Liebe Group through GRDC projects: "Delivering agronomic strategies for water repellent soils in WA – DAW00204"; "Putting PA on the ground in WA – CSA00016"; and "Improved stubble and soil management practices for sustainable farming systems in the Liebe area – LIE0006" projects.

Spading incorporates lime successfully at Miling

TONY WHITE	
MILING	
Annual rainfall:	230mm (growing season rainfall)
Soil types:	Yellow sand plain
Enterprise:	Cropping and livestock

HISTORY

- After extensive subsoil testing for pH, Tony White recognised a significant acidity constraint in the 10–30cm layer. Tony decided to trial incorporation by spading after surface application of limesand to one of his paddocks to speed up the amelioration of the subsurface layers.
- In 2012, limesand was spread on the surface of the paddock at 3t/ha. The paddock was then spaded to 35–40cm depth, leaving an area approximately 40m x 150m unspaded. The paddock was managed as usual and sown to wheat (Figure 1).

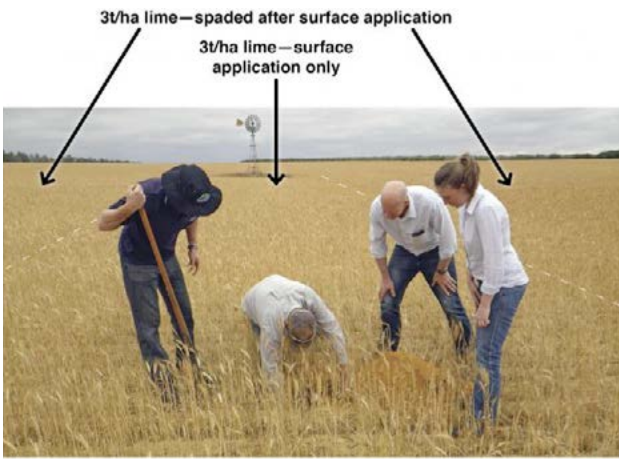

Figure 1: Spading after surface application of lime improved wheat root growth and yield

Effectiveness of lime incorporation

Visual inspection of small soil pits (stained with universal pH indicator) showed that limed topsoil was reasonably well incorporated by the spading treatment (Figure 2).

The distribution of lime was uneven, but there was enough limed soil throughout the acidic 10–40cm layer to provide pathways for roots to grow into the nonacidic soil below. This is reflected in the large spread of pH values at each depth from the replicate samples (Figure 2).

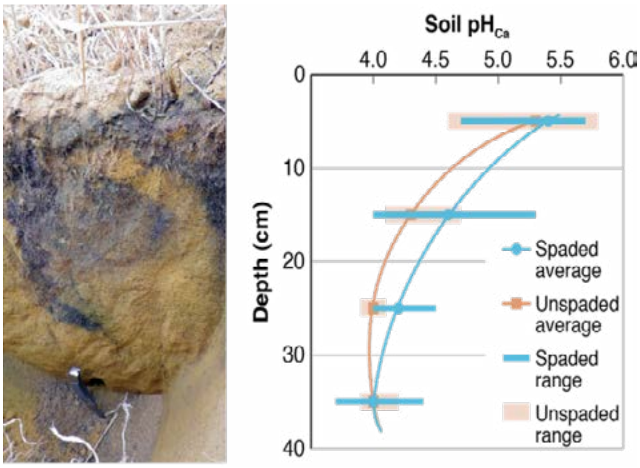

Figure 2: Incorporation of surface applied lime by spading effectively distributed the lime throughout the profile (left) even though the mixing was uneven (areas stained purple and green have higher pH). The variability in subsoil pH was greater in the spaded profile in the 10-20cm, 20-30cm and 30-40cm layers (right).

The soil pH profile of the undisturbed limed area was less variable and showed that there was a significant barrier to root growth from 10cm down to 40–50cm with average soil pH_{Ca} of 4–4.3. Beyond this, soil pH_{Ca} increased to around 5 where aluminium toxicity would not constrain root growth.

In early November 2012 when the crop was ready for harvest, roots in the unspaded profile were present at a depth to 20–25cm. In the spaded profile, many more roots were observed to a depth of 40–50cm (Figures 3). Detailed soil sampling showed that the spaded profile was dryer to a depth of 1m (Figure 4). The crop in the spaded area had been able to access and use subsoil moisture to considerable depth.

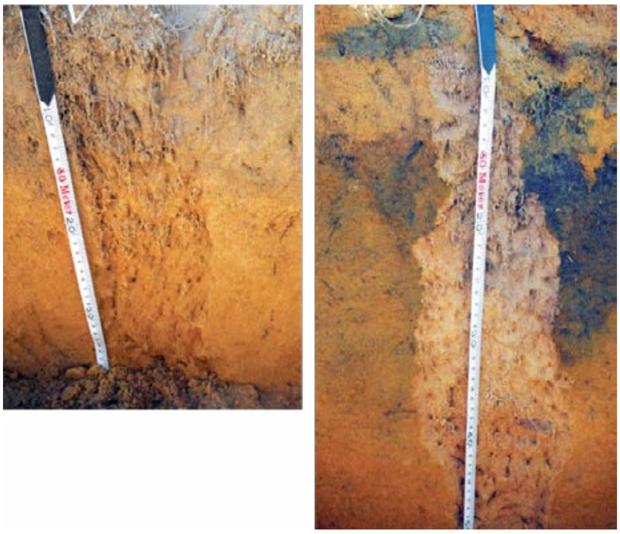

Figure 3: Roots only grew to 20–25cm depth where lime was not incorporated into the subsurface (left), but grew to 40-50cm deep where lime was incorporated by spading.

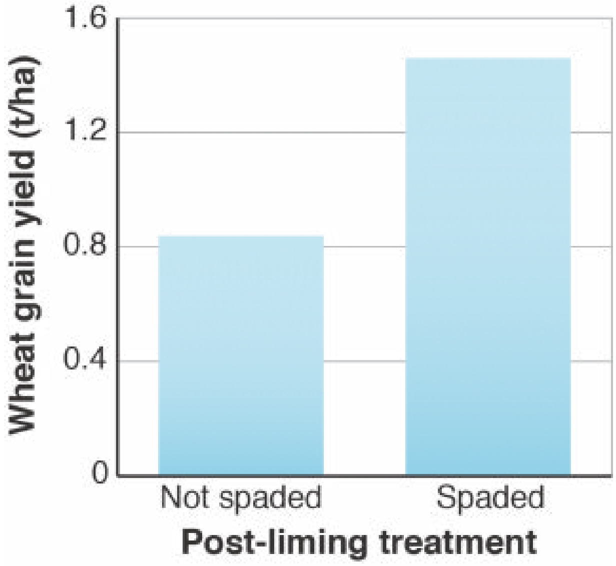

Figure 5: Wheat grain yield was significantly improved by incorporating lime by spading.

Figure 4: Deeper roots were able to extract more soil water. At 50cm the unspaded profile contained significant moisture (top hand), while the spaded profile was virtually dry. Subsequent soil samples showed that the spaded profile was dryer than the unspaded profile up to more than 1 metre.

Deeper rooting depth, and therefore access to more subsurface moisture, resulted in significantly greater grain yield (Figure 5). The value of the extra 0.7t/ha of wheat is enough to have paid for the lime and spading and the benefits of the improved profile will be ongoing.

TRIAL RESULTS SUMMARY

- Incorporation of lime by spading can improve crop growth on an acidified soil profile.
- Lime applied to the surface at 3t/ha was sufficient to bring the 0–10cm soil pH_{Ca} to almost 5.5, which would have improved microbial activity and nutrient availability in this layer. In the first year after liming, where the soil was not spaded, the subsurface soil was still very acidic.
- Over time, some alkalinity will move down the profile and improve the subsurface soil pH. However, this will take many years and requires approximately 5t/ha more lime to be applied over the next 10 years to recover the subsurface pH_{Ca} to 4.8.
- Incorporation of the limed surface soil by spading resulted in a highly variable pH in the subsurface soil but provided pathways of higher pH down to 40cm. Roots were able to grow down through these pathways to access subsoil moisture. Lime will need to be applied to the surface in the future to counter the ongoing acidification that is an inevitable part of agriculture.
- Spading is known to have effects such as removing compaction and distributing nutrients and organic matter.
- There has been no evidence of compaction and the root growth and soil moisture observations strongly indicate that pathways of improved soil pH were primarily responsible for the improved crop performance on the spaded areas of the paddock.
- Incorporation of surface-applied lime by spading is a good option to recover very acidic profiles on deep sands.

Erin Cahill – On-farm results summary

In 2011 a demonstration trial was established to assess the value of spading on deep yellow sandplain and additional advantages that may come from the ability of spading to incorporate lime and nutrients into the subsoil.

Deep ripping and one-way ploughing were included as alternative soil amelioration treatments. The trial was established by Erin Cahill (AgVivo) and CSBP field research.

The site chosen was severely non-wetting. On the day it was pegged, 23mm of rain fell in about 20 minutes. Large amounts of water ponded on the soil surface and it took over an hour for surface water to disappear. When the surface water had finally soaked in the severe water repellent dry patches could still be found when disturbing the soil surface. The site was sown with a knife point seeder.

In 2011 the spaded plots had between 46 and 61 plants/m^2 at the 1 to 3 leaf growth stage compared to 4 plants/m^2 at the 0.5 to 2 leaf stage in control plots. By spring spaded plots had 139 plants/m^2 compared to the un-spaded which improved to have 94 plants/m^2.

In 2011, good yield responses were achieved in all the treatments that involved either ripping or spading or a combination of both with deep ripping alone producing a 0.59 t/ha response and 2t/ha lime, deep ripping and spading a 1.19 t/ha increase over the control (Fig. 1). The one way plough treatments did slightly improve plant establishment but this didn't translate to a significant yield gain (Fig. 1). Average grain yield of all the spaded treatments was 2.09t/ha an increase of 850kg/ha (69% increase) compared to the untreated control which yielded 1.24t/ha.

In 2012, the second year after the treatments were applied rotary spading still had the biggest impact on grain yield (Fig. 2). Treatments that included rotary spading had yields between 1.75-1.94 t/ha while those treatments that did not include spading yielded between 1.14 and 1.61 t/ha (Fig. 2). The average grain yield of the spaded treatments was 1.85 t/ha, a grain yield increase of 710 kg/ha, a 62 per cent yield increase, compared with the untreated control.

Using the measured yield changes and estimated costs for each of the treatments applied in 2011 the net financial benefit for 2 years has been determined (Table 1). Overall spading with and without 2t/ha lime and deep ripping + spading with or without 2 t/ha lime have given significant net benefits well in excess of $200/ha (Table 1). Deep ripping alone has also given a very good net benefit (Table 1). Incorporation of nutrients is quite costly but there is still a positive net return and these may provide additional benefits in the future.

This trial demonstrates the productivity and financial benefits that can arise from implementing rotary spading and indicates that the practice of deep ripping prior to spading appears to be worthwhile as not only does it remove obstacles and make spading easier it also appears to be a benefit to crop growth and productivity particualrly in times of drought. Soil compaction was a significant constraint on this site and deep ripping alone has shown an advantage. Ideally controlled traffic system should be implemented after deep tillage to prevent re-compaction and loss of these benefits.

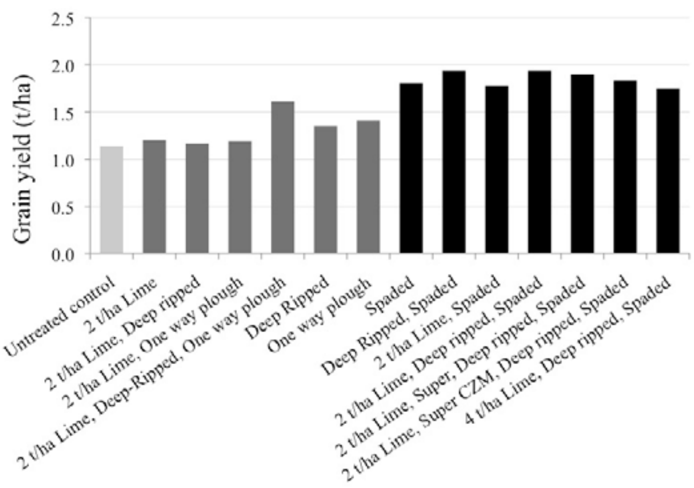

Figure 1: Grain yield of Wyalkatchem wheat in 2011 in response to range of soil amelioration treatments applied in 2011 on yellow sand, Dandaragan.

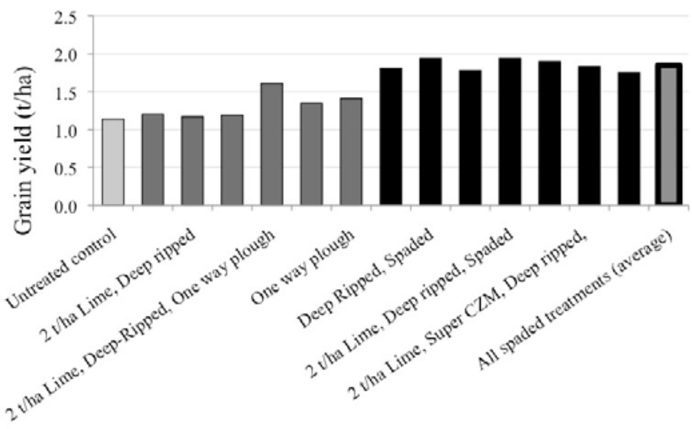

Figure 2: Grain yield of Wyalkatchem wheat in 2012 in response to range of soil amelioration treatments applied in 2011 on yellow sand, Dandaragan.

Image 1: Establishment and growth of wheat on water repellent deep yellow sand that was either untreated (left) or rotary spaded (right), sown with knife points, Moora, 2011.

Treatments	Yield change vs. control (t/ha)		2011 Treatment Cost ($/ha)	2-year Net Benefit ($/ha)	2-year change in net benefit vs. control ($/ha)
	2011	2012			
2 t/ha Lime	0.28	0.06	$68	$594	-$10
2 t/ha Lime, Deep-ripped	0.74	0.03	$118	$642	$38
2 t/ha Lime, One way plough	0.09	0.05	$98	$517	-$87
2 t/ha Lime, Deep-ripped, One way plough	0.49	0.47	$148	$679	$75
Deep-ripped	0.69	0.21	$50	$750	$146
One way plough	0.18	0.27	$30	$669	$65
Spaded	0.69	0.67	$100	$830	$226
Deep-ripped, Spaded	1.16	0.80	$150	$925	$321
2 t/ha Lime, Spaded	1.25	0.64	$168	$880	$276
2 t/ha Lime, Deep-ripped, Spaded	1.19	0.80	$218	$862	$258
2 t/ha Lime, 167 kg/ha Super, Deep-ripped, Spaded	0.90	0.76	$275	$727	$123
2 t/ha Lime, 167 kg/ha Super CuZnMo, Deep-ripped, Spaded	0.87	0.69	$300	$675	$71
4 t/ha Lime, Deep-ripped, Spaded	0.60	0.61	$286	$606	$2

Table 1: Yield response of Wyalkatchem wheat grown in 2011 and 2012 and 2-year net financial benefit in response to 2011 soil amelioration treatments compared with an untreated control on yellow sand, Dandaragan. Grain price for 2011 $230/t APW and for 2012 $280/t APW; actual estimated treatment cost is shown, all other costs estimated at $302/ha.

ACKNOWLEDGEMENT

Many thanks to: Tony and Judy Snell for giving up a portion of their paddock for the trial. Dave Gartner and AgLime Australia for supplying the lime. Paul and David Hayes for spading; Brian Cahill for ploughing; Ryan Guthrie and Rowan Madden (CSBP field research) for pegging topdressing and harvesting; James Hagan (DAFWA) for economic advice. Stephen Davies involvement is funded by DAFWA and GRDC through the "Delivering agronomic strategies for water repellent soils in WA – DAW00204" project.

Delving a cheaper option for non-wetting soils at Bolgart

TREVOR AND RENAE SYME	
WADDI PARK FARMING COMPANY, BOLGART	
Area:	3800 ha
Annual rainfall:	400mm
Soil types:	heavy red loam to white sands
Livestock:	50 breeding cattle on tagasaste
Cropping:	3300 ha of wheat/canola/barley/lupins and oats for hay

In 2013, Trevor Syme was named GRDC Australian Grain Grower of the year for his work in improving yields on unproductive sandy soils at his Bolgart property. His story is inspirational because he had managed to increase yields even while suffering consecutive years of marginal rainfall combined with variable and infertile sandy soils riddled with non-wetting constraints.

Trevor says he left one problem and found another when he sold his farm at Coorow and purchased his current Bolgart property in 1994 in search of more land and less saline issues. He thought that farming the Bolgart sandier soils would provide fresh opportunities – but realised soon after that around 85 percent of his properties' variable sands were highly non-wetting.

He wouldn't have thought back then that a decade later, more than half of his property would have been worked to ameliorate the soils in order to increase cropping yields.

"The previous owner had sheep and it was over stocked and under-fertilised when we got it," Trevor said.

He first started regeneration by planting tagasaste for his cows to graze on the more fragile deep sand hills. Soon after, Trevor heard about claying and realised that he could use the clay being excavated by his neighbour who was digging marron ponds at the time. He used a multi-spreader to get the clay onto the paddocks, but this method didn't last as he realised that he needed to go over it three times to get 90 tonnes of clay to the hectare incorporated.

"I gave up, it was too time consuming and wrecked the spreader," he said. "But we saw results straight away and that gave me the confidence to persevere."

He then got a contractor in with a Lehmann scraper and although the contractor did a great job - he sold his business. The next attempt was done with a six wheel drive dump truck that put the clay on with offset discs (scarifier).

"But the dump truck was too heavy and left too many wheel tracks, so that only lasted a year," Trevor said.

"We then went to a Karri Grader to spread the clay and then used a spader to incorporate it.

Now, after spreading, the clay is smudged twice at 45 degrees both ways to get a good even spread. It is then cultivated to ridge it up and incorporated to stop wind and water erosion. Lime and gypsum is then put on at whatever rate is needed before being deep ripped to get rid of compaction. It is then spaded.

Trevor says that more recent yields in trials on the property, funded by GRDC and Wheatbelt NRM and supported by WANTFA and DAFWA, have proven that the soil amelioration work is worth all the effort. The trials look at delving and spading; spading by itself (also with lime incorporation at varying rates); a clay rate trial and incorporation trial (off set discs, spading and rotary hoe).

"What we wanted to trial was the most effective rate of application and method of incorporation within the top 200 millimetres of the soil."

The trial involved three different rates of clay spread over a trial site 80m in length and 45m in width. The treatments were zero tonnes to the hectare; 250t/ha and 500t/ha.

After the clay was spread, it was mixed into the soil using three different methods - a spader and a rotary hoe at two different depths, and the more commonly used offset discs.

Another part of the trial was mouldboard ploughed, which did not involve the application of any clay. The mouldboard plough was about five metres wide and inverted the top non-wetting soil with clay about 30cm below the surface.

In more recent times, Trevor has started using EM 38 and radiometric surveys to find the depth of clay. He then spreads clay on his non-wetting soils in the areas where the clay is too deep to access (greater than 250mm) then he spades and deep rips the whole paddocks.

"That was what got us into the delving."

The delver can get down to 1 metre and is about half the price of clay spreading.

"We are still using all the techniques of (clay spreading, spading, delving and mouldboard ploughing) depending on the soil type."

Trevor says he now wants to find out which is the most effective technique when it comes to incorporating the clay into the soil.

The first method is using a four-metre wide spader, which works like a big rotary hoe that can dig down to 400mm in depth.

"I want to find out if the spader does the best job, but the problem here is they cost about $120,000 to buy," he said.

The next method uses the more commonly used offset discs, which only reach a depth of about 150mm.

The final technique uses a rotary hoe which doesn't dig, but only mixes the clay into the surface of the soil.

The advantage of the rotary hoe is it is significantly cheaper than the spader.

The trial will run for three years which involves the monitoring of crop yields, soil testing, plant tissue testing and readings taken from moisture probes at seeding then four to six weeks after seeding.

"We still have to use fertiliser because you're putting on stale soil with no trace elements, but we have found in the past some of the clay is very high in pH (alkaline) which meant we didn't have to lime and it also had high potassium levels.

When all the white sandy soils on the farm have been clayed, Trevor is considering tackling his tagasaste country, which supports about 100 Murray Grey and Angus breeders.

"This deep sandy country has the potential to be converted into cropping country if clayed," he said.

"But we need to fix the cropping country first."

During seeding in 2013, a disc seeder was used to further alleviate non-wetting issues and also provide a better means of seeding into stubble now that his crops are getting bigger and there is less rotation in his cropping program.

KEY LESSONS LEARNT

- Different soil types require different techniques so next will be more PA techniques to match application techniques and rates to varying soil types.
- Used to clay whole paddocks but this was expensive and didn't need to be done in some areas of the paddock
- EM and Radiometric survey mapping gives a variable rate map to show where they need to put clay on (areas that can't be reached by a delver). The delver will be able to be lifted up and down to determine how much they need to get to the surface.
- Don't do big areas at once to avoid wind erosion on a large scale.

TRIAL RESULTS SUMMARY

Clay Rate and Incorporation Method

In 2010 a clay rate and incorporation method trial was established by WANTFA with funding from Wheatbelt NRM. Measures of grain yield from 2010–12 were undertaken by DAFWA through the GRDC project "Delivering agronomic strategies for water repellent soils in WA".

The clay-rich subsoil spread on the trial had between 35-40% clay, slightly acidic to neutral pH of 5.9-6.5 (in $CaCl_2$) and was high in S (100-250 mg/kg) but not P and K. The soil at the site is pale deep sand which prior to treatment had 4% clay and 86% coarse sand in the top 10cm.

In 2010 there was only 161mm of growing season (Apr-Oct) rainfall so wheat yields were low (Fig. 1). Despite the low rainfall there was still a response to cultivation in 2010. Cultivation with offset discs, with no clay, increased wheat yield by 300kg/ha; spading alone increased it by 500 kg/ha (Fig. 1).

Spreading of clay without sufficient incorporation tended to reduce grain yields while very good incorporation with a spader showed a trend towards higher yields but the response was variable (Fig. 1). For the offset discs the

incorporation of clay-rich subsoil at the rates applied was probably not adequate for there to be a response to the addition of clay but it was sufficient to prevent the negative response seen where clay incorporation had not occurred.

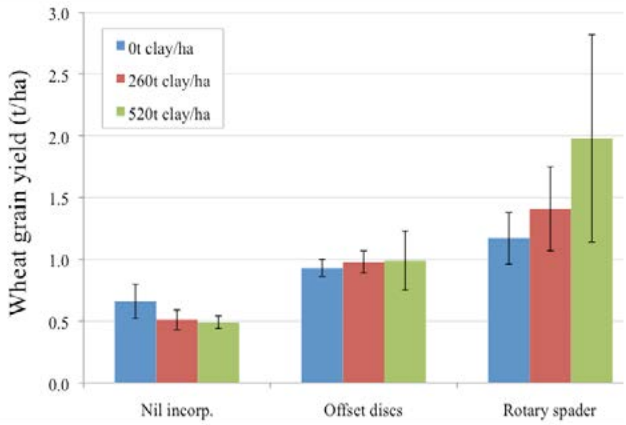

Figure 1. Wheat grain yield response to clay-rich subsoil application rate and incorporation method (Nil, Offset discs or Rotary spader) for a water repellent pale deep sand at Bolgart in 2010, the year the clay treatments and incorporation was applied. Bars are the standard error of the mean of 3 replicates.

In 2011 (Fig. 2) the pattern of yield responses was similar to that seen in 2010 except the growing season rainfall was much higher at 324 mm which meant overall yields were higher (Fig. 2). Deep cultivation with a rotary spader with no additional clay still increased yield by 850 kg/ha over the control in the second year (Fig. 2).

Again there was a trend to higher yield with applied clay when incorporated with the spader but not with the offset discs (Fig. 2). Spreading of clay with Nil incorporation depressed yields even in a wetter season (Fig. 2).

In 2012 the growing season rainfall was 226mm, but there was little rainfall in April (13mm), May (13mm) and July (9mm), which impacted on canola growth and yield, particularly where clay incorporation was inadequate (Fig. 3).

Yield responses across the reps were quite variable so there are large standard errors associated with the means (Fig. 3). Incorporation of the applied clay with either offset discs or rotary spading certainly helped yields recover from the negative impact of inadequate incorporation (Fig. 3).

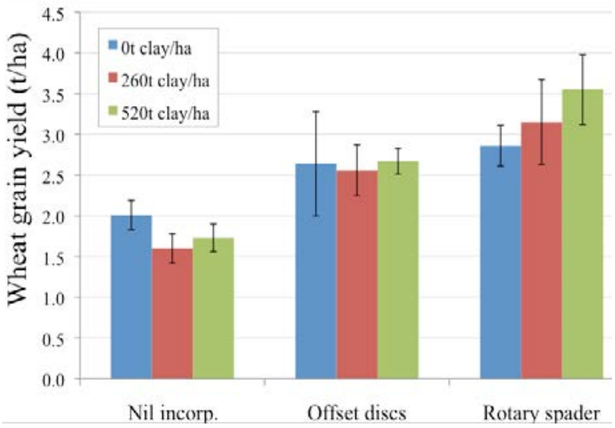

Figure 2. Wheat grain yield response to clay-rich subsoil application rate and incorporation method (Nil, Offset discs or Rotary spader) for a water repellent pale deep sand at Bolgart in 2011. Clay treatments and incorporation were applied in 2010. Bars are the standard error of the mean of 3 replicates.

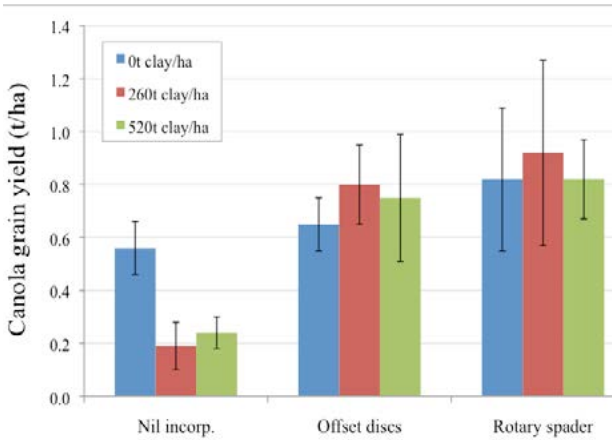

Figure 3. Canola grain yield response to clay-rich subsoil application rate and incorporation method (Nil, Offset discs or Rotary spader) for a water repellent pale deep sand at Bolgart in 2012. Clay treatments and incorporation were applied in 2010. Bars are the standard error of the mean of 3 replicates.

Other Claying Trials in the NAR

Clay rate by incorporation - Badgingarra

In 2009 a clay rate and incorporation demonstration trial was established at Badgingarra. The trial included 4 subsoil application rates: 50, 150, 360 and 450 t/ha. The clay-rich subsoil (31% clay) was incorporated using either offset discs (Fig. 4) or a rotary spader (Fig. 5).

The two incorporation methods cannot be directly compared as the offset disc treatment was on deeper (poorer) sand which had lower yield potential than the shallow sand over gravel where the spading incorporation occurred. It is possible however to see how the relative yields of crops in response to subsoil application rate responded for each incorporation method (Figs. 1 and 2).

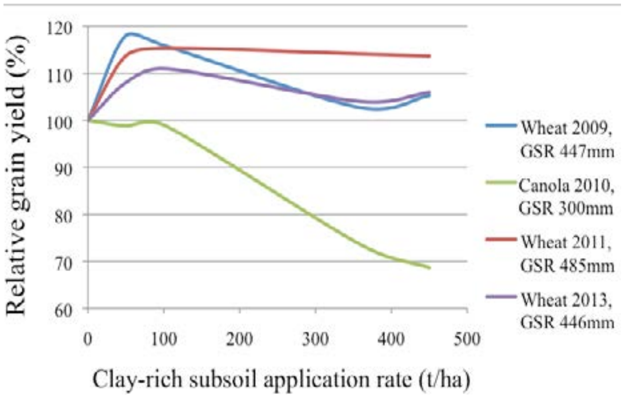

Figure 4. Relative change in crop grain yields in response to the spreading of varying rates of clay-rich subsoil in 2009 incorporated using offset discs on repellent pale sand at Badgingarra. Note the 2012 canola crop could not be harvested due to hail damage.

Overall relative crop yields were optimal at lower subsoil application rates when shallow incorporated with offset discs (Fig. 4) and responses declined at the high application rates, particularly for canola in the drier 2010 season but not in the wet 2011 season (Fig. 4). Wheat yields for 3 of the seasons following treatment were 10-20% higher at subsoil application rates of 50-150 t/ha (Fig. 4).

Relative crop yields showed a different pattern when the clay-rich subsoil was incorporated with a rotary spader (Fig. 5). Lower subsoil application rates of 150t/ha or less were not beneficial when deep incorporated with a spader but there were yield benefits when higher clay rates, in excess of 300 t/ha, were used (Fig. 5).

These results indicate that incorporation method needs to be matched to the rate of clay-rich subsoil applied.

Yield responses from using low to moderate rates of clay-rich subsoil shallow incorporated using offset discs can generally give crop yield responses equivalent to applying high rates and incorporating them with a spader which has a much higher associated cost.

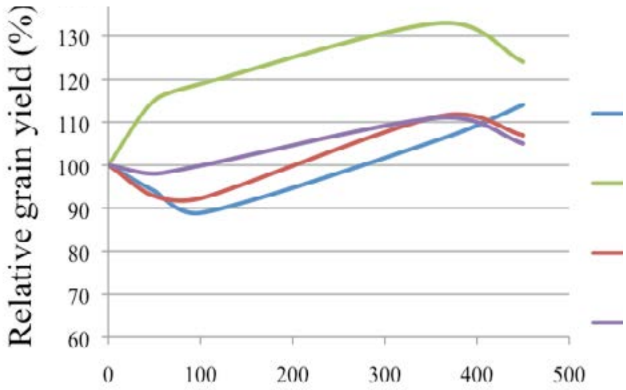

Figure 5. Relative change in crop grain yields in response to the spreading of varying rates of clay-rich subsoil in 2009 incorporated using a rotary spader on repellent pale sand over gravel (duplex sandy gravel) at Badgingarra. Note the 2012 canola crop could not be harvested due to hail damage.

Spreading low rates of clay-rich subsoil to manage repellent soils - Badgingarra

Grain yield increases achieved from spreading relatively low rates of clay-rich subsoil at two sites on severely water repellent pale deep sand at Badgingarra are shown in Figure 6.

Wheat yield responses on the site established in 2009 have improved over time and in 2013 there was a 600 kg/ha yield response due to claying (Fig. 6). At the second site established in 2011, wheat yield increases have been about 400kg/ha but lupin yield response was much larger, over 1100 kg/ha greater yield (Fig. 6), 1.1t/ha in the control verses 2.6t/ha in the clayed (Image 1).

These results indicate that in the NAR it is possible to significantly improve crop productivity with shallow incorporation of clay-rich subsoil at moderate rates of 100-150 t/ha.

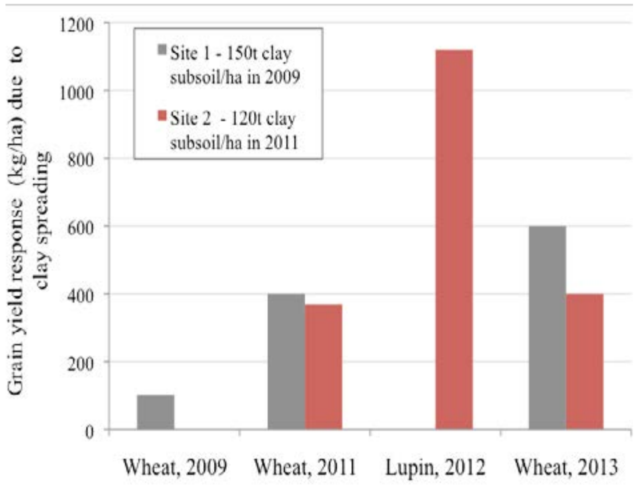

Figure 6. Change in crop grain yields in response to the spreading of 120-150 t/ha of clay-rich subsoil shallow incorporated using offset discs or a scarified with tynes on severely repellent pale deep sands at Badgingarra.

Image 1. Lupin growth on water repellent pale deep sand that has been clay-spread (150 t subsoil/ha) on left compared with the untreated control on the right in October 2012 at Badgingarra. Note dead lupins in centre of image have been sprayed with a knockdown herbicide to delineate the treatments.


Perth
Cugley
Burrell
Fetherstonehaugh
Hill
Lawsons Grains
Cox
Luberda
Gunwarrie
Esperance
Sprigg
Williss
Albany

Southern Tour

A tour of on-farm research in Western Australia - 2014

Water repellence research on the south coast

David Hall, Department of Agriculture and Food (DAFWA), Esperance

The soils on the south coast have many challenges. Charles Darwin in 1836 described the soils around Albany as "sandy and poor …… uninviting country".

Art Linkletter when viewing his Esperance property for the first time in the 1960s was "appalled" at the desert like hills and scruffy vegetation. From a soils perspective, the leaps in productivity have occurred through sequentially addressing macro and micro nutrient deficiencies, wind erosion, weeds and more recently water repellence.

The transformation of the sandplain from scruffy vegetation to pastures and cropping resulted in the building up of organic carbon in the topsoil. In the early 70's, scientists in WA realised that water repellence was related to organic carbon and associated wax and fatty coatings on sand grains. They found that water repellence could be managed through tillage, wetting agents which had become available in the 1960s and through the addition of clay. Despite this early knowledge, serious research into water repellence on the south coast did not commence until mid-1990. By this time cropping was expanding and minimum tillage with herbicides was effectively reducing the severity of weeds and wind erosion.

In the mid 1990's, DAFWA began work on managing repellence on the south coast. Much of the initial work was done on furrow sowing, press wheels and surfactants (wetting agents). Banded surfactants (e.g. AquaSoil) showed marked improvements in seedling emergence on sandplain soils with yield increases of 40 per cent in some years. However their lack of reliability, persistence and systems not being robust hampered their adoption.

Newer non-ionic wetting agents have generated interest, however adoption remains low. The combination of furrow seeding and press wheels was shown to improve crop emergence and has been readily adopted by most growers on the south coast. In more recent years the efficacy of this system on water repellence has diminished to some extent with the introduction of knife points. The flow of soil around the knife point can concentrate the water repellent topsoil into the furrows.

Figure 1 : Claying using a dual carry grader system (Joe DellaVedova) .

Figure 2 Mouldboard ploughing at Esperance using a square plough (Greg Harris)

The application of clay was first identified as a solution to water repellence in the 1960's and 70's, however the first trials on the south coast did not commence until the mid-90's with trials being established from the South Stirlings to Esperance.

Clay coats and adheres to the sand particles masking the waxes. Clay has a high affinity for water. Early work showed the benefits of clay in research trials however it was not until the advent of the Claymate, Lehman scraper and subsequently carry graders that claying became a practical proposition.

Early research was polarised with some research advocating low rates (100t/ha) while other advocating very high rates (300t/ha). The response depended on the clay content of the material applied and the ability to work it in. In the end the best rate was the one that could raise the clay content above 3-5 per cent and where the clay could be evenly incorporated to the depth of the organic layer.

In some instances the high rates of clay led to surface sealing and premature haying off of crops due to poor root growth. Spading machines have since been used to more evenly incorporate clay particularly where high rates have been applied. Spaders have the capacity to incorporate clay applied at rates exceeding 900t/ha to a depth of 35cm.

Claying is a long term, if not permanent solution to water repellence. Long term trials have shown the benefits from claying persisting for more than 14 years with yield increases averaging 50 per cent. Clay not only reduces non wetting but also increases nutrient retention (cations exchange capacity, P, nitrate) due to higher surface area and charge density of the clay. The kaolinitic clays may also have a fertilizer effect as they can have relatively high levels of K (>200 ppm) and S (> 50ppm). Conversely, some clay has high PRI, boron and salt levels which can give temporary reductions in yields. Testing of clays is therefore recommended.

The cost of surface applying clays and incorporating is high ($500- $800/ha) and in many areas with lower production, this expense cannot be readily justified. Delving clays has been practiced on the Esperance sandplain and Mallee for more than 15 years.

Where clays are within 50cm of the surface, delving tynes can often bring enough clay to the surface to effectively overcome water repellence. Given the variability of depth to clay across paddocks, knowledge of clay depth is necessary.

To some extent this can be found by careful drilling (auguring) or mapping, using electromagnetic (EM) surveys. Incorporating the clay evenly post delving is an issue as the paddock surface can be rough.

Delving Mallee soils also needs careful consideration as some subsoil clays have toxic properties (salt, boron) and have been shown to lead to surface sealing when applied at high rates. Again testing of subsoil clays and putting in strip trials to evaluate the effects is recommended.

Mouldboard ploughing in the no tillage era was originally suggested as a means to control herbicide resistant weeds. When trialled in the northern and southern wheatbelt it became obvious that not only were weeds controlled but also water repellence at a fraction of the cost of claying.

The inversion of the profile effectively exposes wettable soil and buries that which is water repellent. In the northern sandplain ploughing also brought up clay subsoils that further reduced repellence. Increases in yields of more than 30 per cent have occurred as a result of ploughing which have persisted for several years. So far, the largest effect has been on yellower well drained sands while the least effect appears to be on pale deep waterlogging sands.

The key limitation to ploughing is wind erosion. Despite most ploughing occurring at times of least wind there is often a 3–6 week period between ploughing and the establishment of a protective cover. In order to reduce wind erosion 'one pass' seeding and ploughing systems have been developed which allow the protective cover to develop earlier, leaves a roughened soil surface that forms a hardened crust when it driers. All of these features reduce but do not prevent wind erosion.

There is considerable debate as to the best type of plough. Square ploughs are cheap, effective in overcoming non wetting, but may not be as effective in fully inverting the profile and burying weeds. European ploughs are more expensive but potentially better at controlling weeds than square ploughs. This is because they have skimmers which remove the weed bearing layer (0.5cm) and bury it at the base of the furrow while the curved boards allow for more complete inversion.

The development of RTK with 2cm seeding accuracy has enabled farmers to seed back into old seeding lines. Growers and researchers have noticed that prior seeding lines tend to wet more than the inter-row. Part of the reason for this is that plants develop root channels which act as preferred pathways for water and root movement.

Figure 4: A one pass seeding and ploughing system using a European plough (David Cox)

The preferred pathways result in improved moisture within the old seeding lines where the roots have been left relatively intact. Seeding into old seeding lines with minimal disruption using disc seeders has resulting in significant increases in crop yields at Munglinup for cereal and canola crops due improved seed and moisture relations at sowing.

Advances in placing seed within or next to the old seeding lines have been further developed that give greater accuracy than RTK. Hydraulically movable drawbars which track old seeding lines and allow the placement of seed directly beneath the previous years' sowing line without disturbing the root channels have been developed and are commercially available (iTill).

In summary there are a range of methods for managing water repellence which vary in terms of their cost and effectiveness.

For growers in marginal cropping areas modification of tyne designs, improved press wheel configurations and more accurate seeding into old seeding lines may be the solution. For higher rainfall growers who are chasing increases in production of more than 1 t/ha then, deeper tillage and claying may be the most profitable solution to non-wetting issues.

A table summarising where each of the above options fit in terms of rainfall and water repellence severity is presented below.

Issue	Severity	Rainfall	Furrow sowing	Wetters Banded	Wetters Blanket	On Row seeding	Mb Plough	Spading	Claying 50-150 t/ha	Claying >200 t/ha	Claying >300 +Spading
Repellence	Moderate	<400	X			X					
	Severe		X			X	X	X	X		
	Moderate	>400	X	X		X				X	
	Severe		X	X		X	X	X		X	X
Repellence	Moderate	<400					X		X		
+ Weeds	Severe						X	X	X		
	Moderate	>400			X		X			X	
	Severe				X		X	X		X	X

Seeding and mouldboard ploughing in one pass at Neridup

DAVID AND SALLY COX	
WATERHATCH FARMS, NERIDUP (OTHER FARMS ARE AT HYDEN)	
Area:	5000 ha (Neridup)
Annual rainfall:	450mm (Esperance)
Soil types:	white and yellow fine sands
Livestock:	cropping and cattle (2000 head)
Cropping:	wheat, canola, barley

David and Sally Cox farm 5000 ha of sand plain on the coast to the east of Esperance. Canola wheat barley and trade cattle are a part of their enterprise mix.

Long term average wheat yields are 2.8t/ha and 1.4t/ha canola. Soils are described as white and yellow fine sands ranging from 100mm of sand over gravel, to deep 2m sand over clay.

The most productive soils are 600mm sand over clay. All soils are affected by non-wetting to some degree.

More than 20 years of no-till farming has solved erosion problems and reduced costs but failed to increase yields. A stratification of nutrients to the top 10cm has made the crops more susceptible to nutrient drought in dry conditions.

David saw ploughing as a way to place the nutrient rich layer 25 to 35cm down where it tended to stay wet throughout the growing season, increasing rooting depth and plant resilience. The added bonus to the operation was that weed seeds and non-wetting soil is also buried.

A system was designed by David and his team to plough and seed in one pass to reduce the drying out effect and compaction of a second pass. A 12 furrow Gregoir Besson plough is hitched behind an air cart with a set of packers trailing the plough to finish the job. Barley and wheat are planted to limit the risk of erosion.

Eventually, David plans to use the system across 3000 ha of his property. The exercise is cost neutral due to using low fertiliser rates and no chemicals at seeding. Extra nitrogen mineralisation from the mouldboard ploughing has also significantly cut out fertiliser bills.

March ploughed and sown barley was successfully grazed by cattle in late April for over a month in 2013. The ploughing assisted in the early germination by bringing up wet soil from summer and autumn rainfall events. Dave warns that stock health must be monitored and treated accordingly on newly ploughed crops.

KEY LESSONS LEARNT

- April ploughing needs to be seeded in one pass to reduce drying out effect and erosion.
- Straight after ploughing go to a controlled traffic situation to reduce re-compaction.
- Soil test to the depth of ploughing so you know what you are going to pull up.
- Lime if required.

Spading provides flexibility to cropping program at Coomalbidgup

PETER LUBERDA	
COOMALBIDGUP	
Area:	1,100 ha
Annual rainfall:	550mm
Soil types:	non wetting sand and sand over gravel
Livestock:	1200 merino-cross ewes
Cropping:	canola/wheat/barley/serradella

HISTORY

- In 2000, 40 ha of clay was spread,
- In 2004 a further 260 ha was clayed. Clay on the property was too deep for delving.
- 2012 a further 240 ha on the property was clayed.

Peter Luberda farms with his father, John on fragile sandplain country close to the Esperance coast alongside the West Dalyup River. The property consists of non-wetting deep sands and sand over gravel, which is prone to both waterlogging and erosion. The soils are generally acidic (pH5).

Over the years, the Luberdas have tried various soil soaker products to deal with water repellence. These gave mixed success and so they began to experiment with clay spreading in early 2000, initially focusing on the very difficult soils. This area had been cleared of banksias and was severely water repellent in the top zero to 10cm layer and contained less than one per cent organic carbon. Weed control was an issue as germination could be staggered and germination of crops was not uniform.

However, in 2004, a dramatic incident occurred when a fire triggered from an electricity pole swept through the back of the home block. This resulted in completely denuded paddocks that required immediate attention to ensure that the topsoil was not lost through erosion. The obvious approach was to clay spread the area and a contractor was used.

Since 1999, DAFWA's David Hall has been running trials on the Luberda's front paddock, funded by GRDC and WANTFA. These included several clay rates in conjunction with deep ripping.

The claying rate for the burnt area was determined from the DAFWA experiments at the front of the Luberda's property.

These experiments had used subsoil material sourced from the property, which contained between 30 to 40 per cent clay. The clay was predominately kaolite. The rates applied were: 0; 50; 100; 200 and 300t of clay-rich subsoil/ha. The treatments were deep ripped at a later date.

The experimental site was managed as a commercial operation. Rainfall was monitored, crop emergence and biomass measurements were collected and soil samples were taken. The profitability of the treatments was assessed using discounted cash flows. The results showed that after eight years, only the treatments receiving more than 100t/ha of clay-rich subsoil, resulting in greater than three percent clay in the topsoil, were more profitable than the control.

Peter therefore chose the highest rate of subsoil material of between 200 to 300t/ha of clay rich subsoil to apply to his damaged back paddocks.

The clay was spread with a carry grader, left on the surface, and further spread by smudging. This consisted of up to three passes using a railway girder. The soil was then two-way ploughed to a depth of fit to 10cm. Unfortunately Peter discovered that it is a fine line between leaving the

Figure 1: Spading unit incorporating clay (Peter Luberda)

clay-rich subsoil on the surface to be broken down by rain and the surface setting hard in the sun. When the latter occurred, water would either puddle or run-off and after significant rainfall the paddocks would become un-trafficable.

Peter soon realised that better incorporation of the clay was imperative and in 2009/10 he invested in a Farmax spader. This has a power roller on the back that can further break down clods and pack down the topsoil. He chose this machine partly due to the ease of being able to replace worn parts.

The 4m wide spader is towed behind a 250hp Fendt tractor fitted with GPS guidance and autosteer. This helps improve the precision of the spading operation.

In 2010, the damaged paddocks were spaded to a depth of 25 to 45cm to better incorporate the spread clay.

Unfortunately, the spading operation brought iron stone rocks from the subsoil material to the surface, which had to be removed to avoid damaging the harvester later in the season. A Mungie rake was used to clear the rocks.

Since spading, Peter's cropping system has become more productive and flexible. Cereal yields on clayed areas increased from 2.5t/ha up to 4.6t/ha the first year after. The soil has become healthier as a result also – with more fungal activity and earthworms.

Peter suspects that the clay now absorbs nutrients that previously leached through the sandy profile. He has also found that crop rotations are more flexible and because the crops appear healthier they are more able to out-compete disease.

Due to the positive results, Peter invested in his own equipment with the purchase of a second-hand JR carry grader which has a capacity of 15t. This is hauled by a 410hp Caterpillar tractor to reduce some of the compaction on the paddocks.

Peter now also contracts out to other farms in the region with his equipment and will continue further work on his farm also.

Water repellence research on the south coast

Margaret Roper, Phil Ward, Ramona Jongepier (CSIRO, Floreat)

Zero/No-till promotes water infiltration in water repellent soils

Trials at Doc Fetherstonhaugh & Gavin Gibson (Munglinup), Stott Redman (Hopetoun)

Under minimum or no-tillage, repellence is concentrated at the surface, but growers on the south coast noticed that crops grew best if the soil was left undisturbed.

If cultivated, bare patches were seen and the soil suffered from wind erosion. Measurements of soil water repellence and organic matter, soil water contents and crop performance were made over several years comparing 1) no-till & stubble retention, 2) cultivation & stubble retention, 3) no-till & stubble burned, 4) cultivation & stubble burned. The results consistently showed that under no-till & stubble retention, soils were wetter and crops performed better than in other treatments despite the soil being more repellent (due to concentration of waxes at the surface).

Blue dye was used to visualise the flow of water in each of the tillage and stubble treatments (Fig. 2). The key observation was that by not disturbing surface soils, old root pathways which behave as conduits for water entry into the soil were preserved (Fig. 2a & c).

These pathways can persist well into the next season (Fig. 2c). Cultivation broke up these pathways restricting water entry into the soil (Fig. 2b) and well into the next season soil remained dry between the new rows (Fig. 2d).

In 2012, cultivation and stubble burning treatments were stopped. Following restoration of no-till and stubble retention, water infiltration and crop performance had still not recovered in the previously burned and/ or cultivated treatments by the end of 2013.

Minimum or no-till offers a viable system for managing non-wetting sands, and can also be used following amelioration techniques such as mouldboard ploughing, spading and claying. By establishing root pathways as quickly as possible following amelioration, erosion risk is reduced and water pathways are established.

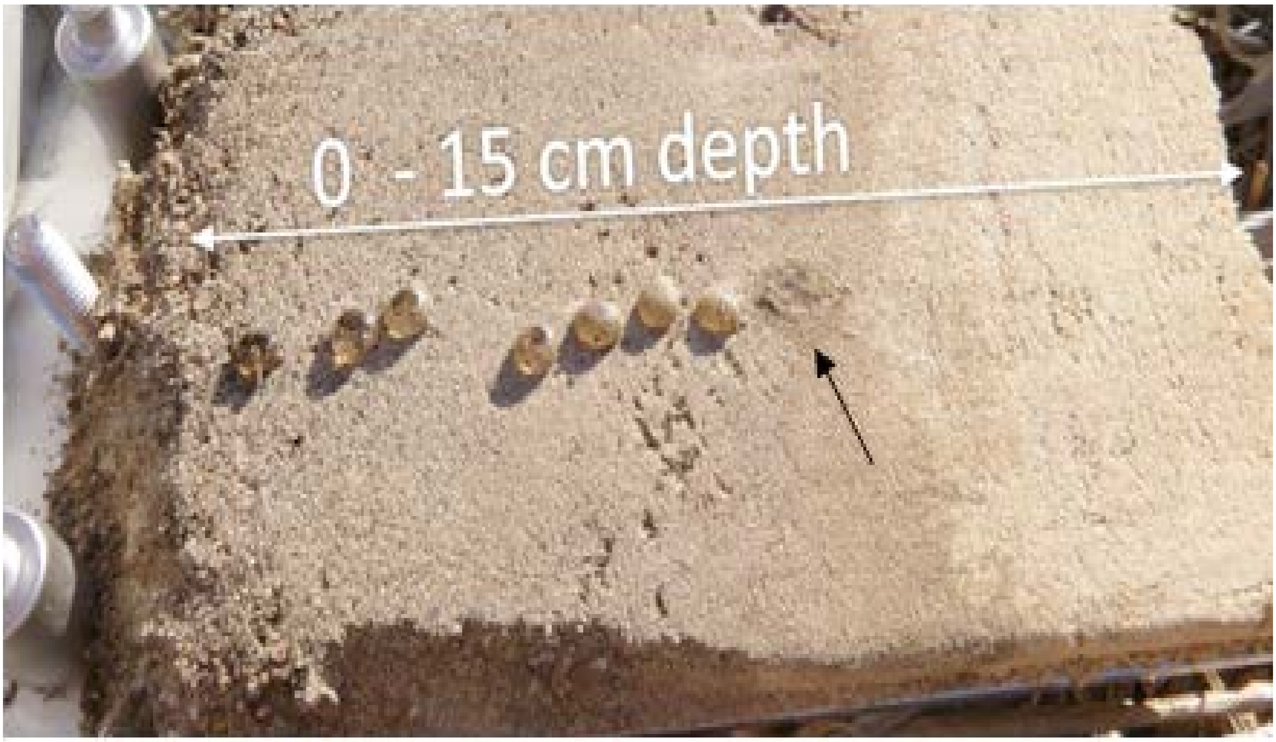

Figure 1. Water droplets fail to enter the soil in the repellent surface layer, but below the organic matter (at approx. 10cm) readily enter the soil (Black arrow).

On-row seeding benefits plant emergence and crop performance

Trials at Paul Hicks (Pingrup), Steve Waters (Calingiri)

Because water pathways form down old root channels, seeding near the previous year's row (on-row seeding) should benefit new crops through greater access to water.

Observations such as at Calingiri (Steve Waters) demonstrated that plant establishment on water repellent soil was improved when seeds were sown on the previous year's row compared to the previous year's inter-row (Fig. 3).

Field trials compared soil water contents and plant performance in on-row and inter-row sown crops in both wet and dry seasons at Calingiri and also at Pingrup, where Paul Hicks has developed a precise seeding system (iTill).

Regardless of the season, soil water contents were significantly higher in the row (Fig. 4a) and this resulted in a decline in water repellence over season in the row compared with the inter-row (Fig.4b).

Trials are continuing in 2014 to measure soil water and crop performance under the two seeding systems.

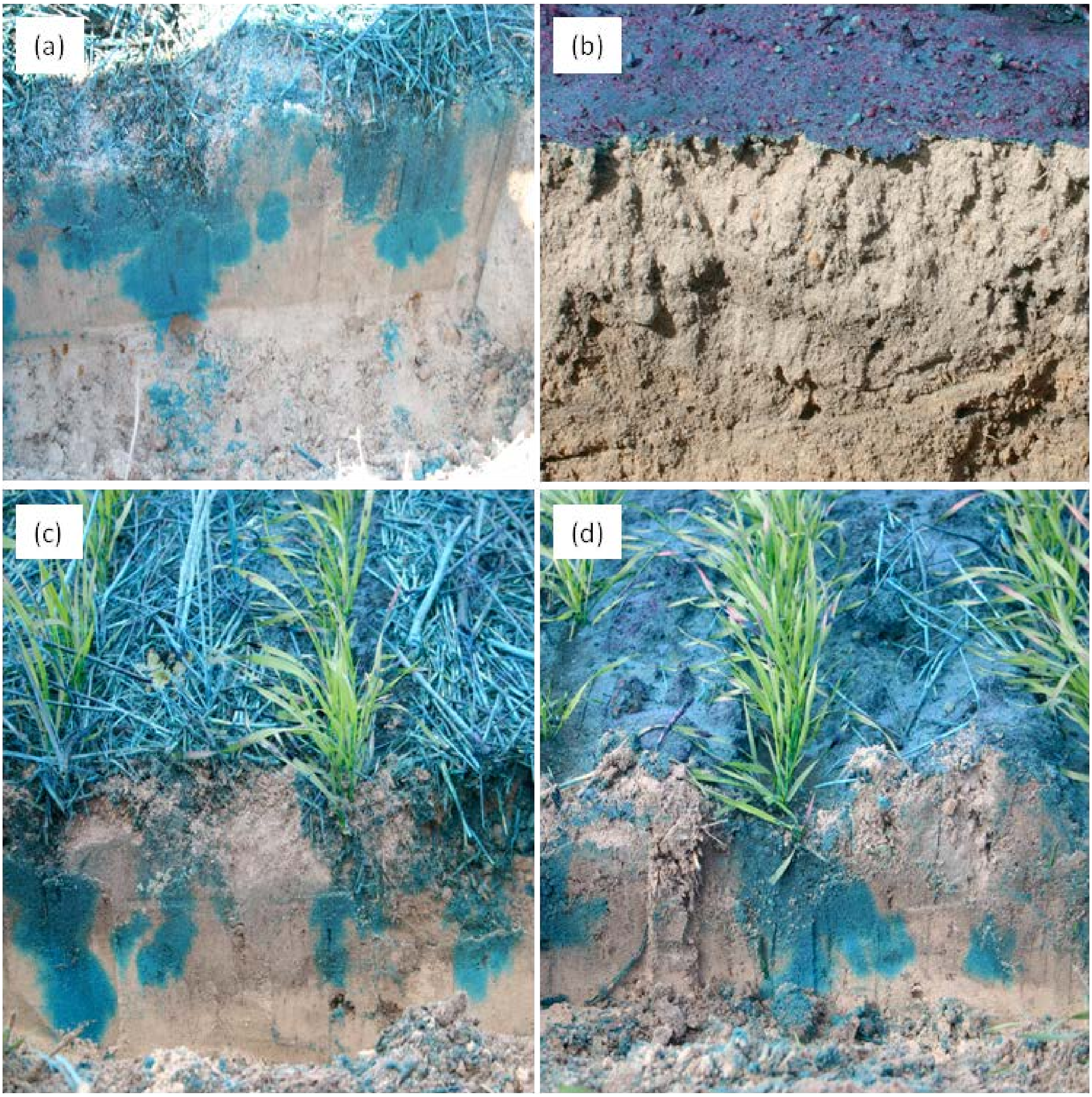

Figure 2. Entry of a blue dye under no-tillage (a & c) and after cultivation (b & d) immediately after stubble treatment (a & b) and 3 months later in July (c & d). Blue dye solution entered the soil via bio-pores formed by root channels, leaving pockets of dry repellent soils at the surface in between the root pathways. Source: Roper et al. (2013a).

Figure 3. Photo shows a barley crop where the seeder width was not matched to previous year's row width. Plants sown on the previous year's row performed much better than those sown on the inter-row. Source: Steve Waters (Calingiri) and Margaret Roper (CSIRO).

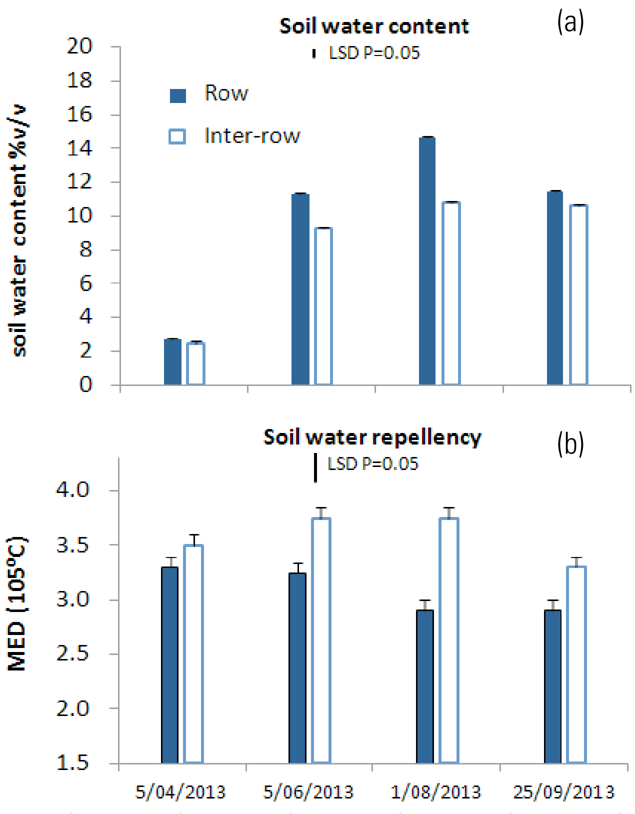

Figure 4. Soil water contents were significantly higher in the row than in the inter-row even during the wettest part of the season (a). These conditions favour microbial activity and a decline in water repellence was observed (b). (Paul Hicks, Pingrup - iTill system)

Soil bacteria can breakdown waxes responsible for repellency

Trials (4 years) at Grant Cooper (Woogenellup)

Soils contain many different microorganisms (microbes) including bacteria that can break down waxes (Fig. 5).

However, microbes need water to grow and be active. Water repellent soils restrict microbial activity because they resist wetting up. Field trials have shown that **irrigation** markedly improves microbial activity and reduces repellency over time.

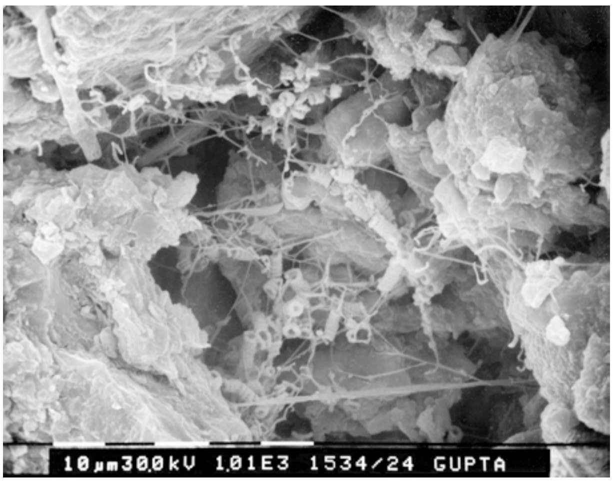

Figure 5. A highly magnified photo of a soil pore containing a range of bacteria (fine threads, coils and other forms). Source: VVSR Gupta (CSIRO)

In broadacre farming, **liming** has also been shown to improve water infiltration into repellent soils particularly after the break of season.

In a trial (Grant Cooper) at Woogenellup, liming water repellent soil increased populations of wax-degrading bacteria 10-fold and resulted in consistently lower repellence than in unlimed soil for the duration of the 4-year trial.

Dry seeding can worsen repellence

Stott Redman (Hopetoun) & James Hope (Kojonup)

Many growers have observed that plants emerge poorly in 'dry-sown' water repellent soils.

Laboratory experiments have repeatedly shown that if non-wetting soils are disturbed when they are dry, repellence becomes worse and water infiltrates much more slowly than if the soil is not disturbed (Fig. 6).

It is thought that under dry disturbance, soil particles collapse into a higher density, reducing water pathways thereby increasing repellence. New research is visualising the packing of particles at a micro-scale and is expected to point to strategies to overcome the problem.

Field experiments at Kojonup and Pingrup are examining the phenomenon in more detail with a view to developing managements which will complement DAFWA research on modifying seeding equipment.

In the meantime it is recommended that growers avoid dry seeding water repellent soils where possible by seeding these soils last in the seeding program.

Conclusion

There is a range of strategies that can be used to manage water repellent soils and maximise crop growth without actually changing the soil properties.

These strategies are also likely to be useful following amelioration treatments by stabilising soil, re-establishing root /water pathways and avoiding future repellence that re-forms as new organic matter accumulates at the soil surface.

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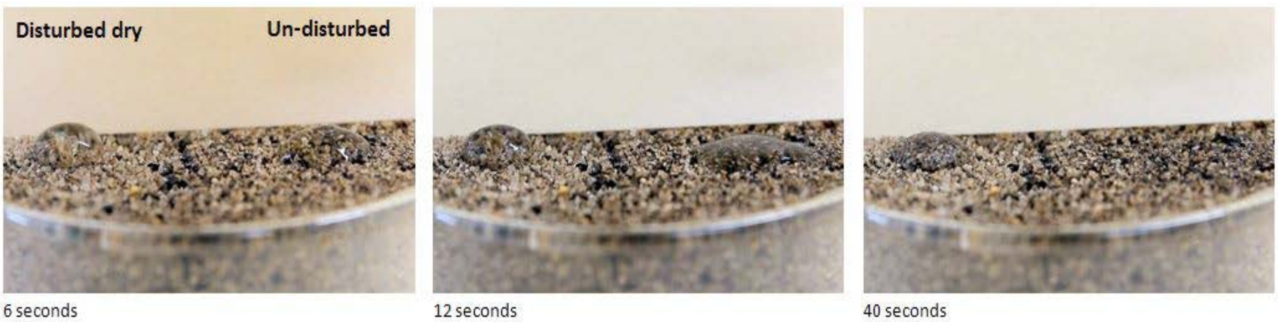

Figure 6. Time course of water drop infiltration into dry water repellent soil which has been disturbed dry (LHS) compared with the same soil which has been dried in a similar way but not disturbed (RHS). The water droplet on the 'dry-disturbed' soil still remained on the soil surface after 40 seconds, whereas in the 'un-disturbed' soil, the water droplet entered the soil shortly after 12 seconds.

Southern Tour

Derk Bakker, Department of Agriculture and Food (DAFWA), Albany

Albany Hinterland area (Willis and Sprigg)

Non-wetting soil treatments along the South Coast and the Albany hinterland have a long history. DAFWA has been very involved in the research and implementation of the various options over the years.

McGee did a lot of work in the 80's with wetting agents, Carter and Hetherington in the 90's with claying, and Peltzer with mouldboard ploughing in early 2000. Little was done to include the gravel areas of the Great Southern though. Currently the emphasis of the non-wetting work is a combination of those options.

Mould board ploughing (MBP) of some of the South Stirling and forest gravel soils has seen variable responses, from negative to positive and to neutral responses. The negative ones were caused by seeding too deep and sand blasting. The positive ones were the result of a larger rooting depth and/or lack of weed competition.

The neutral responses were found in areas and years when the start to the season was early with sufficient rain and non-wetting was not really an issue. In all the MBP trials the surface was always completely wettable. Even after 8 years, observed in the earliest DAFWA MBP trial at Woodgenellup, the non-wettting had not returned.

Despite the lack of non-wetting in the MBP plots it generally did not improve the crop establishment to the extent that the positive yield responses could be explained. The negative yield responses were certainly caused by poor establishment on the MBP plots.

Claying albeit very expensive, has seen a large uptake in the Albany hinterland. The positive impact has been consistent, even though the magnitude of the improvement has been variable, and sometimes not warranting the cost. Many of the worst affected areas have been clayed over the years and the attention is now shifting to areas that cause intermittent non-wetting problems, depending on the start of the season.

Wetting agents have seen little uptake on the sandier topsoils of the Albany Hinterland, despite consistent testing and research of various groups. The uptake is higher in the area of the forest gravels in the Great Southern. The results of blanket and banding wetting agents have been more positive in those areas but not consistently so. Many of the current users of those products report more even establishment, less gappyness in the rows, and consequently higher yields. Detailed observations by DAFWA tend to back this up even though the economics of the applications do not always stack up. Timing of the application in relation to rainfall, the lay of the land, and the nature of the break-of-the-season appear to influence the impact of the wetting agents.

Ben Sprigg, Weir Road, Cranbrook

Mixed farming, with canola-wheat rotations

This undulating paddock is a loamy shallow gravel and in some areas extremely non-wetting. In 2012 wetting agents did make a difference in this paddock in small plot trials but not in 2013.

Ben has started using banding wetting agents in 2013 in areas where he thought it would benefit. Better and more even establishment were the results of that.

In 2014, a series of treatments were implemented after receiving funding from CFOC to address non-wetting. These are: wetting agents (banding and blanket), mouldboard ploughing to two depths (deep and shallow), claying (3 rates: 50, 75 and 100 t/ha), seeder points (knife and winged). The trial is managed by Living Farm.

Lloyd Burrell, Mt Madden

Cropping only

Lloyd Burrell has seen non-wetting becoming more and more of an issue over the years. He's tried wetting agents with some success even though the economics of the applications were neutral.

He's noticed large effects of seed/row placement relative to the previous stubble rows, and has purchased special seeder bar guidance that allows for the accurate placement of the seed near or on the previous year stubble row.

In 2013 the RAIN grower group implemented with the technical assistance of DAFWA and financial help of the GRDC via RCSN funding a trial of several non-wetting soil treatments. These were claying (75 and 150 t/ha and Bentonite (8t/ha)), wetting agents (banding), spading, mouldboard ploughing, and on and off the row seeding.

The layout of the trial was what is commonly known as the SEPWA-layout, ie. two treatments shouldered by a control. The results are presented in the following table. The MBP and the Spading treatment brought a lot of clay to the surface in certain areas of the plots which were 200m long and 12m wide. These areas had a very poor crop establishment.

There was also a strong spatial trend in the yield. After allowing for this in the yield results (see table) the claying came out on top followed by the wetting agents. Ploughing performed the worst, after the adjustment. It should also be noted that Inter-row seeding was better than on-row seeding which was contrary to common experience in the area. The layout of the SEPWA arrangement is statistically not very strong because the treatments are only applied once.

In 2014 the trial has been repeated but was extended with deep ripping as well as mouldboard ploughing on the opposite side of the trial.

Layout in the field	Yield (t/ha	Ranked	Mean (t/ha)	Ranked	Adjusted Mean (t/ha)
MBP + SP	2.51	Cultivation	2.03	MBP +SP	2.12
Control	2.75	Cross seeding	2.22	On the Row	2.33
MBP	3.01	Control	2.43	Cultivation	2.38
OR Seed	2.59	Bentonite clay	2.48	Control	2.45
Control	2.65	MBP +SP	2.51	Cross seeding	2.53
Spading	2.87	On the Row	2.59	Spading	2.68
OffR Seed	2.87	Millet	2.65	MBP	2.70
Control	2.59	Wetter	2.71	Bentonite	2.71
Clay 75	2.90	Wetter	2.85	InterRow	2.72
Banding 20cm	2.85	InterRow	2.87	Wetter	2.81
Control	2.47	Spading	2.87	Wetter	2.83
Clay 150	2.97	Clay (75 t/ha)	2.90	Millit	2.84
Band 10cm	2.71	Clay (150 t/ha)	2.97	Clay (75 t/ha)	2.84
Control	2.31	MBP	3.01	Clay (150 t/ha)	3.03
Bentonite	2.65				
Millet	2.48				
Control	2.29				
Scar	2.22				
Cross Seed	2.03				
Control	1.94				

Table 1: Results of the non-wetting treatments at Burrell in 2013.

Claying solves weed issues on non-wetting soils at South Stirlings

MAL, CLINT AND TAMMY WILLIS	
SOUTH STIRLINGS	
Area:	4050 ha plus share cropping
Annual rainfall:	400mm
Soil types:	Sand over clay (at varying depths)
Enterprises:	Cropping, share cropping and 2400 breeding ewes for prime lambs

Around 90 per cent of the soils Clint Willis uses for cropping do not wet-up on the surface during the growing season and some pockets always remain dry. This causes sporadic crop and weed germination and, if left untreated, decimates grain yields.

Clint, wife Tammy and father Mal are predominantly using clay spreading to address these non-wetting issues and the Department of Agriculture and Food WA (DAFWA) has also being doing some mouldboard ploughing trials on the property.

Weeds on the property germinate throughout the season. They especially germinate after seeding and crop establishment, which makes the first herbicide knock-down ineffective and often there are weeds germinating and setting seed right through crop development.

Trying a range of crop varieties in the year-in, year-out canola and cereal rotation has been ineffective in bringing wild radish, ryegrass and brome grass numbers under control.

From claying the deep sandy hills Clint is now moving into claying the more shallow duplex soils. An abundance of clay on the property has made the process economically and physically possible, although the need for a three pass operation does make it an expensive exercise.

To make it more affordable, Clint digs up the clay from pits close to paddocks and spreads it at a rate of about 170 tonnes per hectare. A smudge bar is used to smash up the clay and then smooth the surface before incorporation is done with a chisel bar fitted with sweeps.

At an operating rate of about 1ha/hour and 200ha/annum, about half of the non-wetting area has been treated during the past five years.

Clint says that the process has probably doubled their crop yields in favourable seasons – although seasonal variation makes it hard to gauge what the actual gains have been.

However, their historically worst paddock produced canola yields in 2012 that were 0.5t/ha better than any other paddock on the farm.

But Clint warns that in years, when there is a dry finish, clayed areas can be badly droughted, but the benefits so far have outweighed this issue.

Clint says a major benefit of claying is that weeds germinate in a tighter period in the first year, allowing an effective first knockdown herbicide application.

Then he uses rotations, good agronomic advice, robust herbicide rates and manipulation of herbicide modes of action to keep weeds under control and the risk of chemical resistance at bay.

Clint says mouldboard ploughing appeals to him after hearing about local trials where yields have doubled on treated areas due to non-wetting issues being addressed and less in-crop weed competition.

The shallow depth to the clay makes mould board ploughing attractive but variable depth makes it difficult to implement on a large scale. A possible combination of ploughing and claying may happen in the future.

Willis – DAFWA research site

In 2013, six plots were ploughed with a 3-furrow plough. The yield response was positive (1.75t/ha vs 1.33t/ha canola). Weeds were much less of an issue in the mouldboard ploughed plots.

Where white sand was brought to the surface, sand movement was noticed but that did not affect the crop because this occurred before seeding. Poor establishment of canola in white sandy areas was noticed. The reason for that is still unclear. Seeding depth was ruled out, but it could have been a soil temperature effect.

In 2014 the entire paddock was clayed. Additional areas were ploughed and top dressed with some clay. The rationale for that was only the consolidation of the sandy top soil, because the non-wetting was eliminated by the ploughing. Where the clay was very shallow, the surface became very cloddy and undesirable for seeding.

Notes

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