DEEP RIPPING
FACT SHEET

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Deep ripping not appropriate for all soil types

A comprehensive understanding of the cause and location of high soil strength is required before undertaking deep ripping as research has shown it is does not provide an economic solution in some soil types.

KEY POINTS

- Deep ripping of compacted soils is most likely to improve grain yields on sandy soils and where compaction has occurred on upper parts of the soil profile through machinery traffic or livestock trampling.
- Deep ripping is less effective on heavy clay soils unless combined with gypsum on sodic soils prone to waterlogging.
- Deep ripping will provide little benefit if other subsoil constraints such as salinity, sodicity or acidity are also present.
- Recent advances in machinery, such as 'slotting' and deep placement equipment to simultaneously introduce ameliorants at depth with ripping, could increase the financial and agronomic effectiveness of this approach to managing subsoil constraints.

PHOTO: BRAD COLLIS

The greatest yield responses following deep ripping have been recorded in sandy soils.

Soils with high strength can occur naturally or due to compaction, but either way, left untreated, these soils can significantly limit on-farm profitability by reducing grain yields and quality.

Soil compaction can occur in many cropping soils of southern Australia and may be traffic or livestock-induced or naturally occurring.

By limiting the ability of crops to gain access to water and nutrients, soil compaction can reduce crop growth, grain yields and quality.

Deep ripping involves disturbing the soil below the normal cultivation layer, often up to 40 centimetres, without inverting the soil.

By breaking up the soil, deep ripping can free the way for roots to penetrate the soil and access water and nutrients, leading to yield increases.

However, it is only effective on certain soil types and is only likely to be financially viable when combined with strategies to ameliorate other subsoil constraints such as nutrient deficiency or toxicity, or sodicity (see Sodicity).

How the soil is managed after ripping also affects the return from ripping. Converting to stubble-controlled traffic farming can help retain the value of deep ripping.

Deep ripping also presents an opportunity for deep placement of ameliorants. Nutrients can be deep placed to ameliorate nutrient deficiencies and toxic concentrations of aluminium, deep placement of lime can ameliorate acidity and gypsum can ameliorate sodicity.

What is deep ripping?

Deep ripping, sometimes known as subsoiling, involves disturbing the soil below the normal cultivation layer, often to 40cm, with strong, narrow tines without inverting the soil. It is not the same as delving, also called clay delving, where wide-bladed tines are used to mix deep clayey subsoil with sandy topsoil.

Why deep rip?

Deep ripping breaks up traffic-induced or naturally occurring layers with high soil strength. With deep ripping, roots can penetrate the soil faster and deeper to absorb more soil moisture, capture more soil nutrients and improve yield. These benefits vary with soil type and are more likely to be observed where there are no other chemical constraints, such as sodicity, present.

Care must be taken to avoid immediate re-compaction by minimising wheel traffic on newly-ripped paddocks. Some growers move to controlled traffic to reduce re-compaction. By matching all implement widths and tractor wheel spacing, controlled traffic ensures all vehicle traffic is confined to the same tracks, minimising the area of re-compacted soil.

When to deep rip?

Deep ripping is slow and costly. Timing of ripping is critical but the results can last for many years if appropriate management practices are used.

For maximum yield response, the depth of ripping must be below the traffic pan and this may mean penetration to at least 30cm. Moist soil throughout the ripping depth is necessary to reduce the power requirement and wear of points and to obtain efficient softening.

The main difficulty in accommodating deep ripping within the farming system is the availability of suitable soil moisture conditions.

If soils are too dry, draft and fuel consumption are increased significantly. Ripping very dry soils can often result in large soil clods being brought to the surface. Conversely, if soils are too wet, smearing can result. A good rule of thumb to assess appropriate soil moisture condition is to roll the soil (at different depths where the ripping will occur) between your hands. If a long ribbon (>10cm) forms easily then the soil is still too moist. If no ribbon can be formed or if the soil is too hard to reform then the soil is probably too dry.

When suitable soil moisture conditions exist, deep ripping should be done prior to the cropping phase but sufficient time allowed for subsequent seedbed preparation. In many environments/seasons this is not always possible.

In Western Australia, in the areas where ripping has been adopted fastest, responsive soils are often cropped continuously with wheat and lupin rotations. Ripping can be done after substantial summer rains, or at the break of the season before sowing wheat.

Ripping at the break conflicts with lupin seeding or with early sowing of wheat. Delaying wheat or lupin planting can reduce yields. However, this must be weighed against potential yield advantages from ripping, including its residual value.

PHOTOS: KELLIE PENFOLD

The block clods of the compacted layer following ripping (right) compared to the small friable aggregates in an uncompacted soil (left).

HIGH SOIL STRENGTH

Many of Australia's cropping soils are pre-disposed to compaction because the proportions of sand, silt and clay particles in these sandy or loamy soils are ideal for tight packing. Also the types of clays in these soils do not often promote strong swelling and shrinking, which helps break up compaction.

Soil compaction can reduce crop growth and yield as it limits the ability of crops to gain access to water and nutrients. Compacted layers can occur naturally due to the chemical and physical characteristics of the soil or may be induced by traffic (as seen in Figure 1) or livestock.

These layers may be visible or indicated by distorted root growth. When measured they will record a penetration resistance of at least 2 Mega Pascals (MPa). Generally a subsoil strength of 1.5MPa is the accepted threshold at which root growth is restricted. At a strength of 3MPa root growth is significantly reduced.

Deep ripping is one method of reducing soil compaction, however yield responses from deep ripping depend on soil type, rainfall and crop species.

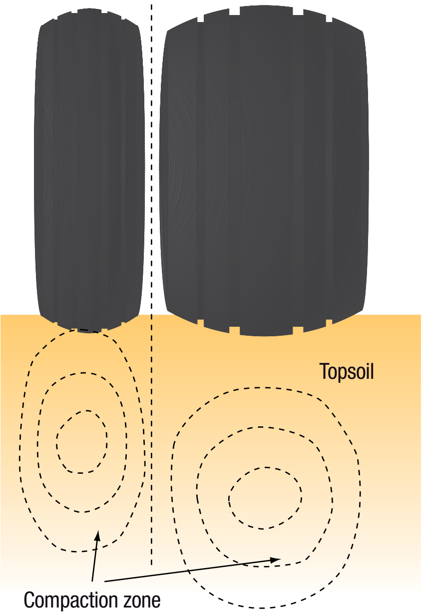
An audit of agricultural land in Australia by the National Land and Water Resources Audit (2001) suggested that once the bulk density exceeds 1.6 – 1.8g/cm^3 in sandy soils and above 1.4g/cm^3 in silty and clay soils, root penetration, and consequently plant growth, are affected.

Compacted or hard layers can also cause water logging within the root zone, often resulting in a perched watertable. If this occurs, the soil profile above the hard layer can become saturated, oxygen can be excluded and plant roots can eventually die.

Although no comprehensive surveys have been undertaken to estimate the extent and severity of compacted layers in Australian agricultural soils, the available evidence suggests compacted layers are a major problem in some soils.

Tyre width can change the shape, position and degree of compaction beneath the tyre tracks but compaction still occurs.

FIGURE 1 AFFECT OF TYRE WIDTH ON THE SHAPE OF COMPACTION IN UNDERLYING SOIL



SOURCE: *Subsoil, kirby, et al,* Soiil and Tillage Research, Elservier, Netherlands, 1991

Identifying high-strength or compacted soils

When talking about high-strength soils, the terms ‘high bulk density’ and ‘compaction’ are often used interchangeably.

Bulk density is the weight of soil in a given volume. Many subsoils naturally have high bulk density and sandy soils are more prone to high bulk density.

When soil compaction occurs the bulk density of the soil in the compacted layer increases. Compaction typically occurs to a depth of about 30 to 40cm due to traffic by machinery and/or animals. The type of tyre, the air pressure in the tyre, the weight of the vehicle and, most importantly, soil moisture, all have a bearing on soil compaction by vehicles.

Compaction is typically measured by the amount of force (in megapascals) required to penetrate a layer; bulk density is measured as the mass of soil per unit volume (g/cm^3).

Penetrometer

An accurate and rapid method for determining soil strength (to depths of more than 45 centimetres) is to use a cone penetrometer. High penetration resistance may reveal a compacted layer but the measurement is strongly affected by soil moisture. The measurements should ideally be taken when the soil is wet to field capacity (usually in winter when the soil profile has wet-up to at least 50cm depth) as soil water content can have a bigger influence than compaction on penetration resistance. Readings of more than 1.5MPa should be investigated further. If the soil is not wet, field capacity readings from the suspect compacted site should be compared with those from a known uncompacted site. Both sites should have the same soil type and the same soil water content.

Plant symptoms

Identifying plant symptoms that are directly caused by compacted subsoil horizons is difficult because other factors can cause similar symptoms. Overall, compacted subsoils impede root growth, causing reduced plant vigour and poorer water-use efficiency as roots have limited access to water and nutrients, especially in the subsoil. Other symptoms include a lack of roots present below a certain depth (shallow root system) and, in some cases, roots turning or branching to grow horizontally above the compacted layer. This horizontal growth can often be easily observed in pulse and oilseed crops by carefully excavating a few plants with a shovel. Plant roots can penetrate compacted layers through cracks and macropores in structured soils causing very little impact on yield.

Soil and land type

Sandy soils tend to have higher bulk densities compared to clay soils, so awareness of soil type will help in diagnosing high bulk density. Soil strength is generally independent of soil type and so provides a unifying measure of compacted soil.

Subjective assessment of soil structure

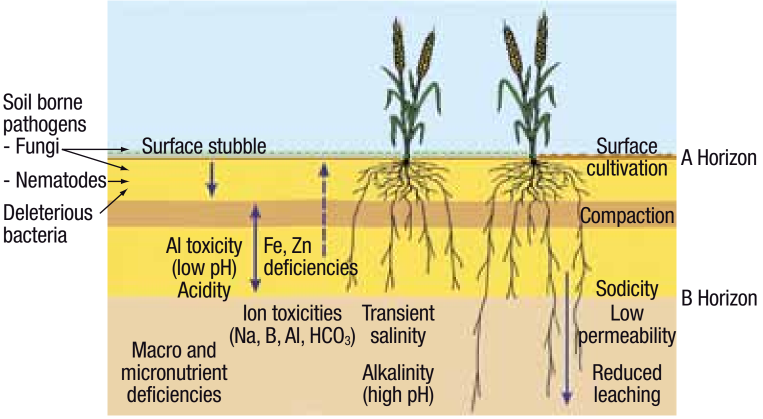
The presence of physical constraints can be assessed visually by digging a shallow soil pit (see box below) to observe crop rooting depth, the presence of compacted soil layer and fracture planes. The occurrence of wet soil within the rooting zone at harvest also indicates the presence of subsoil constraint/s.

Signs of compaction are large peds (or clods) with a platy (horizontal) shape or massive (featureless) look. In poorly structured cracking clays, ped faces are dull rather than shiny. The soil may feel puggy when wet and peds will tear apart like raw pastry. When dry, peds are not friable; they break where you apply force rather than parting along natural fracture faces.

Soil pits

In-crop soil pits allow the rooting depth of a crop to be determined. They can help identify potentially limiting soil layers that negatively impact on root growth. These can include compacted layers or hard pans, carbonate layers, ferricrete or calcrete. This method is useful in diagnosing the presence of chemical and physical subsoil constraints. Once identified, detailed testing is required to determine the extent of any limitations and whether it is feasible to reduce or remove them. Aerial photographs, EMI (electromagnetic induction) maps that indicate soil moisture, salt and clay content and maps of yield or biomass can be used to determine the best locations to dig soil pits and to take soil samples.

FIGURE 2 ROOT ZONE SOIL CONSTRAINTS – PHYSICAL, CHEMICAL AND BIOLOGICAL



Where to deep rip

The success of deep ripping in improving crop growth and yield is strongly dependent on the soil type and presence of other soil chemical/physical constraints to crops.

Generally, ripping is most successful on sandy soils and least successful on heavy clay soils (see summary compiled by John Kirkegaard, CSIRO, Table 1). Its effectiveness in improving subsoil structure is also strongly dependent on implement design, soil water content and the depth of ripping as well as the concurrent use of amendments. The primary aim of deep ripping should be to maximise disturbance (loosening) in the subsoil whilst minimising the draft.

Deep ripping appears to be more successful where compacted layers induced by tillage are present rather than where the subsoil is sodic and has inherently high soil-strength, for example sodosols. Sodosols are common in the cropping areas of Victoria and South Australia. On sodic soils, ripping is unlikely to have significant long-term beneficial effects unless the structure of the soil is simultaneously stabilised through amelioration with gypsum (calcium sulphate) or organic matter (see Soil pits, page 3). Recent advances in machinery, such as slotting equipment and high-pressure injection to simultaneously apply ameliorants at depth with deep ripping, could increase the effectiveness of this approach.

Once deep ripping and amelioration are completed, strategies such as stubble retention and controlled traffic should be considered to maintain soil structural improvements, otherwise re-compaction will quickly occur in most soil types.

Generally, sand-over-clay soils will not respond to ripping unless the depth of the sand is deeper than the depth of ripping. Sand-over-gravel soils have responded to ripping if the gravel is not a completely restrictive layer.

In WA deep ripping has increased cereal yields in areas with more than 350 millimetres rainfall by more than 600 kilograms per hectare in deep sandy soils that have a compacted layer less than 40cm deep and where the subsoil is not highly acidic.

A study in the northern Mallee of Victoria recorded yield responses in wheat of up to 40 per cent by deep ripping on non-sodic sandy loam soils. Studies in WA have also demonstrated yield increases of 25 per cent in wheat and 30 per cent in chickpea compared to control (non-ripped) treatments on lighter textured soils. In 46 trials conducted between 1981 and 1989 in WA on yellow loamy sands, all but two demonstrated increased yield with ripping.

In other areas and on different soil types deep ripping has been much less reliable and benefits persist for shorter periods. It is not clear whether this is due to the compacted layers having less impact on crop productivity or that the deep ripping approaches have not been fully effective.

A review of crop responses to deep ripping to 40cm in southern NSW from 1980 to 2005 showed yield improvements in only five of the 15 crops measured despite deep ripping reducing soil strength to less than 1MPa. Ripping had no effect on yield at five sites and significantly reduced crop yield/biomass at four sites.

The current published evidence does not support deep-ripping of soils in south-eastern Australia, except in combination with gypsum on sodic clay soils, where winter water-logging can cause significant yield reductions in wet seasons.

TABLE 1 SUMMARY OF DEEP-RIPPING RESPONSES

	ONSES			VARIABLE RESPONSES			FE
Soil type and depth	Deep acid sand	Neutral/ alkaline sand	Sodic clay (grey/brown vertosol)	Duplex-deep	Duplex-shallow	Red loams (Kandosol)	Black vertosols
Cultivated zone 0cm 10cm			Waterlogging				Self mulching
Compact layer	Strength >1.5 – 2.0 MPa; Distorted roots						
25cm	Acid layer		Waterlogging			Acid layer	
Associated subsoil problems 100cm 200cm	High density Low water and N holding N leaching	Low nutrient availability Salinity Boron	Sodic clay Anaerobic High density Poor structure Salinity	Sodic clay Anaerobic High density Poor structure Salinity	Sodic clay Anaerobic High density Poor structure	High density well structured	Salinity (Cl-)
Mean crop response range (wheat)	WA 20–37%	Vic/SA 23% (0–43)	NSW 33% (0-300) WA 47% Vic 25%	WA 22% NSW 0–20%	4%	Few	Few
Best bet management	Rip with lime if acid claying	Rip with nutrition	Rip with gypsum Avoid re-compaction	Rip if clay >30cm Possibly add gypsum/lime	Do not rip	Few responses	Few responses Self repairing
References	Jarvis (2000) Davies *et al* (2006) Hamza (2003) Hall (W'shop)	Sadras *et al* (2005) Wilhelm (W'shop) Armstrong (W'shop)	Chan *et al* (2003) Armstrong (2001) McKenzie *et al* (1990) Hamza (W'shop)	Crabtree (1989) Davies (2006) Jarvis (Various) Ellington (1986) Kirkegaard (W'shop)	Crabtree (1989) Davies *et al* (2006)	Kirkegaard (W'shop)	Dalal (W'shop)

Rainfall

On suitable soils, responses to ripping have been least reliable in areas with less than 325mm annual rainfall. Plant roots only grow where there is subsoil moisture. With limited rainfall, soil may not be wet deep down in the soil profile. Ripping, therefore, will not provide roots any additional access to water.

On responsive soils in the medium rainfall area, ripping will almost always produce responses in crop growth, but grain yield responses may be curtailed if there are poor finishing rains or soil moisture is restricted.

If the season has had good rainfall or significant amounts of soil water have accumulated during the previous summer, there is more potential for root growth, water and nutrient extraction from deeper in the soil profile when subsoil constraints have been dealt with.

Negative responses to ripping can be observed in some seasons with a 'dry finish' as crops growing on deep ripped soils grow more vigorously. They produce more biomass, and use up the available subsoil water more quickly, leaving insufficient soil water for grain filling.

Deep ripping impacts

Following deep ripping, roots can penetrate the soil faster and deeper to absorb more soil moisture, capture more soil nutrients and improve yield. There are other impacts of deep ripping, both positive and negative.

Residual value of deep ripping

The response to deep ripping can last for many years. In responsive soils the residual benefit of the ripping in the second year is about half the initial response and declines further over time due to:

- re-compaction by traffic;
- natural soil settling and cementation; and
- the greater removal of nutrients and water by the previous year's higher-yielding crop.

The use of controlled traffic after deep ripping has been shown to help retain the benefits of deep ripping for longer, especially in heavier soils.

Other benefits of deep ripping

The soils that are most likely to respond to deep ripping are sandy, so they are potentially groundwater recharge areas. They are also likely to be susceptible to soil acidification, partly through leaching of nitrate.

Apart from the productivity gains from deep tillage, the higher-yielding wheat crops will use more water and nutrients. This will reduce the leaching of nitrate, through deeper rooting and greater nitrogen uptake, and in the long-term will reduce flooding and salinity of lower landscapes.

Deep ripping downsides

Although deep ripping can increase water infiltration into the soil, it can also destroy the natural soil aggregation and macropores of loamy or finer-textured soils, bring sodic subsoil to the surface (resulting in poor establishment of crops), and deplete soil organic matter. It can also reduce soil water content in the surface layers by disturbing and exposing the soil to evaporation, which can reduce crop yield in dry seasons.

PHOTO: STEPHEN DAVIES

Differences in root growth are clear between un-ripped soil (left) where very few roots penetrated below 30cm and the rip line (right) where roots were still common at 40cm.

The economics of deep ripping

Economics should be the overall deciding factor on whether an amelioration strategy is implemented or not. The final strategy selected will, in turn, depend on the capacity of the landholder to afford these costs and their attitude to risk.

The benefit of deep ripping on crop performance varies widely. Most studies indicate that deep ripping alone provides little or no long-term impact on the physical condition of clay subsoils. Yield benefits have been recorded from deep ripping on non-sodic sandy loam soils in the northern Mallee. On dispersive (sodic) soils, ripping is unlikely to have significant long-term beneficial effects unless the structure of the soil is simultaneously stabilised through amelioration with either calcium or organic matter.

A sensitivity analysis can be a useful method of assessing the change in crop yield by identifying a specific price required to return the cost of deep ripping. In the example in Table 2 the total amelioration cost for deep ripping based on contract rates is $40/ha. With an average production cost of $165/ha the total cost of production equals $205/ha. The breakeven points for both wheat price and yield are highlighted in yellow over the page.

Sodicity

Sodicity occurs naturally in soils that contain a high level of sodium relative to calcium, potassium and magnesium. It causes dispersion of soil particles, which leads to the collapse of soil structure and loss of pore spaces, which limits seedling emergence, the growth and efficient function of plant roots and increases waterlogging. Gypsum (calcium sulphate) application is extensively used to counter sodicity.

TABLE 2 THE ECONOMICS OF DEEP RIPPING

Yield (t/ha)	Price ($/tonne)					
	100	150	200	250	300	350
0.5	50	75	100	125	150	175
1	100	150	200	250	300	350
1.5	150	225	300	375	450	525
2	200	300	400	500	600	700
2.5	250	375	500	625	750	875
3	300	450	600	750	900	1050
3.5	350	525	700	875	1050	1225
4	400	600	800	1000	1200	1400
4.5	450	675	900	1125	1350	1575

An example of the impact of changes in price and yield to achieve payback from deep ripping in the first year if the total cost of production including deep ripping is $205/ha.

SOURCE: *Identifying, understanding and managing hostile subsoils for cropping - A reference manual for neutral-alkaline soils of south-eastern Australia.*

Deep ripping equipment

Deep ripping can be achieved using a variety of implements.

Various tine designs have been used successfully in deep ripping including a ‘winged’ design (Spoor and Godwin 1978), shallow tines in front of the deep tines (Hamza *et al*. 2005), and the ‘Paraplough’, as well as more traditional tines with straight shanks.

Draft requirements increase rapidly with the depth of soil disturbance so a good knowledge of where the principal soil physical limitation is in the soil profile is required. For example, on soils with a shallow but fertile topsoil (for example, 10cm), overlying a dense subsoil, disturbance may need only be confined to relatively shallow depths (for example, 20cm). Once deep ripping and amelioration are completed, strategies such as stubble retention and controlled traffic should be considered to maintain any improvements in soil structure. Otherwise, re-compaction will occur quickly on most soil types.

Recent advances in machinery, such as ‘slotting’ equipment to simultaneously introduce ameliorants at depth with ripping, could increase the effectiveness of this approach to managing subsoil constraints.

Where compaction is closer to the surface a deeper pass with narrow tillage points has been able to break up thin compacted layers.

Useful resources:

■ **A general description of various subsoil constraints and how to manage them for grain production (including deep ripping) can be found in *Identifying, understanding and managing hostile subsoils for cropping - A reference manual for neutral-alkaline soils of south-eastern Australia*, published by The Profitable Soils Group (2009) (ISBN 978-0-9806136-0-5) which can be downloaded from**	**www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soil_mgmt_subsoil**
■ **Roger Armstrong, DPI Victoria**	**(03) 5362 2336, Email roger.armstrong@dpi.vic.gov.au**
■ **Stephen Davies, Department of Agriculture and Food, WA**	**(08) 9956 8555, Email sdavies@agric.wa.gov.au**
■ **John Kirkegaard, CSIRO Plant Industry**	**(02) 6246 5080, john.kirkegaard@csiro.au**
■ **Western Australia**	**www.agric.wa.gov.au/objtwr/imported_assets/content/lwe/land/cult/fn088_1994.pdf**

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