Subsurface compaction limits crop potential on sandy soils

Key facts

- Anecdotal evidence suggests widespread compaction occurs on sands in low-rainfall areas.
- Restricting root growth reduces leaf area and the plant's ability to capture resources (nutrients and sunlight).
- Deep ripping can improve yields by more than 40% and benefits can last for many years.
- Controlled traffic farming (CTF) can extend the benefits of deep ripping.

Subsurface compaction can severely limit production, especially on sands, where natural packing can occur. Restricting root growth prevents crop access to critical resources, such as water and nutrients.

Subsurface (or subsoil) compaction describes the rearrangement of soil particles and total pore space as a result of applied stresses.

The main cause of subsurface compaction, particularly on sands, is wheeled vehicular traffic — especially heavy dual-axle tractors.

Subsurface compaction can be broken down into two main types:

1. **plough pans:** more common on heavier-textured soils (i.e. clays and loams)
2. **traffic pans:** more common on lighter-textured soils (i.e. sands).

Plough pans

Plough pans can be characterised by an abrupt boundary between the tilled and compacted soil layers and there are often signs of smearing on the surface of the compacted layer. The depth of a plough plan in the soil profile depends on how deep the soil-engaging equipment penetrates the soil profile.

This type of compaction is caused by repeatedly tilling the soil at the same depth for many years. As tines wear, this can smear and compact the soil immediately below their operating depth.

Traffic pans

Traffic pans are layers of high strength in the subsoil caused by traffic compressing the soil over time. This type of compaction lies deeper in the soil profile than plough pans, with the layer of maximum strength often occuring at 10–40cm.

Soil compaction induced by wheeled traffic is typically apparent at around 15cm below the soil surface, but can be deeper in sandy soils.

Other sources of compaction

Livestock can also cause short-term subsurface compaction. Research carried out by the CSIRO indicates soil pressure from sheep hooves can be as great, or greater than, that applied by tractors given the pressure is applied to a relatively smaller

PREVIOUS PAGE: Subsurface compaction is common on sandy soils and limits the ability of plants to access water and nutrients critical for optimal growth. Photo: DAFWA

RIGHT: The severity of compaction from heavy machinery can be compounded when soil is wet. Photo: Brad Collis, GRDC

surface area. However, compaction caused by sheep is often restricted to a narrow band across the soil surface, is limited to a depth of 5–10cm and is readily penetrated by normal tined sowing implements (Figure 14).

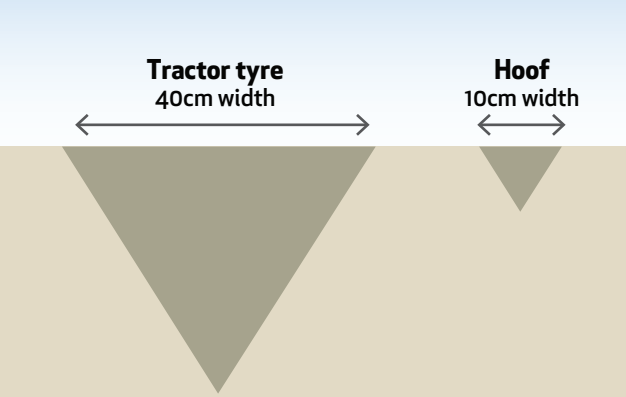
Some Mallee sands have a natural tendency to form impenetrable layers just below the soil surface. A natural sorting and movement of soil particles whereby fine sands, clays and silts settle further from the soil surface over time causes these soils to become compacted. Similar to compaction caused by livestock, this natural form of compaction can be penetrated by a tined implement at a regular sowing depth.

Measuring soil compaction

Penetration resistance is an empirical measure of the degree of compaction. Penetration resistance can be measured using a penetrometer, which measures the force needed to push a rod through the soil when a soil is at field capacity (i.e. approximately 24 hours after a soaking rain).

Researchers from Charles Sturt University, New South Wales found that root growth is typically impeded at a resistance of 1.5MPa, severely restricted at 2.5MPa and root growth ceases at 5MPa.

Figure 14. Traffic-related compaction versus livestock compaction



The width of the applied pressure from livestock is less than vehicle traffic so the depth of influence is shallower at the same contact pressure.

Source: Australian Grain (March–April 2010)

High-soil strength restricts root growth, with the effects exacerbated in drier soils — roots cannot grow beyond the wetting front in high-strength soils.

In the absence of a penetrometer, growers can identify compaction by observing the relative force required to dig a hole with a shovel.

Plant growth can also be an indicator of compaction, given compaction limits growth, often leading to stunted crops.

Responses of crop types to soil compaction

Restricting root growth to a shallow zone restricts plant access and uptake of water and nutrients. A corresponding reduction in leaf area can impede the ability of a plant to capture energy from sunlight.

Field experiments indicate that roots of cereal and grass species, such as wheat and barley, are less able to penetrate compacted soil layers than broadleaf species, such as legumes and brassicas.

Continuous cropping with cereals, can exacerbate the impact of compaction as cereal roots are less likely to produce useful root channels.

Root thickness, not root density, is the key property that allows a plant to penetrate hard soil layers. Given the roots of broadleaf species are relatively thicker than cereals and grasses, and thus more able to effectively penetrate compacted soils, they could alleviate compaction if grown after cereal crops.

Managing compaction

Ameliorating subsurface compaction using deep tillage (ripping) can result in spectacular yield responses.

Multiple trials have shown that in ripped soils, plants can extract more soil water at depth. Trials carried out by CSIRO at Loxton and Caliph, SA during 2005 measured wheat yield increases of up to 43% in response to ripping and responses were still evident in the second-year crop after ripping.

Deep ripping can deliver additional benefits including: the breaking up of hard pans, reduced water repellence by re-distributing wax-coated sand particles through the soil profile, and improved mineralisation rates, increasing the plant availability of nutrients during the growing season.

The legacy of ripping will depend on the frequency of re-wetting of the soil profile and the relative dependence of the crop on soil water located at depth. A SARDI research team

Tips for deep ripping

- **Timing** — Deep ripping carried out immediately after sowing, before the emergence of a cereal crop, will limit issues of trafficability following ripping. Some growers have experimented with ripping before sowing, but have found it reduces trafficability, which is challenging for paddock preparation and sowing .
- **Recompaction** — Ripped soil is more prone to re-compaction. Avoid unnecessary traffic following ripping.
- **Depth** — Ripping depth should be 1.5 times the disturbed depth of standard sowing equipment.
- **Residual effect** — The effects of ripping on responsive soils generally lasts for up to three years, but occasionally the benefits can continue for up to eight years. Generally, half the initial yield response could be expected over the subsequent two years.
- **Reliability** — Deep ripping is a reliable tactic for managing the compaction of sandy soils and enables roots to access soil water stored deeper in the profile, which is particularly important when there is a dry finish to the season.

Tips for deep ripping

RIGHT: Photo: GRDC

at Minnipa, SA found the effects of deep ripping were only apparent and most significant for 1–3 years. Responses will be most evident in those seasons when deep soil water is critical to yield.

Controlled traffic farming

The benefits of deep ripping can be prolonged if traffic is confined to one set of tram lines for every operation across the paddock — also know as controlled traffic farming (CTF).

Trials and experiences that compared (uncontrolled) conventional and CTF between 1997 and 2003 from Western Australia showed a yield increase of 10% in wheat along with an improvement of grain quality under a CTF system.

Controlled traffic farming CTF also creates opportunities for novel weed control options, such as inter-row spraying using precision agriculture (PA) technology.

Tips for controlled traffic farming

- A 3:1 ratio between sprayer and sowing equipment width, based on wheel spacing configurations of major machinery manufacturers and grower experience, is the most economically-convenient option.
- While it is best practice is to have all equipment on tramlines, the priorities are sowing, spraying and top-dressing (spreading) rigs. It would be ideal to have the harvester also set up on tramlines, but given harvest usually occurs when the soil is relatively dry, the risk of compaction is less during harvest.
- Tracked vehicles provide better traction on permanent tramlines than those with single wheels.

Tips for controlled traffic farming

Further information

- *Deep ripping Fact sheet*, GRDC (2009) https://grdc.com.au/uploads/documents/GRDC_DeepRipping_6pp_.pdf
- Ripping benefits quickly negated by wheel traffic, Ground Cover, GRDC (2015) https://grdc.com.au/Media-Centre/Ground-Cover-Supplements/Ground-Cover-Issue-118-Soil-constraints/Ripping-benefits-quickly-negated-by-wheel-traffic
- 20 Questions You May Ask About Controlled Traffic in Western Australia:Paul Blackwell, DAFWA http://www.liebegroup.org.au/wp-content/uploads/2013/07/Questions-you-may-ask-about-Controlled-Traffic-farming-in-WA-v-3.pdf
- *Controlled Traffic Farming Fact Sheet*, GRDC, 2013 https://grdc.com.au/~/media/Documents/Resources/.../GRDCFSCTFhigh-respdf.pdf