PHYSICAL SOIL CONSTRAINTS FACT SHEET

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The villains of hard subsurface layers in sandy soils

KEY POINTS

- Sandy soils commonly have physical constraints that reduce crop root growth and exploration and water use efficiency, which ultimately reduces yield.
- Hardened subsoil layers within sandy soils vary in nature and distribution through the soil profile. They are typically categorised into two forms:
  - Traffic-induced compaction (cultivation pan) – soil particles bind together tightly due to the application of external forces, such as the weight of machinery, mainly when the soil is wet.
  - Natural subsurface hardening
    - *Hardsetting* – a reversible chemical process in which a hard layer forms as the soils dries out, restricting root growth, but softens on wetting
    - *Cementation* – an irreversible chemical process in which salts precipitate (solidify) and cause cementing, even when wet.
- Understanding the differences between soil-hardening processes can assist with amelioration strategies and future planning.

FIGURE 1: Comparison of root depths. a) Roots restricted to 20 to 25cm in hardened soil. b) Deep ripping removed hardening, allowing roots down to 60cm (Karoonda, SA, 2021).

Photos: Bill Davoren

The cost of subsoil constraints

Many Australian sandy soils have hardened subsoil layers that prevent root penetration and reduce access to nutrients and water deeper in the soil profile. Agricultural production loss associated with soil compaction in Australia is estimated to cost about $850 million per year.[1]

Hardening subsoil layers

The nature and distribution of hard and/or cemented soil horizons varies. Two broad categories of natural subsurface hardening within sandy soils are typically identified.

Traffic-induced compaction, also known as a cultivation pan, is a result of external forces applied to soils through farming operations (including livestock traffic), especially when the soil is wet. Root growth can be severely restricted (Figure 1a) and yield compromised. Soil structure is reduced through binding of soil particles, which decreases soil porosity and permeability to both air and water through the pan, in comparison to the soil horizons above and below.
Natural subsurface hardening is caused by chemical processes, leading to either reversible or irreversible hardening. *Hardsetting* is reversible with soils becoming hard as they dry out and soft once the soil moisture increases. When looking at a soil profile, as in pictures above, the hardsetting layers cannot be indented when pressure is applied with a forefinger. Rooting depth can be extremely limited because the strength increases dramatically as the soil dries out in spring, limiting root penetration even though the soil moisture may be sufficient for root growth and water extraction. Persistence of this form of hardsetting depends on soil moisture conditions. Therefore, the severity of hardening is likely to vary within or across seasons depending on soil type and rainfall conditions. *Cementation*, in contrast, is irreversible soil binding due to precipitation of chemical compounds. These cementing compounds usually come from groundwater. The degree of cementation ranges from weak (crushable between thumb and forefinger) to very strong (cannot be broken by a hammer or extreme force). Unlike hardsetting,

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cemented soil layers do not become soft on wetting. They can be observed even in uncleared native sandy soils, which suggests that farming practices are not necessarily the cause.

Diagnosis

Compaction and natural subsurface hardening can coexist[2], but understanding the differences can support effective management decisions.

To determine if the hardened soil layer is cemented, place a piece of a clod of dry soil (~30mm) in water for one hour. If it slakes and breaks up without agitation, it is uncemented; if not, it is cemented. The degree of cementation can range from weak to very strong.[3]

AMELIORATION OPPORTUNITIES

Traffic-induced compaction

- Deep tillage practices fracturing the hardened subsoil layer have shown beneficial agronomic responses, particularly in following seasons.
- Considering the life span of deep tillage is essential, as subsequent traffic can cause soil to re-compact over time.
- Deep tillage may be required every five to 10 years to manage constraints. If the soil is prone to hardsetting, machinery traffic may not be the sole cause of hardening and deep tillage may be required more frequently.

TABLE 1: Indicative characteristics of subsurface hardening (guide only).[a]

Characteristic	Traffic-induced compaction (cultivation pan)	Natural subsurface hardening	
		Wet soil	Dry soil
Bulk density (Soil weight to volume)	High	Same	Same[b]
Total porosity (Pore space between soil particles per volume of soil)	Low	High	Low
Permeability (Flow of air and water in the soil)	Low	High	Low
Soil strength when wet and drained (Force applied to the soil at the time of testing)	High	Low	High

a. Blue – characteristic is at a non-desirable indicator level; Green – characteristic is at an acceptable indicator level.
b. Exceptions apply

TABLE 2: Testing methods and thresholds for determining subsurface hardening.[a]

	Traffic-induced compaction	Natural subsurface hardening
Test	(a) Bulk density (BD) analysis (b) Penetrometer – wet and drained soil	(a) Bulk density (BD) analysis (b) Penetrometer – range of soil water contents between field capacity and permanent wilting point.
Thresholds (rules of thumb)	(a) Where BD is ≥1.6g/cm^3 soil is regarded as compacted and root growth is restricted. Root growth is prevented when BD ≥1.85g/cm^3[a]. (b) Where soil resistance is ≥2.5MPa measured in a wet, well-drained soil it will limit root growth.	(a) Soil hardening occurs even with BD below 1.6g/cm^3; hence cannot be a diagnostic tool. (b) Hardsetting soils will exhibit a significant increase in strength as the soil dries out, exceeding the 2.5MPa threshold. Non-hardsetting soils will not present such difference in penetration resistance when wet and dry.

a. Parker, W, Isbister, B, Hoyle, F, Leopold, M (2021) *Soil quality: 6 Soil compaction* (ebook). SoilsWest, Perth, WA.

MORE INFORMATION

For further information on how to test using a penetrometer refer to the ***Soil Quality: 6 Soil Compaction*** ebook[4]
https://books.apple.com/au/book/soil-quality-6-soil-compaction/id1581017530

REFERENCES

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3. CSIRO Publishing and The National Committee on Soil and Terrain (Australia) (2009) ***Australian soil and land survey field handbook***. CSIRO Publishing, Collingwood, Victoria.
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