DEALING WITH DISPERSIVE SOILS
FACT SHEET

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

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How to identify and manage constraints of sodic and dispersive soils

Are your soils dispersive, sodic or both?

KEY POINTS

- Excess exchangeable sodium (Na) is the most common cause of dispersion, but other factors including organic matter, salinity, and clay content affect soil dispersion.
- The easiest way to check if soil is dispersive is with a 'jam jar' (Emerson Aggregate) test.
- Gypsum ($CaSO_4$) is the most common treatment for dispersive sodic soil. Gypsum won't improve soil structure on non-dispersive soil but can add Ca and sulphur (S) for crop nutrition.
- Ripping to get gypsum deeper can sometimes make things worse by bringing up clods of unfavourable soil. Highly dispersive soil is best left untouched. Do a test strip on moderately dispersive soil before ripping.

PHOTO: FRAN HOYLE, UWA

David Hall (DPIRD) at Merredin discussing the constraints associated with a sodic and dispersive soil.

Grey sticky clay, hard-setting clay, Moort clay and Sunday soil are some of the common names for WA dispersive soils. Dispersive soils cover 8–10 per cent of the Western Australian grainbelt and cost WA growers about $577 million a year in lost production (Petersen 2017). They are more common in the eastern part of the grainbelt and on broad, flat landscapes.

The main cause of dispersion is too much sodium (Na) attached to soil particles. This is why dispersive soils are often called 'sodic' soils, although the two are not synonymous. Because the term 'sodic' is loosely used, it is often assumed dispersive equals sodic equals gypsum responsive (to displace high Na), but this is not always the case. See the section 'Dispersive, sodic or both?' later in this fact sheet.

When a dispersive soil gets wet, the Na ions act like two positive ends of a magnet, pushing soil particles apart. This makes soil aggregates (clumps) swell and break, destroying soil stability. When the soil dries, the particles are still dispersed and the soil hardens into a tough mass without pores for water, air and crop roots to move through.

Dispersive topsoil gets a crust that:

- reduces seedling emergence
- reduces soil aeration/gas exchange, meaning less oxygen for plant roots and microbes
- prevents infiltration, leading to run-off, erosion and less in-crop moisture.

Dispersive subsoil restricts root growth and the amount of subsoil moisture roots can access. Because dispersive soils tend to be on flat landscapes, less drainage means sodic soils are also prone to waterlogging.

Sodic soil is often also saline and/or alkaline (pH >8), presenting chemical challenges in addition to the physical

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problems described. Saline-sodic soils are more common in low-rainfall areas with the salts making it harder for crops to take up already limited water.

Chloride can be directly toxic to crops. In alkaline soils, as pH rises, essential nutrients such as phosphorus (P), manganese (Mn), copper (Cu) and zinc (Zn) tend to be less available for crop uptake, while others such as boron (B) can become toxic. Most crops do not suffer from Na toxicity, but high Na can interfere with the uptake of other cations such as potassium (K).

How to identify dispersive soil

IN THE PADDOCK

During or just after rain, puddles in the paddock are cloudy/milky, water runs off or infiltrates very slowly, and the paddock gets boggy quickly. Dispersive clay readily sticks to boots, tyres and tynes. When dry, the surface crusts and sometimes cracks. In low-rainfall areas you can sometimes see salt crystals.

These visual clues are helpful, but not always definitive. Therefore, it is a good idea to check the soil is actually dispersive, where within the paddock it transitions from dispersive to non-dispersive, and if there is dispersive subsoil lurking beneath a non-dispersive topsoil (e.g. in a duplex soil). There is a simple benchtop jar test that can be used.

THE DIY JAR TEST

The easiest (and cheapest) way to gauge if your soil is dispersive is the 'jam jar' test, more formally known as the Emerson aggregate test (see references).

In the paddock, collect small dry soil clumps (aggregates) about five millimetres in diameter from representative areas, making sure you know where each one has come from. Collect at least two from each sample area. It is common to collect 20 to 30 aggregates when getting serious about identifying where dispersive soils are located.

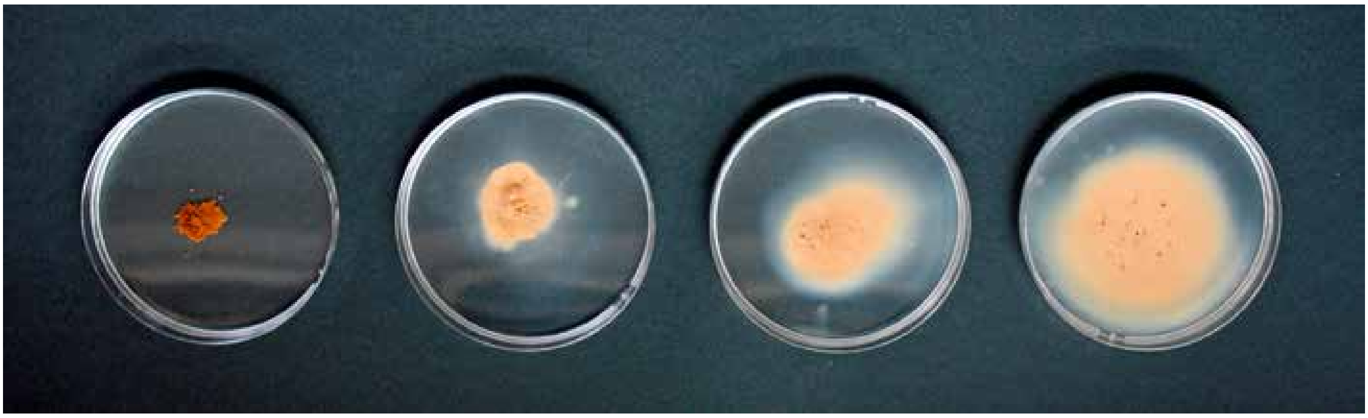
If you are on duplex soils and think there is subsoil dispersion, collect aggregates from different layers in the soil, noting the depth. Because sand does not disperse, you only need to collect samples from soils that have some clay in them.

Back in the house, office or shed, set up a series of clear containers – jars, glass cups, plastic cups or petri dishes. The containers need to be wide enough so you can gently place (not drop) the aggregates in the bottom of the container. If the aggregates are damp/wet, leave them out to dry for a day or two before continuing.

Sodic soils – milky puddle.

PHOTO: DAVID HALL, DPIRD

FIGURE 1 Degrees of soil dispersion (nil to severe) for soils that are non-sodic to highly sodic (from left to right).



SOURCE: ALISON LACEY, DPIRD, 2020.

Where subsoil sodicity is a problem, getting gypsum to depth can be tricky. Gypsum will gradually move through the profile with rainfall but because the soil already has low permeability, it will take a few years to move. Research in the east is finding responses in the second and third year (Menzies et al, 2015) and finding a better response when applying both organic and inorganic amendments. In low-rainfall areas, gypsum could take a decade or more to move and in very dense subsoil any displaced Na may be unable to leach.

- Put a few centimetres of distilled water or rainwater into each container. Do not use chlorinated tap water as this can interfere with the test.
- Place each aggregate gently into a container with the water.
- Watch the aggregates for the first 10 minutes, then check again after 30 minutes, two hours and 24 hours.

If the water around the aggregate turns cloudy, the soil is dispersive. The cloudier the water, the more dispersive the soil. The faster dispersion becomes obvious, the more dispersive it is. In highly dispersive soil, the water will turn cloudy within minutes. Wait the full 24 hours before making your assessment as dispersion can take a while to show up in low to moderately dispersive soil. If more than half of the aggregate disperses (e.g. 'moderate' dispersion or more as shown in Figure 1), the soil is highly likely to respond to gypsum.

If the aggregates crumble – if this is going to happen, it will show within the first few minutes – but the water does not go cloudy, the soil has slaked, not dispersed. Slaking is a physical problem and means the aggregates were not strong enough to withstand the pressure of the sudden influx of water into their pores. It is usually caused by low organic matter. Slaking is very common and does not cause the same management problems as dispersion.

Soils can both slake and disperse. A soil that slakes will not necessarily disperse, while a soil that disperses will also slake.

Section 1 of *Soil Quality 2: Integrated Soil Management* (Pluske, Boggs and Leopold, 2018) has a time-lapse video comparing a stable aggregate to one that slakes and one that disperses.

IN THE LABORATORY

To put numbers to the degree of dispersion, a sample can be sent to a laboratory for analysis of exchangeable cations. Because Na is the main cause of dispersion, lab tests measure the amount and percentage of exchangeable Na in the sample as well as calcium (Ca), magnesium (Mg) and K.

If the exchangeable sodium per cent (ESP) is >6, the soil is considered 'sodic'. If the ESP is >15, the soil is considered strongly sodic. There is a rough relationship between the degree of dispersion in the jar test and ESP (DPIRD, 2020, Table 1, and Department of Sustainable Natural Resources, NSW, Emerson aggregate test).

Lab results can be useful to see if Mg is also influencing soil dispersion and to calculate gypsum rates. If you are going to send a sample for lab testing, get pH and salinity tested too.

Dispersive, sodic or both?

While Na is the main cause of soil dispersion, it is not the only cause. Not all sodic soils disperse and not all dispersive soils are sodic. Other factors affect soil aggregate stability, including:

- clay content – soils need 15 per cent or more clay to disperse. Below this the soil is too sandy for dispersion to be a problem
- organic matter (OM) – lower OM can mean aggregates that are less stable
- higher ionic strength (i.e. salinity) – as counterintuitive as it sounds, more salt is better for aggregate stability. Soils with low salinity levels $EC_{1:5}$ <0.2 dS/m are more prone to dispersion. This is why it is good to check salinity if you are getting a lab test
- exchangeable Mg – while not as problematic as high Na, a low Ca:Mg ratio (<2:1) and high exchangeable Mg (>30 per cent) can exacerbate soil stability problems.

How to manage dispersive soil

GYPSUM

Gypsum ($CaSO_4$) is the most common treatment for dispersive sodic soil. Gypsum only works on dispersive soils. Adding gypsum to non-dispersive soil is a way to add Ca and/or sulfur (S) for crop nutrition (particularly S for canola), but will not do much for soil stability.

Gypsum helps improve soil flocculation (aggregate formation) in two ways.

In the short term, the Ca in gypsum increases the ionic strength (the salinity) of the soil solution, which suppresses dispersion. This temporary spike in

PHOTO: FRAN HOYLE, UWA

Soil clods can result from deep ripping under non-optimal conditions on a dispersive soil.

salinity is immediate and does not require much gypsum (<2t/ha). On the flip side, the effect is short-lived, especially with a low application rate. Higher rates of gypsum (>5t/ha) can increase salinity and affect plant growth.

In the long-term, Ca in gypsum replaces Na on soil particles, which helps the soil form aggregates. The idea is that the Na ions are leached deeper into the soil profile. This change is permanent, unless more Na is added to the soil. The amount of gypsum required to displace Na with Ca is much higher than the short-term effect. In some cases, the amount of Ca needed to displace all Na is so high (>30t/ha) you would kill the crop with salinity in a single gypsum application. Therefore, lower and more frequent applications are better. You will get the short-term ionic strength effect on a regular basis while also gradually replacing Na with Ca.

Lime is not a substitute for gypsum when treating alkaline-sodic soils. While lime does supply Ca, soil pH needs to be low (<5.5 in $CaCl_2$) for it to be soluble enough to displace Na. In the uncommon scenario of a soil that is both acidic and sodic, lime can be useful.

In alkaline-sodic soils, gypsum can help lower pH. The Ca ions in gypsum precipitate as $CaCO_3$, consuming some alkalinity. For this to work the soil needs to have a pH above about 8.3 and you will need to apply bullish gypsum rates, e.g. at least 5t/ha.

Where subsoil sodicity is a problem, getting gypsum to depth can be tricky. Gypsum will gradually move through the profile with rainfall but because the soil already has low permeability, it will take a few years to move. Research in the east is finding responses in the second and third year (Menzies et al, 2015) and finding a better response when applying both organic and inorganic amendments. In low-rainfall areas, gypsum could take a decade or more to move and in very dense subsoil any displaced Na may be unable to leach.

ORGANIC AMENDMENTS

Adding OM can improve aggregate stability, which helps maintain soil pores and makes it easier for Na to leach below the root zone.

Research is underway (Tavakkoli et al, 2019) on putting organic amendments at depth, with the best results in areas that have organic and inorganic amendments applied together, e.g. gypsum and pea hay and nutrients, for a multi-pronged attack. At the moment this amelioration approach makes more economic sense in high rainfall and some medium-rainfall zones in the east, where some growers have developed their own machinery to apply subsoil treatments. Economic analysis and proof of concept work is ongoing.

MINIMISE TILLAGE

Some growers try to rip to get gypsum deeper, but in many cases this just makes things worse. Ripping can break up the compacted soil, but it also increases the amount of soil that disperses when it rains. Ripping sodic subsoil also tends to bring big clods of dispersive and sometimes chemically unfavourable soil to the surface.

At the moment, water harvesting research is covering the inter-row with plastic so when rain falls it is concentrated into the furrow. There has been some yield improvement in low-rainfall years, but the approach seems more effective where salinity is a problem; non-saline soils do not respond well.

Highly dispersive subsoil is best left untouched. Moderately dispersive soil might be alright, so it is best to do a test strip first. Rip a small section and see what happens after it rains.

If the rip lines infill and become denser than before, it is best not to rip any more of the paddock. If you do decide to rip, use the opportunity to get gypsum to depth. Implementing controlled-traffic farming will be beneficial as the soil will be highly prone to compaction after ripping.

ROTATIONS

In lieu of ripping, some crops such as lucerne and safflower can act as bio-cultivators. Their strong root systems can create root channels in the dense subsoil that future crops can use.

WATER HARVESTING

As dispersive saline soils are a bigger problem in low-rainfall areas, researchers are looking at water harvesting – channelling rainfall into the furrow to help salts leach. Some growers are doing a similar thing by modifying seeding points to try to create a more favourable micro-environment, i.e. the first rains leach salts in the micro-environment from near where seed is placed.

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In one trial that included a non-saline sodic soil (Mulvany et al, 2019), there was a yield penalty, because without the salinity to counter dispersion the surface crusted and the water pooled and evaporated. Like deep placement of amendments, water harvesting is still in the research phase.

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MORE INFORMATION

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FURTHER RESOURCES

Dispersive and sodic soils:
https://www.agric.wa.gov.au/dispersive-and-sodic-soils/dispersive-sodic-soils-western-australia

https://www.agric.wa.gov.au/climate-land-water/soils/managing-soils/dispersive-and-sodic-soils

https://www.agric.wa.gov.au/climate-land-water/soils/identifying-wa-soils

My soil diagnostic tool:
https://www.agric.wa.gov.au/managing-soils/mysoil

Soil quality website:
http://www.soilquality.org.au/au/wa

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