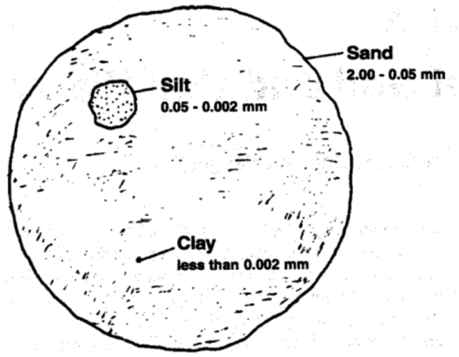
Understanding sodic soils

Key points

Soil has four major components; minerals (sand, silt and clay), organic matter, water and air.

Sand particles are between 100 and 1000 times larger than clay particles and silt particles are 10 to 100 times larger than clay particles.



The proportion of sand, silt and clay determines the **soil texture**.

The way the sand, silt and clay particles arrange and bind together determines the **soil structure**.

The 'glue' that binds sand, silt and clay particles together are plant roots (organic matter) and the by-products from soil microbes that have eaten the organic matter. Clay particles are also bound by this glue.

Clay particles also have a second type of glue to bind them together, which involves specific elements known as **cations**.

The most important cations that glue clay particles together are calcium (Ca), magnesium (Mg), Potassium (K) and sodium (Na).

The glue from organic matter creates physical bonds whereas the glue from cations creates chemical bonds.

Calcium (Ca) is the strongest chemical glue, however sodium (Na) and to a lesser extent magnesium (Mg) are much weaker. Calcium is 43 times stronger at bonding than sodium and 1.6 times stronger than magnesium.

Australian Government
National Landcare Program
precision agriculture

When water drains into a soil, it pushes between the soil particles. Physical bonds generally are not broken by water infiltration, but soils with clay particles that have a lot of sodium (Na) and magnesium (Mg) are pushed apart.

The breaking of the bonds between the individual clay particles is called **dispersion.**

The chemical 'gluing' of clay particles together is called **flocculation.**

When the clay particles disperse, they move between the sand and silt and block the channels where water, air and plant roots wish to move. This makes the soil denser.

Testing for soil stability (dispersion / flocculation)

Visual and laboratory testing can be used to determine the stability and structure of a soil.

Visual measurement

The visual measurement involves looking for cloudy water in puddles after rain or the crusting or sealing of the topsoil once the soil dries out.

A simple dispersion test has been developed to conduct a visual assessment of the soil stability (see below).

Chemical measurement

The most commonly used laboratory measurements (found on a soil test) are:

- the ratio of calcium to magnesium (the Ca:Mg ratio) and
- the total amount of sodium compared to all other elements (called the exchangeable sodium percentage or ESP).

The table below indicates the idea range for these two tests

Measurement	Ideal
Sodium % of cations (ESP)	Less than 6
Ca:Mg ratio	2 to 6

If either of these measurements are outside the ideal range, there is a tendency for the clay particles in the soil to disperse and block the air and root spaces in the soil.

A word of warning. Just because the ratio of cations may not be ideal according to the soil test, this does not guarantee the soil will disperse. In soils that have not been disturbed for many years such as a pasture paddock or minimum till cropping the plant roots and organic matter by-products may be enough to hold the soil together. However cultivation or compaction of the soil can break these physical bonds and then the soil may disperse.

Dispersion test for soil

1. Select 3 air-dry aggregates, 5–10 mm diameter (about the size of a pea).

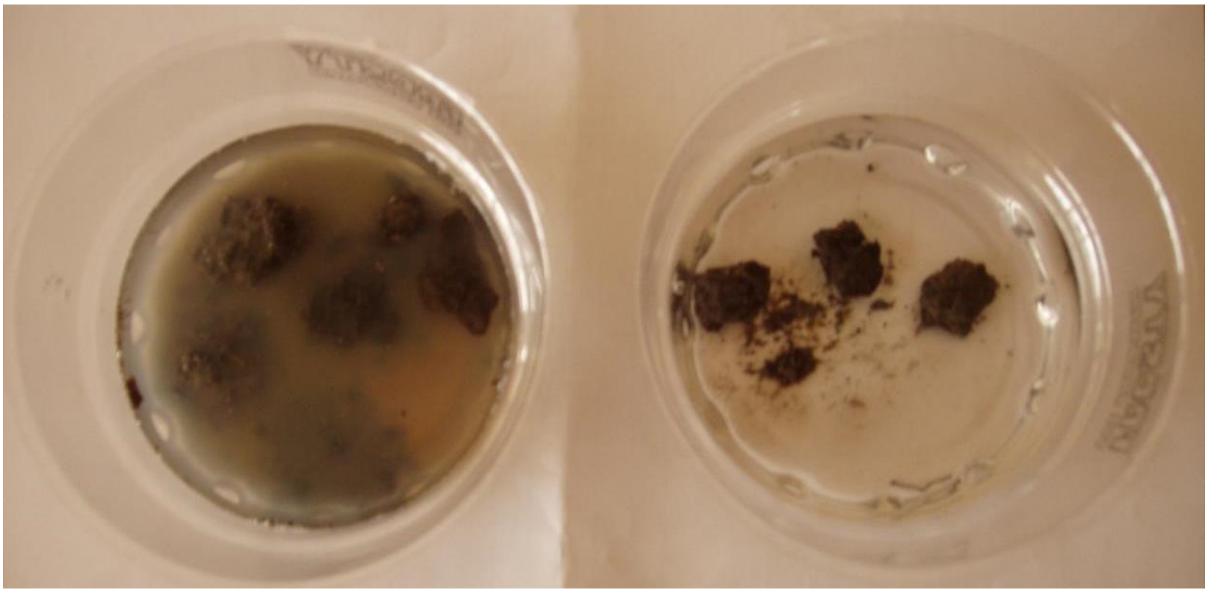
2. Place 75 mL distilled water in the container. Place the 3 aggregates in the container of water, spaced equally around the side. Do not stir or otherwise disturb.

3. Record the time placed in the water. After 2 hours and 20 hours, observe the aggregates for cloudiness (will be the colour of milky tea).

4. If the aggregate has not dispersed, place about 20–40 g of soil (<2 mm) in a mixing bowl and add sufficient distilled water to bring the soil to a soft consistency. Mix for 30 seconds.

5. Without using your fingers, form a 5 mm cube of the reworked soil using a spatula or mould. Place the cube of reworked soil into another container of distilled water. Do not stir or otherwise disturb. After 2 hours and 20 hours, observe the degree of dispersion.

NB: Step 5 is intended to simulate cultivation.



Dispersed soil **Flocculated soil**

Results

1. Four of the six paddocks had variation in topsoil (0-10 cm) exchangeable sodium percentage (ESP).

2. All six paddocks had areas with topsoil ESP greater than 6% and therefore should be dispersive

3. There was no large or consistent yield responses to the application of gypsum in the first year. Yield differences were ~ 100 kg/ha and sometimes negative.

Table 1: Average canola yield in gypsum and no gypsum test strips for sites 1 & 2.

Site	Crop	Obs	Gypsum rate (t/ha)			P value
			0.0	3.0	6.0	
1	Canola	742	1.8	1.7		<0.01
		742	1.8		1.8	NS
2	Canola		3.6		3.7	< 0.01

Table 2: Average canola yield in gypsum and no gypsum test strips for sites 3 & 4.

Site	Crop	Obs	Gypsum rate (t/ha)			P value
			0.0	2.5	3.5	
3	Canola	2266	3.5	3.6		<0.01
4	Canola	3248	3.6		3.6	NS

Table 3: Yield of various crops (t/ha) at site 7 to applied gypsum compared to no gypsum.

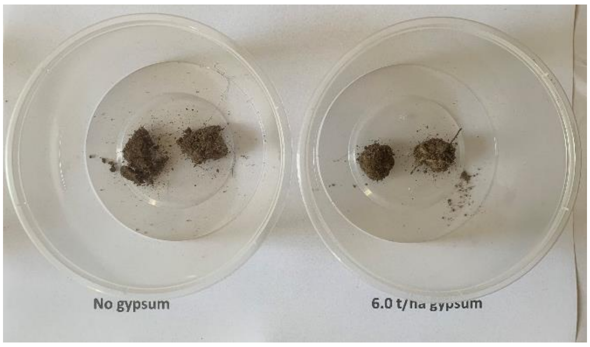
Year	Crop	Obs	Gypsum rate (t/ha)		P value
			0.0	4.5	
2016	Oats	698	5.2	5.7	< 0.01
2017	Canola	642	2.7	1.8	< 0.01
2018	Wheat	192	2.8	2.8	NS

Table 4: Yield of various crops (t/ha) at site 8 to applied gypsum compared to no gypsum.

Year	Crop	Obs	Gypsum rate (t/ha)			P value
			0.0	1.5	3.0	
2016	Wheat	916	9.8	9.7		NS
		1032		9.9	9.8	NS
2017	Canola	842	2.8	2.3		< 0.01
		712		2.2	2.2	NS
2018	Wheat	354	2.7	2.7		NS
		336		2.7	3.1	< 0.01

4. All soils were not immediately dispersive despite the ESP being greater than 6. Some soils without gypsum dispersed after remould suggesting the physical bonds were adequate to prevent dispersion.

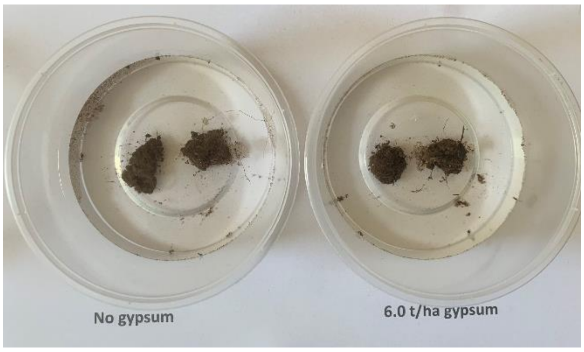
Site 1



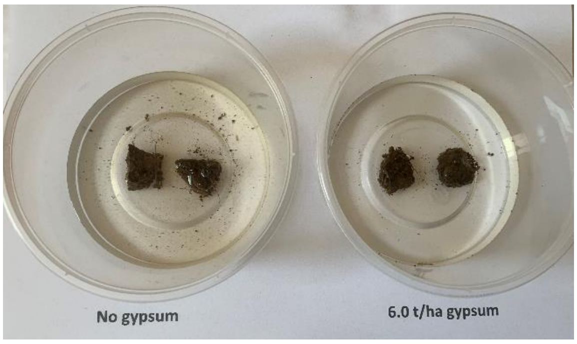
Start

Site 2

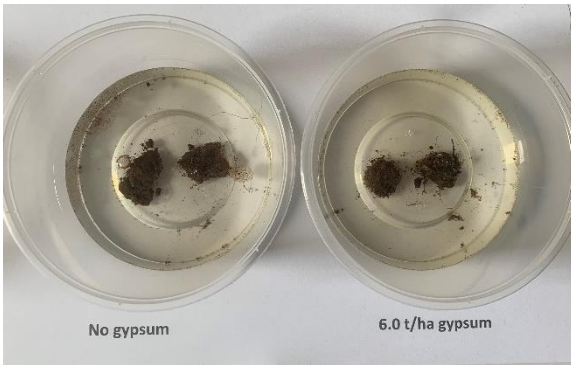
Start



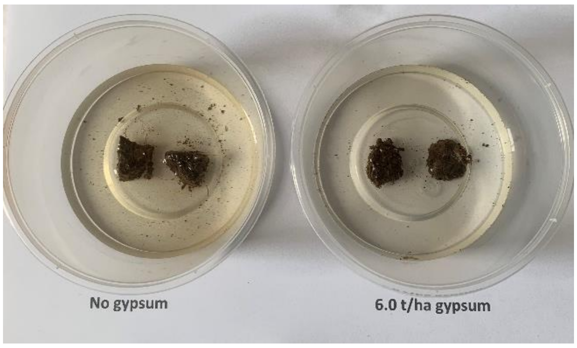
5. Observation after 2 hrs



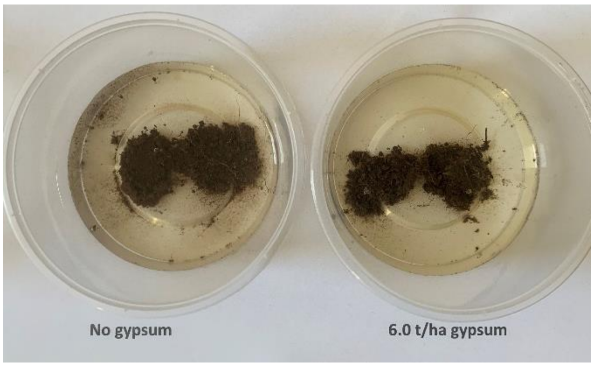
Observation after 2 hrs



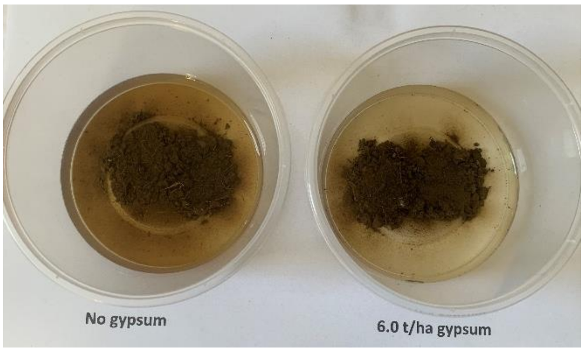
Observation after 20 hrs



Observation after 20 hrs



Observation 20 hrs after remould



Observation 20 hrs after remould

Using gypsum to improve soil structure

Dispersive soils can be improved by increasing the physical and chemical glue that binds the clay particles together.

Increasing the physical glue is a 'chicken and egg' type problem. To increase these bonds relies on healthy root growth and active microbial activity in the soil. If the soil is poorly structured, roots won't want to grow and the soil bugs won't be active. Therefore we start by getting the chemical balance right so it is more favourable to plant growth and organic matter break down.

Changing the chemical balance is easier. It requires:

- a product to add more calcium (a strong glue) to the soil and
- enough water to move through the soil to flush away or leach the sodium and magnesium (weaker glues).

Gypsum is the preferred product to apply more calcium. Gypsum is calcium sulphate dihydate ($CaSO_4.2H_2O$) and dissolves rapidly in water.

Lime (calcium carbonate, $CaCO_3$) is not recommended to improved soil stability because while it contains calcium, it is generally too slow to dissolve in water to get the rapid effect required and usually it contains less calcium per ton of product.

To dissolve 1 tonne of gypsum per hectare requires 50 mm of water. To dissolve 1 tonne of lime per hectare requires about 4000 mm of water.

Buying gypsum

There are three major sources of gypsum. These are:

- natural gypsum, accumulated in shallow layers or pits
- by-product gypsum (phospho-gypsum) formed by the manufacture of fertiliser. This also contains 1% to 2% phosphorus but is hard to get.
- Manufactured gypsum (rejected plasterboard)

The quality of natural gypsum can vary in purity, moisture content and amount of sodium chloride it contains. Pure gypsum contains 23% calcium.

Calcium sulphate sold in Victoria as gypsum must state the grade of the product on the label.

- Grade 1 contains a minimum of 80% gypsum (19% calcium)
- Grade 2 contains a minimum of 65% gypsum (15.5% calcium)
- Grade 3 contains a minimum of 50% gypsum (12.5% calcium)

It should also contain less than 0.8% sodium chloride (salt).

Phospho-gypsum must contain 21% calcium.

The regulations also require that the label on any gypsum product must specify the percentage of gypsum capable of passing a 2-mm sieve.

There is a Natural Gypsum Miners Association (40+ members). They can be found at www.gypsum.asn.au

How much gypsum to apply

The amount of gypsum to apply is pretty crude and is based on the exchangeable sodium percentage (ESP). The usual recommendation is anywhere between 2.5 and 5 t/ha, but my rough rule of thumb is:

ESP	Clay loam (t/ha)	Clay (t/ha)
6	2.5	2.5
10	4.0	5.0
15+	5.0	7.5 - 10

A more precise method is to calculate the amount of sodium that needs to be replaced by calcium. This requires additional information about the bulk density of the soil, total cation exchange capacity (CEC), efficiency of sodium displacement and leaching. Some of these results are estimates at best

Quantity of grade 1 gypsum required (t/ha) for different CEC and ESP levels (0 -10 cm, clay soil with bulk density of 1.4, 40% efficiency of sodium displacement and 50% leaching).

Cation exchange capacity (CEC)	Exchangeable sodium percentage (ESP)					
	6	8	10	12	14	16
10	0.8	2.3	3.8	5.3	6.8	8.0
12	1.0	2.8	4.5	6.3	8.0	9.8
14	1.0	3.0	5.3	7.3	9.3	11.3
16	1.3	3.5	6.0	8.3	10.5	13.0
18	1.3	4.0	6.8	9.3	12.0	14.5
20	1.5	4.5	7.3	10.3	13.3	16.3

If gypsum is applied, then the effect relies on receiving enough water to leach the sodium and magnesium out of the root zone. Insufficient rain, layers in the soil that prevent downward drainage and/or a high watertable can reduce the effect of the applied gypsum.