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Improving soil structure with gypsum and lime

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* This Agfact was previously published as *Improving soil structure with gypsum.*

Gypsum is the common name for calcium sulfate, one of a group of chemicals called salts. Unlike common salt (sodium chloride) gypsum contains calcium and sulfur, and is only slightly soluble in water.

Gypsum occurs naturally as colourless, white or brown crystals in various locations throughout NSW. One crystalline variety is known as 'seed' gypsum because the crystals are about the size of wheat grains. There is also a fine earth variety called 'kopi'. In some areas gypsum deposits occur in old lake beds or adjacent dunes; these deposits are often mined.

Phosphogypsum is a form of gypsum that contains a small amount of phosphorus. It is a by-product of the manufacture of concentrated phosphatic fertilisers.

The main reason for applying gypsum to soils used for agriculture is to maintain or improve their structure*. Gypsum, rather than other forms of calcium, is most commonly used for this purpose because it is easy to obtain, relatively cheap, easily handled and can be used on all types of soils.

SOIL STRUCTURE, SODICITY AND GYPSUM

'Soil structure' means the ***arrangement*** of sand, silt and clay particles and organic matter in the soil to form aggregates (crumbs). It differs from 'soil texture' which indicates the ***proportions*** of sand, silt and clay in soils.

Soils with an excess of exchangeable sodium cations (positive ions) attached to clay particles are called sodic soils. Sodicity should not be confused with salinity. Salinity refers to the total amount of salts dissolved in the water in soil, whereas sodicity refers to the exchangeable sodium cations bound to clay particles. Sodicity is expressed as the ESP (exchangeable sodium percentage), which is the amount of exchangeable sodium expressed as a percentage of the soil's CEC (cation exchange capacity).

Salinity can be reduced by leaching (draining rainwater or non-saline irrigation water through the soil), but leaching has little effect on sodicity. Some soils in NSW are both sodic and saline, but many more are sodic without being saline, particularly in the subsoil.

The sodium ions in NSW soils originated from:

- wind-blown dust during drought
- wind-blown salt spray near the coast
- salt-rich bedrock in the upper catchment areas
- near-surface saline groundwater
- seawater flooding.

Since European settlement some soils have become more sodic due to irrigation with sodium-rich groundwater and, less often, surface waters, or because of rising watertables carrying dissolved sodium salts.

Two aspects of soil structure that are particularly important for agriculture are:

- the numbers of pores (holes) of various sizes, and how these change as the soil swells and shrinks
- the stability of the soil structure to wetting.

Pore size and swelling/shrinking

The two types of soil pores important for plant growth are transmission pores and storage pores. Transmission pores are large (greater than 0.03 mm in diameter) and include cracks and channels created by roots and soil organisms such as earthworms. They transmit water through the soil and drain easily after rain or irrigation. The storage pores are small (less than 0.03 mm in diameter) and their main role is the storage of water for plant use.

A good balance of both types of pores is very important in plant production to encourage water intake and drainage (through transmission pores) and water retention (by storage pores).

Most soils that contain a high proportion of clay (the clay loams and clays) swell on wetting and shrink on drying. Clay soils that have high sodicity and low salinity tend to swell and shrink the most. Swelling and shrinking affect soil pores in two important ways:

- the total amount of pore space filled with water increases as the soil swells, and decreases as it shrinks
- swelling changes the distribution of pore sizes — from a combination of transmission pores and storage pores to almost entirely storage pores in a fully swollen soil.

One of the effects of gypsum on clay soils is to reduce the degree of swelling, helping to preserve a favourable balance of transmission pores and storage pores.

Structural stability to wetting

There are two main types of soil structural breakdown:

- Slaking, which is the breakdown of soil aggregates in water to smaller aggregates, known as micro-aggregates. This is a rapid process that occurs mainly within the first few minutes of wetting and is promoted by low levels of organic matter.
- Dispersion, which is the breakdown of micro-aggregates in water to individual sand, silt and clay particles. This is a slower process

* Gypsum is sometimes applied to soils to correct a calcium or sulfur deficiency (see Agfacts P2.8.4 *Using sulphur on pastures* and P5.2.1 *Canola*). This use is not discussed here.

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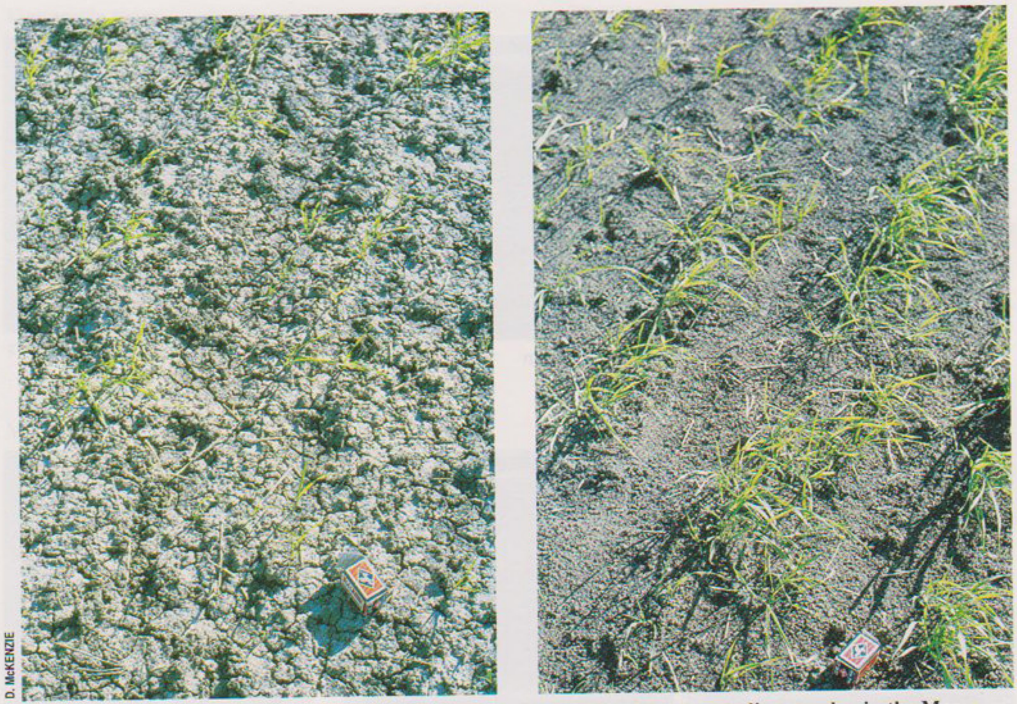

Illustration 3. The effect of gypsum on the emergence of dryland wheat on a sodic grey clay in the Moree district of NSW. The soil on the left was untreated, that on the right was treated with gypsum. The friability of the soil was greatly improved by gypsum application.

on left), and how much less boggy with gypsum (boot on right).

Also, it may be possible to use lighter machinery in some circumstances, such as a rod weeder for weed control instead of a heavy duty scarifier.

Subsoils

Many soils in NSW have sodic clay subsoils of low permeability. These soils waterlog easily after heavy rain or irrigation. Under these circumstances subsoil oxygen levels remain low for long periods during which root development is seriously restricted. Waterlogging also favours the development of root diseases, including crown rot and ***Phytophthora***, and the loss of nitrogen by denitrification.

Gypsum can improve these soils by reducing swelling and, possibly, clay dispersion. This increases permeability and reduces the time taken for the oxygen content to return to levels satisfactory for root growth. However, treatment with gypsum is rarely as successful for subsoil as it is for topsoil, because of the difficulties of applying gypsum to the subsoil (see 'Application of gypsum').

An important step in developing land for surface irrigation is landforming, which often involves cutting and filling. This reduces the depth of the topsoil in some places, frequently exposing sodic clay or bringing it closer to the surface. These cut areas are notorious for their poor production and often require gypsum, increased fertiliser application and extra organic matter to improve soil fertility.

PREDICTING SOIL RESPONSE TO GYPSUM

Soil properties

Soils that are most likely to show economic responses to gypsum application have the following features in the topsoil, subsoil or both:

- high clay content—greater than 30%, particularly greater than 40%
- high sodicity level—ESP greater than 5, particularly greater than 10
- low salinity level—electrical conductivity of a 1:5 soil:water suspension (EC 1:5) less than about 0.4 decisiemens per metre (dS/m), particularly less than about 0.2 dS/m, depending on sodicity level.

Sodicity and salinity are related: the higher the sodicity, the higher the salinity level needed to prevent dispersion. For example, a clay soil with an ESP of 8 may disperse in rainwater, and or not the soil is responsive to gypsum and, if so, what rate to use over the entire paddock.

Continued observations in subsequent years, preferably backed up by routine soil testing, will indicate when to reapply gypsum. Consult your local NSW Agriculture advisory officer or agribusiness adviser for assistance. This method is subject to seasonal and other effects (see 'Plant yield response').

CHOOSING WHICH GYPSUM TO BUY

Quality of gypsum

Gypsum quality is assessed by considering two main factors: purity and fineness.

Gypsum may contain a variety of impurities, including water, soil, limestone, sodium chloride, cadmium and fluoride. In NSW the purity of gypsum is defined in terms of percentage sulfur (S) on a wet weight basis, that is, percentage S of gypsum as supplied. Most of the gypsum sold in NSW is calcium sulfate dihydrate ($CaSO_4.2H_2O$), which has 18.6% S when completely pure.

Fineness refers to the size of the gypsum particles. It is important because it largely determines how quickly the gypsum dissolves in water. Lumpy gypsum may be unsuitable, not only because of difficulties in spreading, but also because it is very slow to dissolve.

There are two main sources of gypsum: from mining and as industrial by-products.

Mined gypsum. Mined gypsum may contain a high proportion of impurities (mainly soil) and is often quite lumpy or coarsely crystalline (see Illustration 6). Its quality can be quite variable, as the gypsum type and content change with depth in the pit. Solubility in water tends to be low (see Table 1). Mined gypsum is usually sold by volume (cubic metres). Transport can be expensive because the major deposits are in isolated locations in western NSW. However, because of its generally lower levels of cadmium and fluoride than by-product gypsum, mined gypsum is usually preferable when these impurities are of concern.

By-product gypsum. By-product gypsum comes mainly from the manufacture of concentrated phosphatic fertilisers and is often called 'phosphogypsum' (see Illustration 6). It contains a small amount (0.1–0.3%) of phosphorus as phosphoric acid and is usually sold by weight (tonnes). By-product gypsums tend to have a higher purity, and be more

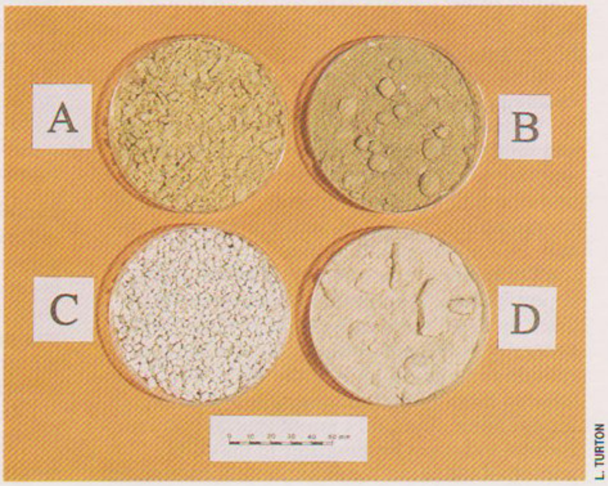

Illustration 6. Examples of mined (A and B) and by-product (C and D) gypsum products that are available in NSW.

A: mined gypsum, Bourke;

B: mined gypsum, Riverina;

C: waste plasterboard, Kurnell;

D: phosphogypsum, Newcastle.

Purity and solubility of these gypsum products are shown in Table 1.

Table 1. Purity and solubility of the gypsum products shown in Figure 6.

Gypsum product	Purity*	Solubility (dS/m)**
A (mined, Bourke)	17.1% S; 92% $CaSO_4.2H_2O$	0.4
B (mined, Riverina)	15.0% S; 81% $CaSO_4.2H_2O$	1.0
C (waste plasterboard, Kurnell)	18.3% S; 98% $CaSO_4.2H_2O$	2.1 (particle size less than 2 mm) 1.0 (particle size 2–4 mm)
D (phosphogypsum, Newcastle)	15.8% S; 85% $CaSO_4.2H_2O$	1.9

* Percentage S and percentage $CaSO_4.2H_2O$ expressed on wet weight basis (product as supplied).

** Solubility expressed as electrical conductivity of solution obtained by adding the equivalent of 10 g pure $CaSO_4.2H_2O$ to 1 L demineralised water, gently shaking (20 times end-over-end) and centrifuging for 10 minutes.

Table 2. Ratings of gypsum quality.

Purity as percentage sulfur (S) (wet weight basis) and equivalent percentage $CaSO_4.2H_2O$

S (%)	Equivalent % $CaSO_4.2H_2O$	Purity rating	Remarks
Less than 12	Less than 65	Low	Cannot be registered for sale in NSW
12.0–14.0	65–75	Medium	Mostly mined gypsums
14.1–16.0	76–86	High	Mostly by-product gypsums; some mined gypsums
16.1–18.6	87–100	Very high	Some mined and by-product gypsums

Fineness as percentage passing a 2 mm sieve

Fineness(%)	Fineness rating	Remarks
0–50	Low	Some mined gypsums
51–80	Medium	Most mined gypsums
81–100	High	Most by-product gypsums

Water content (%)

Water content (%)	Water content rating	Remarks
0–5	Low	Most mined gypsums; some by-product gypsums
6–10	Medium	Some by-product gypsums
11–15	High	Some by-product gypsums
Greater than 15	Very high	Cannot be registered for sale in NSW

Chloride content as percentage Cl (wet weight basis)

Cl (%)	Chloride rating	Remarks
0–1.2	Low	Suitable for all agricultural purposes
Greater than 1.2	High	Suitable for reclamation of saline sodic soils but not for other agricultural purposes

Table 2 gives a guide to the interpretation of figures for purity, fineness, water content and chloride content.

Choice of gypsum

In deciding what type and brand of gypsum to buy, the main points to consider are:

- the total cost of supply and application of gypsum, expressed on the basis of pure $CaSO_4.2H_2O$
- how quickly the gypsum dissolves in water
- how easily and evenly it spreads.

Cost and purity. To obtain the total cost of supply and application of gypsum per tonne of pure $CaSO_4.2H_2O$, the following information is required:

A. the cost at the farm gate of gypsum per tonne or cubic metre;

B. the cost of spreading or mixing in irrigation water per tonne or cubic metre of gypsum;

C. the purity, as percentage S (wet weight basis); and

D. if buying by volume, the density in tonnes/cubic metre of gypsum as supplied.

Then, the total cost of supply and application of gypsum per tonne of pure $CaSO_4.2H_2O$ is calculated as:

either $ $\frac{(A + B) \times 18.6^*}{C}$, if buying by weight,

or $ $\frac{(A + B) \times 18.6^*}{C \times D}$, if buying by volume.

Examples:

1. The cost of a by-product gypsum is quoted as $25.00 per tonne at the farm gate and $6.00 per tonne to spread. Its purity is 15.8% S (wet weight basis).
   The total cost of supply and application of gypsum per tonne of pure $CaSO_4.2H_2O$ =

   $ $\frac{(25 + 6) \times 18.6}{15.8}$ = $36.49.

* Pure calcium sulfate dihydrate ($CaSO_4.2H_2O$) has 18.6% S.

Please call or email ReGyp for the full NSW AgFacts article.

Note: ReGyp's screened product sizes are not reflective of the actual gypsum particle size, the solubility and particle surface area. This is because during the plasterboard process, high quality mined gypsum from South Australia is milled to a mean particle size of sub 75 micron. Example ReGyp's sub 10mm product consists of these small milled gypsum particles clumped together. Theses larger porous clumps are easily broken down in your fingers and the increased surface area of the thousands of milled gypsum particles provides the increased solubility over as mined gypsum, shown in the AgFacts document above.

The full NSW Agriculture's AgFact AC.10 (Agdex 514) document contains the following contents:

1. Soil Structure, Sodicity and gypsum,
2. How gypsum improves soil structure,
3. Predicting soil response to gypsum,
4. Choosing which gypsum to buy,
5. Application of gypsum (methods, application rates, frequency),
6. Plant yield response,
7. Gypsum compared to lime,
8. Using gypsum in rice growing soils,