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Claying to ameliorate soil water repellence

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Claying to ameliorate soil water repellence

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Claying involves adding and incorporating clay-rich subsoil into water repellent topsoil to overcome the repellence. Adding clay-rich soil provides a long-term solution to soil water repellence, and increases soil water holding capacity, reduces wind erosion risk, and may reduce frost risk.

Claying is best suited to medium to high rainfall environments in Western Australia, with higher crop and pasture yield potential.

Caution – deep cultivation can lead to wind and water erosion

Deep soil mixing using rotary spaders or large offset discs, and soil inversion with mouldboard, and one-way ploughs typically remove all soil cover and completely loosen the soil to the depth of operation. This has a high risk of wind and water erosion, especially during and after dry seasons.

How does claying work?

Claying is the process of applying and incorporating clay-rich (30 to 50% clay) subsoil to the topsoil. This can be done by spading, delving depending on depth to clay, or clay spreading.

Claying water-repellent topsoil increases the soil surface area, dilutes the hydrophobic organic matter that causes the repellence, and increases soil wettability, and evenness of wetting.

Benefits of claying

Benefits of claying include:

- improved crop and pasture establishment resulting in better groundcover
- improved pasture utilisation
- long-term (30 years or more) remedy of soil water repellence
- improved water and nutrient holding capacity in the surface soil layers
- improved soil structure
- reduced wind erosion risk
- build-up of soil organic carbon
- reduced frost risk.

Productivity responses to claying

Production increases

Effective claying can increase crop yield by 20 to 100% or more. Yield benefits can last for more than 30 years.

Production increases from claying are more likely when:

- sands are deep (>60 cm), but have reasonable plant available water holding capacity
- soils are highly repellent
- cation exchange capacity is low (<3)
- potassium is marginal or deficient (<50 parts per million).

Production problems

Claying done wrong can cause yield reductions. Poor incorporation of high rates of clay-rich subsoil is a particular concern.

Avoid these problems:

- Using the wrong clay: clay that does not slake (fall apart when in contact with water) and disperse remains in clumps, does not mix throughout the repellent topsoil, and takes longer to become effective.
- Using clay with deficiencies or toxicities: moderate to high rates of alkaline subsoil can induce micronutrient deficiencies, such as manganese deficiency, in lupins. These subsoils can also contain toxic levels of boron, salt, carbonates, and bicarbonates. The impact of these toxicities can decline over time as they leach deeper into the profile.
- Poor incorporation and too much clay, which can result in surface crusting, increased run-off, increased evaporation, poor establishment, and poor subsoil root development.
- Loaded carry graders increase subsoil compaction, which reduces crop yields. Deep ripping can treat compaction and returning to a controlled traffic farming system will limit the area of compaction.
- system will limit the area of compaction.
- Claying when other unrectified soil constraints are present will limit the size of any yield benefit.

Cost benefits of claying

Deep-ripping and spading are cheaper than delving, and delving is cheaper than excavating and spreading clay. Choice of claying method depends on the depth to clay and clay quality.

Deep-ripping costs about $60 per hectare (ha) for sandplain soils, more on heavier soil, and may require incorporation by off-set disc or one-way plough (about $25/ha).

Spading costs about $110 to 120/ha, depending on the depth (usually 30 to 40 cm). Deep-ripping and spading are often done together.

Delving costs vary considerably with the depth to clay and the depth of delving into the clay ($125 to 200/ha).

Excavation and spreading costs depend on the source of clay and the rate of spreading. Incorporation is always needed, and spading is preferred. Contract clay spreading costs in the order of $6 per ton of clay spread (quote obtained 2024) with incorporation costs in addition to this.

The financial benefits from claying depend on-site conditions. Where there is a good case for each of the claying options, costs are often recovered in 2 to 7 years.

Where to use claying

Claying can benefit sandy textured topsoils with less than 5% clay content with water repellence that regularly affects crop and pasture growth. Extensive areas on the sandplains of the south coast and the northern agricultural areas have sands with about 1% clay and 1% soil organic carbon.

Susceptible soils are pale deep sands, sandy duplex, and sandy gravel soils. In the south-west agricultural region, 3.3 million hectares of soil are at high risk of soil water repellence, with another 6.9 million hectares at moderate risk.

Alternatives to claying

Where water repellence is a problem for short periods (such as a few seasons), or on very shallow duplex soils, other options are likely to be more cost-effective. These include wetting agents, delayed seeding, increased seeding rate, soil forming, soil inversion or mixing, and change of land use to perennials.

Do you have the right clay?

Finding clay

To find the right clay to excavate and choose the method of claying, use an auger or post-hole digger to check depth to clay and collect clay samples. Clay content can be estimated using hand texturing to form a ribbon between the thumb and forefinger. A continuous unbroken soil ribbon of about 75 mm indicates a clay content around 30%.

Contractors may have ground-penetrating radar, which is useful for measuring depth of sand over contrasting layers, such as clay or gravel.

Clay quality

Always test the subsoil for claying. The subsoil should:

- contain 30 to 50% clay, WA clay soils are typically 30 to 40%
- have clay aggregates that slake or disperse in water
- be tested for pH, and be treated if highly acid or alkaline
- be tested for salt content, and be managed if very saline
- have non-toxic levels of boron or other toxic minerals.

Estimate the clay content of subsoils by field hand texturing (see the document, Estimating soil texture by hand, in the documents below), or measure via laboratory soil tests.

Slaking or dispersion can be tested by immersing subsoil aggregates in fresh water: if the aggregates slump, disintegrate, or turn the water milky around the aggregate, the clay is likely to be suitable for claying. Slaking or dispersing clays spread more easily throughout the soil while non-dispersive clays take longer to improve repellent soils.

Clay-rich subsoils usually have high potassium content, which can significantly benefit crops. Alkaline clays can inhibit lupin growth in the first year of incorporation, but typically not beyond.

How to apply clay

Apply clay by:

- excavating and spreading clay-rich subsoil: where there is 60 cm or more sand over clay – clay is excavated from a pit and spread on the water repellent soil
- lifting clay subsoil from beneath the sand using a delver: where there is 25–60 cm of sand over clay – large tynes penetrate and lift clay to the soil surface
- mixing clay subsoil with upper horizons by spading, ripping and shallow delving: where there is less than 30 cm of sand over clay – rotary spaders, some deep-rippers or shallow delving can be used to lift clay.
- On shallow sandy duplex soils where there is less than 30 cm of sand over clay, use caution when lifting clay because the benefits may not be large and there is a risk of bringing up too much clay to the surface. This could result in a hard-setting surface that restricts germination.

In general, repellent shallow sandy duplex soils will wet more quickly than deeper sands because they can more readily wet from underneath because of slow infiltration into, and perching of water on, the clay B horizon.

Excavating clay subsoil

Sources of clay-rich subsoil need to be near the site where clay will be spread – less than 1 kilometre in most cases – to reduce the high cost of transporting large volumes of clay-rich subsoil. If possible, use clay excavated from the same paddock as spreading clay.

In Western Australia, clay subsoil is typically found below a layer of sand or gravel. Remove the overburden, then excavate the clay with rippers, carry graders, bulldozers, or scrapers. Where the subsoil is in large aggregates, the clay may need to be broken up in the pit before spreading.

Options for spreading clay subsoil

Carry graders can be used to excavate the clay subsoil and spread it in strips across the paddock. These strips are then 'smudged' with iron bars to spread the clay and can be worked with tynes to breakdown clods and further spread the clay. This method can be used to spread high rates of subsoil (>150 t/ha). It is critical to spread the subsoil in an even layer across the surface.

Heavy duty multi-spreaders can spread clay subsoil that has been well broken up and does not have large aggregates. Multi spreaders tend to spread the broken-up subsoil evenly, often with multiple passes and overlap to achieve the required rate. Smudging is not needed. This method has been used to apply from 50 to 250 t/ha of subsoil.

Subsoil compaction is a risk from spreading. Where possible, avoid spreading when the subsoil is wet and more prone to compaction. Spreading with heavy graders in wet summers causes serious compaction in deep sands.

Deep ripping after claying can incorporate the clay and remove much of the compaction. Returning to a controlled traffic system maintains the benefit of ripping.

Delving clay subsoil

Clay delving involves using large delving tynes that can penetrate the subsoil clay layer and lift clay to the surface.

Delver design

Tynes can be up to 2.5 m long, 10 to 20 cm wide, and are typically 80 to 100 cm apart.

Because of their large size and operating depth, delvers typically only have 2 tynes, spaced 1.8 to 2 m apart, and are run with a half overlap to achieve a delving spacing of about 1 m.

Delvers are pulled with tractors with 400 horsepower or more. Tracked machines are preferred because they have better traction.

Typically, the tynes operate at an angle of 45 degrees. The optimal design is wider at the tip and becomes narrower towards the top, which helps the 'blocks' of clay subsoil, which may be sticky, come off the tynes as they reach the surface. A shallow concave shape or raised edges on the face of the tyne helps hold the clay on the tyne so it can be lifted to the soil surface.

Delving has several advantages:

- It is cheaper than subsoil spreading and uses the in-situ clay-rich subsoil.
- Delvers have a deep-ripping effect, creating loose pathways for rapid root growth.
- Sand falling into the clay B-horizon rip lines can increase rooting depth.
- Applying gypsum behind the delving tynes improves the structure and root access of sodic subsoils.

Problems with delving include:

- Depth to clay and therefore rate of clay lifted varies across a paddock. In areas where insufficient clay is brought to the surface, there may be a deep-ripping benefit, but this will not be as long lasting as claying benefits.
- The soil can be left very soft, rough, and difficult to traffic and maintain an even seeding depth. The incorporation process will help level the soil, and rolling or working along controlled traffic lines can help with trafficability.
- It can be difficult to break up, spread, and mix the large clods of clay brought to the surface. Rotary spaders effectively break up clods, otherwise smudge bars, cultivators, rollers, heavy harrows, or prickle chains can be used.

Incorporating clay subsoil

Achieving effective incorporation is critical for successful claying. Poorly incorporated clay can ultimately hinder crop establishment and limit crop productivity by increasing the risk of haying off. The type and extent of incorporation required depends on the amount of clay-rich subsoil that has been spread on the soil, the existing clay content of the topsoil, and the depth of repellent topsoil.

Traditionally, incorporation has been undertaken with offset discs and tyned implements, such as scarifiers, cultivators, or heavy harrows. These are adequate for rates of clay less than 150 t/ha and for shallow incorporation but are inadequate for rates of subsoil application of 250 t/ha or more, and for deep incorporation. Rotary hoes and rotary spaders are more suited to incorporate higher rates of applied subsoil, as illustrated in Table 2.

Rotary spaders can effectively incorporate clay to depths of 25 to 30 cm. This depth may be excessive for clay applied at lower rates because the clay concentration at the surface may become too diluted and not fully effective at overcoming soil water repellence.

Table 2 Suggested equipment and incorporation depths for different rates of applied clay-rich subsoil

Application rate of clay-rich subsoil	Suitable incorporation equipment	Incorporation depth
150 t/ha or less	Offset discs, tyned cultivator with wide shares, one-way plough	10 to 15 cm
150 to 250 t/ha	Rotary hoe, disc plough with large discs (such as the Plozza plough), rotary spader	15 to 20 cm
More than 250 t/ha	Rotary spader	20 to 30 cm

Incorporation effects

Table 3 shows the effect on surface clay content of adding various rates of subsoil with 30% clay content to a water repellent sand with a bulk density of 1.45–1.60 tonnes per cubic metre (t/m^3), a clay content of 1%, and soil organic carbon of less than 1%. This is for a non-gravelly soil and assumes the subsoil is evenly mixed to the incorporation depth. Mixing evenly in the first year is not practical. The target clay content is at least 3%.

Table 3: The surface clay concentration after adding subsoil of 30% clay content to a water repellent sand with a bulk density of 1.45 to 1.60 t/m^3 and a clay content of 1%

Depth of incorporation	Subsoil application rate			
	150 t/ha	200 t/ha	250 t/ha	500 t/ha
10 cm	3.72	4.52	5.26	8.44
15 cm	2.81	3.37	3.90	6.27
20 cm	2.36	2.78	3.20	5.08
25 cm	2.09	2.43	2.77	4.33
30 cm	1.91	2.20	2.48	3.82

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Related content

Refer to the department website at dpird.wa.gov.au for mor information about the following:

- Soil water repellence
- Rotary spading and deep cultivation to ameliorate soil water repellence
- Soil inversion to ameliorate soil water repellence
- Developing a controlled traffic (tramline) farming system
- Estimating soil texture by hand - Factsheet

Other resources

Managing south coast sandplain soils to yield potential (dpird.wa.gov.au)

Claying and deep-ripping can increase crop yields and profits, by D. J. M. Hall, H. R. Jones, W. L. Crabtree, and T. L. Daniels (2010) Australian Journal of Soil Research | CSIRO (csiro.au)

Longer term effects of spading, mouldboard ploughing and claying on the south coast of WA, by David Hall, Tom Edwards, Stephen Davies, Richard Bell, Imma Farre, Liz Petersen and David Dodge (2018) GRDC Updates 2018 | Grains Research and Development Corporation (grdc.com.au)

Combatting non wetting soils - GRDC | Grains Research and Development Corporation (grdc.com.au)

Video – Claying delivers better crop emergence and weed control | Grains Research and Development Corporation (grdc.com.au)

Video – Clay spreading research and farmer comments in the West Midlands of WA | Grains Research and Development Corporation (grdc.com.au)

Video – Clay spreading, Graham White, Badgingarra, WA | Grains Research and Development Corporation (grdc.com.au)

Video – Overcoming production constraints through clay spreading and delving | AgExcellence Alliance (agex.org.au)

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