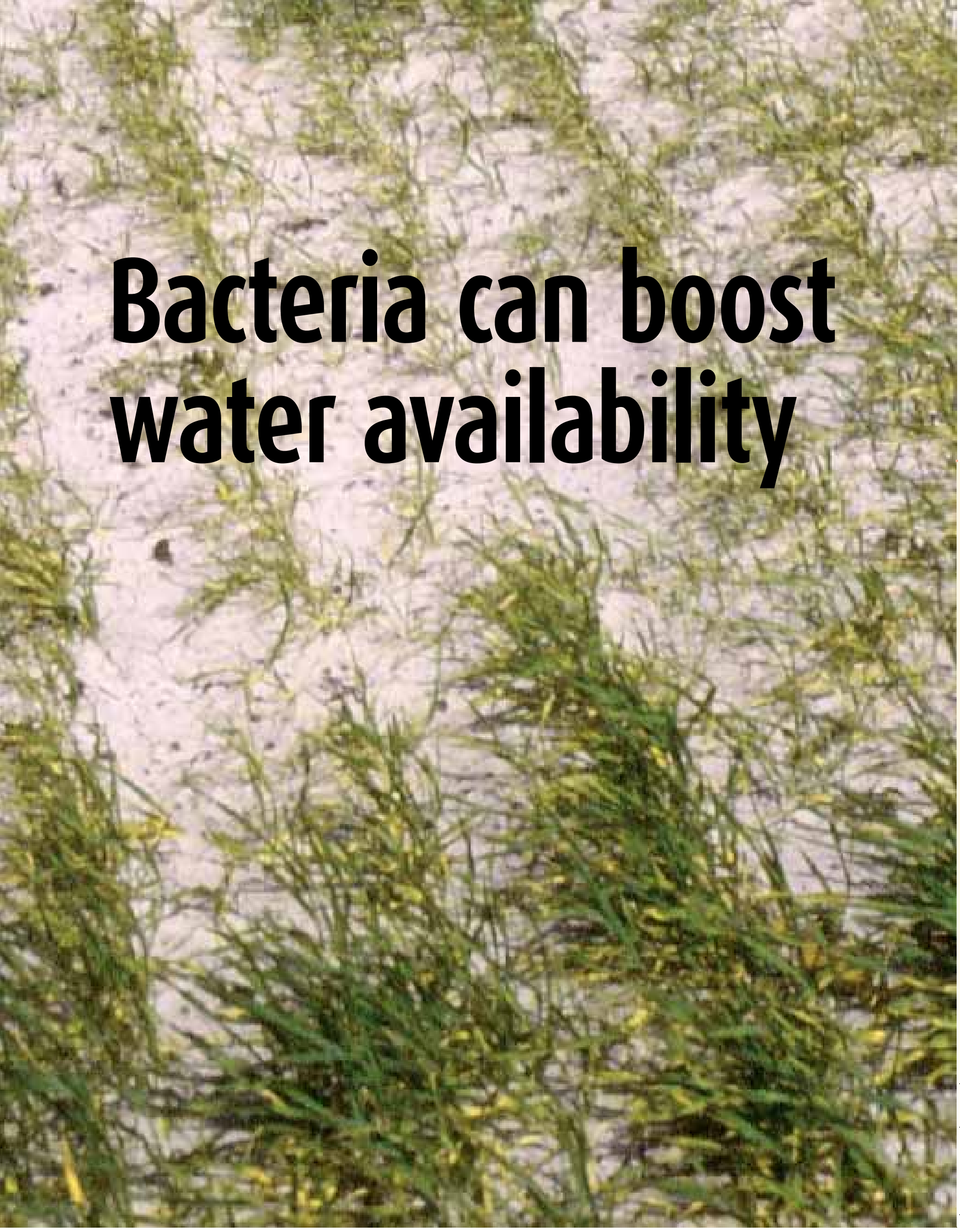
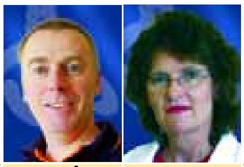


Bacteria can boost water availability



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Water-repellent sandy soils pose major problems for many farmers because they hinder water infiltration into the soil, resulting in uneven and delayed crop germination and lower yields. But CSIRO trials show soil wettability can be increased by inoculating water-repellent soils with certain bacteria or simply applying lime, which helps stimulate naturally occurring bacteria in the soil that can reduce water repellency.

Photos: CSIRO Plant Industry

Poor growth: *Water cannot infiltrate sandy soils when they develop a waxy, hydrophobic skin around individual sand grains. The result is poor plant growth due to limited water.*

At a glance

- Water repellency is caused by the formation around sand grains of skins of hydrophobic substances derived from plant waxes and other products from the natural process of plant biodegradation.
- The problem of water-repellent soils affects about five million hectares of farmland in Australia and causes annual production losses of more than $100 million.
- Some naturally occurring bacteria that decompose organic matter also can help break down the wax barriers that form on some soil particles.
- Adding lime to water-repellent soils can help stimulate these bacteria and improve the wettability of soils.

Farmers in Australia's western and southern grain-growing belt where water-repellent sandy soils occur can use lime to help boost water availability and improve crop yields and pasture production.

Lime increases initial water infiltration by creating a moister, more favourable environment for certain bacteria to grow.

This was one of the key findings of a CSIRO Plant Industry study that examined the potential of bioremediation using wax-degrading bacteria to alleviate water repellency.

Water-repellent soils

Soil water repellency (also known as soil hydrophobicity) occurs when hydrophobic 'skins' made from plant waxes and other products from the natural process of plant biodegradation form around individual sand grains.

The skins effectively repel the water from the soil and limit water availability to the crop or pasture.

Water then pools on top of the soil without soaking in and evaporates, runs off the surface (sometimes causing soil erosion) or moves down 'preferred pathways', leaving large amounts of soil dry.

Reduced crop yields

The uneven infiltration of water into the soil can reduce crop and pasture yields through uneven and delayed germination, poor stand establishment and the increased risk of wind and water erosion.

Plants need water to infiltrate the soil surface and then for it to be held in the soil profile for use when needed.

Water-repellent soils pose a very significant problem, with more than five million hectares of farmland affected and annual crop and pasture losses estimated at more than $100 million.

Beneficial bacteria

CSIRO researchers have found certain bacteria belonging to the actinomycetes group can help break down the hydrophobic skins or wax barriers that form on some soil particles.

Actinomycetes are a common form of soil bacteria that decompose organic matter and return important nutrients to the soil. They are known for their ability to metabolise a wide range of organic compounds as sole carbon sources for energy and growth.

The types involved in breaking down wax barriers are from the *Rhodococcus* and *Mycobacterium* species. These actinomycetes were found in all soils tested but they needed a moist environment to be effective.

Researchers have found certain bacteria can break down the wax barriers that form on some soil particles.

Boosting actinomycete levels

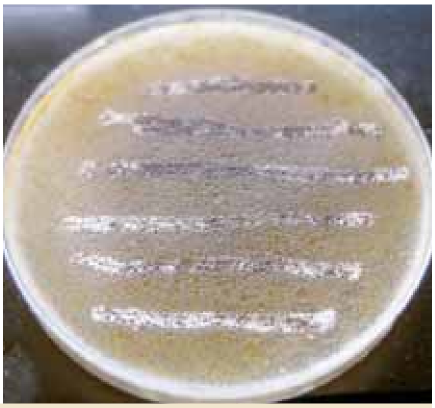
To activate the actinomycetes, researchers investigated two options — inoculation of water-repellent soils with wax-degrading bacteria and the use of management practices.

Inoculation was successful, especially with the *Rhodococcus* species but the improvements in wettability, although statistically relevant, were small.

Other options

The research team also tried adding lime. By applying lime, the soil can become wet enough to stimulate the actinomycetes that can then start to reduce water repellency and increase soil water storage. The calcium in lime is also needed for the structural development of actinomycetes.

Wetting agents (surfactants) also can be used effectively to increase water infiltration but they are more expensive and less likely to be readily available and suitable for farmers. Their use is limited largely to turf grass, although increases in barley and lupin yields have been achieved when wetting agents were applied as a band in furrows above the seed.



Beneficial bacteria: *Wax-degrading bacteria growing on an agar plate with wax as the only carbon source. Applying lime to water-repellent soils can help increase the population of these bacteria in the soil.*

The clay mineral kaolinite has successfully ameliorated water repellency but large amounts (about 100 tonnes per hectare) are required, making this option economic only if clay occurs on site.

Paddock trials established

Laboratory experiments showed there was potential for remediation of water-repellent soils by inoculation with wax-degrading bacteria.

In paddock trials water repellency was monitored in sandy soils inoculated with a range of wax-degrading bacteria both individually and in mixtures.

Two levels of lime were superimposed to determine 'inoculant by lime' interactions.

Measuring water repellency

The water repellency of the soils was measured using the molarity of ethanol drop (MED) test (also known as the percentage ethanol or critical surface tension test).

This method gauges a soil's 'wettability' in the first moment of contact with the liquid. Drops with an increasing concentration of ethanol are applied to the soil to measure surface tension indirectly, effectively determining how strongly the water is repelled.

Using this method, soils range from wettable (a MED of 0) to extremely water-repellent (a MED of 4).

A soil that is moist on collection can be potentially water-repellent if after drying it resists water infiltration and has a positive MED.

Small-scale inoculation

A small-scale paddock trial was established at Anketell, Western Australia, to test the effect of inoculation of wax-degrading bacteria on the water repellency of sandy soils. The soil was a water-repellent, deep white sand, coloured grey at the surface due to organic matter. It had a pH of 4.8.

Metal boxes (500 millimetres square and 120mm deep) were inserted into the soil so about 20mm remained above-ground.

Seven cultures were used: one each of *Roseomonas*; *Streptomyces*; *Mycobacterium*; *Nocardia*; and three of *Rhodococcus* (66b, 73a and 83a). Samples were collected either fortnightly or monthly after inoculation (12 soil cores each 25mm wide and 50mm deep).

Three months later another soil core was taken to assess the recovery of the inoculants — of the seven only *Nocardia* was not present.

Irrigation used

The site was spray irrigated: about 14mm per day was applied during summer and reduced during winter to supplement rainfall.

Measurements indicated a significant inoculant effect.

Of the seven inoculants only two resulted in significant reductions in water repellency (*Rhodococcus* 66b and *Roseomonas*) without any additional

Big problem: *Water-repellent sandy soils are a major problem across the western and southern grain growing areas of Australia but if the number of beneficial bacteria in these soils can be increased, water repellency can be reduced.*

Reducing repellency: *Applying lime to water-repellent sandy soils can stimulate naturally occurring bacteria in the soil that can reduce water repellency.*

Wasted water: *Water lies on the surface of the soil following heavy rain. Dry soil can be seen moving under wind erosion in the background.*

nutrients or soil conditioners, compared with the non-inoculated control.

Large-scale inoculation

A large-scale evaluation of inoculation of wax-degrading bacteria was held near Woogenellup, WA.

Soil at the site was a shallow, bleached sand, underlain by ironstone gravel within 100mm of the surface. It had a pH of 5.2 and was very repellent (average 3.9). Before the trial the site was sown with the annual forage legume serradella (*Ornithopus sativus*, Cadiz variety).

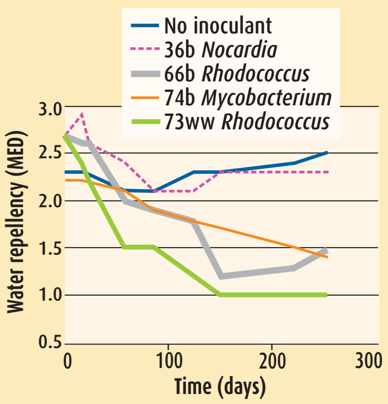
Compost, fertiliser applied

Before inoculation, a premium compost and mineral fertiliser were applied to support inoculants in the nutrient-poor sands.

To raise the calcium content, agricultural lime was applied at one tonne per hectare to half the plots.

Six cultures of actinomycetes, five of *Rhodococcus* (66b, 73a, 73ww, 83ww1, 85b) and one of *Mycobacterium* were inoculated individually or in a mixture to the soil.

FIGURE 1 Effect of inoculation*



* Effect of inoculation of water repellent soil with individual cultures of wax-degrading bacteria in the laboratory.

Source: CSIRO Plant Industry. Illustration: Kondinin Group.

Only two inoculants (*Rhodococcus* 73ww and 83ww1) were detected in soil samples six months after inoculation.

Only one inoculant boosted soil wettability and reduced water repellency without lime.

Lime reduces repellency

Applying lime to half the plots raised the pH and calcium content of the soil to favour actinomycetes.

This produced significant 'inoculant by lime' interaction and resulted in significant reductions in water repellency with all limed treatments containing five individual inoculants of *Rhodococcus* (73ww, 66b, 73a, 83ww1 and 85b) and a mixture containing the five cultures of *Rhodococcus* and one of *Mycobacterium*.

Only *Mycobacterium* significantly improved soil wettability and reduced water repellency without lime.

Although applied at a very low rate there was a significant difference between limed and un-limed soils — lime application alone significantly reduced water repellency in the un-inoculated control.

This supported previous results, which showed that compared with untreated soils, applying lime resulted in a more rapid and sustained decline in water repellency following the start of winter rainfalls after the dry summer and an increase in populations of naturally occurring wax-degrading bacteria.

Results consistent

The results of the paddock trials were consistent with those of the laboratory experiments but the benefits in the paddock were much less than observed in the laboratory (see Figure 1).

In the laboratory, inoculation of water-repellent soils by two cultures of *Rhodococcus* and one of *Mycobacterium* reduced repellency significantly.

In paddock trials, inoculation reduced water repellency at two separate sites. *Rhodococcus* species were the most successful inoculants overall and when their numbers were monitored, these organisms were the longest surviving inoculants in the soil.

But under paddock conditions inoculants introduced to bulk soil are subject to wetting and drying, large fluctuations in temperature and competition from existing microbial populations.

Although statistically significant, improvements in wettability in the paddock trials were relatively small compared with the laboratory and the costs of production and application of inoculant would outweigh the benefits.

Better results might have been achieved at the Woogenellup site had the soils been inoculated earlier at the time of the first rainfalls after the dry summer.

Repeated inoculation on an annual basis might also provide further benefits.

Improving water infiltration

Paddock trials in south-western Australia confirmed lime could improve water infiltration into soil.

Where lime was applied there were up to 10 times as many actinomycetes than in untreated soil. This resulted in a significant and substantial reduction in water repellency for at least four years.

Researchers used a range of concentrations of lime up to 15t/ha but smaller amounts of 3–5t/ha can increase populations of naturally occurring wax-degrading bacteria and reduce water repellency significantly.

Under dryland conditions lime interacted favourably with inoculation and increased soil wettability. This increased with the amount of lime applied.

Lime is cheap and easy to apply and has the added benefit of raising low soil pH to levels that favour other soil micro-organisms also important for soil health and plant growth.

Acknowledgements: Grains Research and Development Corporation; Anne McMurdo and Cindy Myers, CSIRO; Grant and Helen Cooper, Woogenellup, WA; and Doug and Debbie Lievense, Anketell, WA.

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