Soil Water Repellency

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What is it?

A water-repellent soil (or hydrophobic soil) does not wet up spontaneously when a drop of water is placed upon the surface. It is common to see water pooling on the surface of dry soil rather than wetting it up. In turf, this translates into "dry patches" or localised dry spots—irregular shaped areas where the grass or other plants suffer from drought because the repellent soil below does not wet up uniformly following rain or irrigation. Much of the affected area remains dry between the "fingers" of higher infiltration.

If you think you have this problem then you are not alone. A recent survey of the Golf Course Superintendents Association of America found that 98% of golf course superintendents are using ameliorants for this problem. Papers addressing this issue in relation to turf health have been found from Australia (W.A., S.A. and Q'ld), the Netherlands, the United States and New Zealand.

Some notable quotes follow:

"It appears that water repellency is the norm rather than the exception, with the degree of water repellency variable." Wallis, M.G., Scotter, D.R. and Horne D.J. 1991.

"… water repellency is plant induced, and therefore probably more the rule than the exception in most field soils." Coen J. Ritsema 1996.

What causes it?

Soil water repellency is caused through the production of complex organic acids during the decomposition of organic matter. These complex organic acids are wax-like substances that form a coating over particles of soil.

Researchers claim that coarse textured sandy soils are more likely to become repellent as they have a relatively low surface area compared to finer materials. However, certain clay soils have been found to become repellent as the coatings have formed on aggregates of fine material.

The physical properties of water can be explained by the combination of two forces creating surface tension. Water has strong cohesive forces (attraction of water molecules to themselves) helping to hold water drops intact. It also has adhesive forces (attraction of water molecules to other substances) which cause the water to spread out and cling to other surfaces such as soil particles. The compounds causing repellency in soil are polar compounds with hydrophobic (water repellent) and hydrophilic (water attractant) ends. During dehydration the shape of the compound changes, so that the hydrophobic surface is exposed to the air/water in soil pores.

This then creates a hydrophobic layer preventing the spread of water over the soil particles.

When soil moisture is above a critical value (which is different for every soil), the water repellency effect is temporarily eliminated. When it falls below this critical value, the soil returns to a hydrophobic condition. The time taken for water to infiltrate increases for repellent soils. It takes as little as 3 to 6 % hydrophobic materials in the soil matrix to cause non-wetting problems.

What are the consequences?

- ***Drainage and leaching of nutrients***

Areas of weakness in the water repellent layer allows water to enter the soil in discreet areas or "fingers" forming zones of preferential flow. Preferential pathways through the soil, being small in area, lead to water infiltration deeper into the soil profile. Depending on the intensity of the rainfall or irrigation event, there is a potential for flow beyond the root zone. Water draining below the root zone is lost to the plant and could be considered wastage. Not only is water wasted, but any soluble fertilisers in the soil will also be carried out of the range of plant accessibility. Vertical solute leaching is approximately three times greater in "fingers".

- ***Runoff***

On sloping sites surface water runs off. There is also a loss of nutrients and,potentially sediments, which may end up in surface streams and water ways with the potential to cause significant pollution. Nutrient and sediment losses are enhanced during summer storm events.

- ***Uneven distribution of applied chemicals***

This can include soluble fertilisers or the various pesticides, which again leads to non-uniformity in turf quality.

- ***Overall symptoms observed in turf = Localised Dry Spot (LDS)***

These are localised areas where the turf is experiencing water and nutrient stress . They appear as spots of varying size and shape where turf is wilted and/or brown. This equates to non-uniform turf of poor quality. It is more severe in summer when moisture stresses are more prevalent due to rapid drying of the soil profile.

The bottom line is that there are losses of water and nutrients which are economically wasteful and result in environmental degradation.

Are there preventative measures we can take?

No, not really! It is a consequence of the decomposition of organic materials, which are an essential component of a healthy soil. To entirely remove them from the system would not be good, however in a USGA or California green it is essential to control organic matter build up for reasons of maintaining adequate infiltration and drainage.

What treatment options do we have?

FIRST AND FOREMOST <u>- IDENTIFY THE PROBLEM!</u>

LDS is the symptom of a number of stresses such as soluble salts, fungal diseases, insect attack and uneven irrigation. Application of surfactants to non-hydrophobic soils does not increase infiltration.

Water repellency is identified through a simple water drop penetration test. This involves taking a profile core (about 1.5 – 2 cm diameter is sufficient) and allowing it to dry naturally for 1-2 weeks. A drop of water placed on the soil close to the thatch layer should be taken up by the soil in under 5 seconds in a non-hydrophobic soil. Use Table 1 as a guide. Check the level of repellency along the length of the core. This will provide an indication of the depth of water repellency and aid in the choice of treatment options. If only the thatch or soil-thatch interface is repellent, then management options that control the quantity of thatch may be all that is required. If the repellency continues into soil layers, then a surfactant will be needed.

Table 1. Level of severity of water repellency based on water drop penetration test results.

Water drop penetration time	Severity
< 5 seconds	No problems with water repellency
5 seconds–1 minute	Slightly repellent—treatment will help improve uniformity
1–10 minutes	Repellent—treatment required
> 10 minutes	Severely repellent—treatment essential

Management practices

There are several management options that provide a means of protecting turf from the effects of localised dry spot. These include:

- Raising the cutting height for mowing so that plants have greater top growth to enable root growth. Roots can then access water from deeper in the soil profile. However, the water repellency still remains, so the problem of leaching/runoff still exists.
- Removal or alteration of the coating—this requires large volumes of water and there is a question as to where the hydrophobic compounds end up.
- Increase the surface area of the soil by the addition of fine materials such as clays. This is not an option on most sandy sites, as it causes the bridging of particles and reduces infiltration significantly. Dispersible sodic clays (1:2 type clays) have been found to be more effective than Ca saturated clays. However, sodic clays have very poor structure so I wouldn't recommend this practise.
- Biostimulants. There is some discussion on the use of biostimulants. These materials DO NOT affect the water repellency of the soil particles. The value may be in their action of enhancing root growth so that the plant can take up water from deeper in the profile. BUT, where the soil is hydrophobic, it is doubtful that the water can actually enter the soil to be stored deeper in the profile.
- The introduction of commercial mixes of microbes has been suggested. This is generally not appropriate as the repellent compound is a product of organic matter breakdown. There is no evidence that 'new' microbes will further breakdown these materials.
- Some anecdotal stories claim that the application of fungicides has reduced LDS. I would suggest that fungicides are actually acting against fungi whose symptoms match those of soil water repellancy. Fungi such as fairy rings can cause water repellency due to organic matter breakdown. In these situations it is important to treat with a fungicide **and** follow up with a treatment against water repellency.

Where the turf growth and quality is poor due to water repellency causing insufficient storage of water in the soil it is better to treat the cause and not the symptom.

- The overall goal then is to maximise input effectiveness in terms of irrigation or precipitation and minimise output losses through transpiration, evaporation, runoff, leaching and drainage.

- In practice, water repellency in higher profile turf sites is usually managed by periodically applying surfactants to the affected areas to improve water penetration. Surfactants, literally, are surface active agents (SURFace ACTive AgeNTS).

Are all surfactants the same? No!

Types of surfactants

- **Anionic Surfactants**

Anionic surfactants are negatively charged compounds which can have a deleterious impact on soil structure and are often harmful to plants (phytotoxic). These compounds are not used to manage soil water repellency.

- **Cationic Surfactants**

Cationic surfactants are positively charged and strongly adsorb to soil particles and have the potential to render soil particles water repellent. These compounds are biocides and are **not** used to manage soil water repellency.

- **Amphoteric Surfactants**

May be + or – charged. Not commonly used in agriculture.

- **Non-ionic surfactant**

Non-ionic surfactants, as the name suggests, have no net charge although they are polar molecules. They generally have a low phytotoxicity and are the major class of surfactants used in soil applications.

They are detergent-like substances that reduce the surface tension of water allowing it to penetrate and wet the soil more easily. These compounds allow the water to ‘spread out’ by weakening the cohesive forces allowing adhesion to occur. The chemical make-up of these materials is ethylene oxide and propylene oxide units known as EO/PO block copolymers. These are essentially long chain polymers of varying complexity with a hydrophilic end and a hydrophobic end. The hydrophobic end binds to the coating on the soil particle while the hydrophilic end extends into the pore space allowing water to adhere to it.

- **Lubricants**

These are considered the ‘new generation’ in soil wetting agents. These materials contain several types of poly-oxyalkylene glycols. They tend to be more short lived and are less phytotoxic than EO/PO block copolymers and generally have good soil wetting properties.

- **Granular soil wetting agents**

These are some inert clay or organic material impregnated with surfactant. The type of surfactant varies with each product. The advantage of these is that they are easy to apply and have a low burn potential. Conversely they are generally expensive in terms of the quantity of surfactant applied per square metre of turf. The evenness of application is crucial to their effectiveness.

- **Synergistic compounds**

There is evidence to suggest that a combination of non-ionic surfactants and lubricants creates a response that is greater than the sum of the two. Materials are appearing on the market that are extremely effective in overcoming soil water repellency and improving soil water infiltration.

- **Environmentally friendly soil wetting agents:**

These are generally non-phenol types that are highly degradable. They are short lived in the soil.

- **Soil Humectants**

Soil humectants are compounds that attract and retain moisture. Skin moisturisers are based on the chemistry of these products as they attract water vapour back to the skin. They are large complex molecules that have many sites for water molecule attraction. Their large size, however, limits their transport in the soil. They tend to concentrate near the surface of the profile. They do have surfactant properties, but not to the same degree as true surfactants. Their burn potential is also very low.

- **Organic acid solubilising compounds**

These materials claim to dissolve and remove the hydrophobic compounds. The number of different compounds that these materials can remove is yet to be verified with adequate independent research.

How do we apply these materials?

Treat the ENTIRE area to create a more uniform infiltration pattern.
When irrigating after treatment, apply a sufficient quantity of water to wet the entire hydrophobic zone, not just the surface layer.
READ THE LABEL.
Avoid phytotoxicity by only applying surfactants at the recommended rate. Do not use higher rates in the hope of increasing the efficacy.
Some treatments may require irrigation after being applied to wash the compound off the leaves and prevent a phytotoxic response.
Ensure the treatment can actually penetrate the thatch layer—control the thatch through core aeration to 3 inches.
Injection systems may be useful for delivering surfactants to the root zone; particularly where the water drop penetration tests indicate that water repellency is occurring deeper in the soil profile.

What are the advantages in using soil surfactants?

- Turfgrass managers report an increase in moisture retention as a result of using surfactants. This may be due to the compound allowing wetting of finer pores which were previously "blocked" by hydrophobic substances.
- Irrigation efficiency is maximised.
- Output losses are minimised.
- Better uniformity and overall turf quality.

Acknowledgements

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References and further reading

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