CISTERN

SOIL SURFACTANT AND HUMECTANT COMPLEX

TECHNICAL INFORMATION BULLETIN

CISTERN is a novel soil amendment containing multi-functional soil surfactants and humectants that have been carefully "tuned" so their components work together to enhance plant tolerance to water deficit and heat stress by correcting hydrophobic conditions in the subsurface layers of the soil profile as well as by improving moisture retention and reducing the loss of water due to evaporation and drainage.

Water Deficit Stress

Even when grown in moist soil, plants may experience daily periods of water deficit. Water deficit is a normal phenomenon that occurs in plants during the daytime when loss of water from the leaves exceeds water uptake in the roots. This deficit is normally made up through irrigation, at night and during periods of rain and dew formation.

Under high transpirational demand (such as occurs in midsummer), daytime wilting occurs when roots are incapable of drawing enough water from the soil to replace daytime water loss. This can also happen if the plant's roots are not physically capable of reaching sources of water, when water is unavailable or when water is diverted from roots due to non-uniform movement of water through the rootzone (preferential flow).

Plant Available Water (PAW) is the amount of water held in a soil between the limits of Field Capacity and Permanent Wilting Point. However, only the water near to Field Capacity may be Readily Available Water (RAW).

As soils dry out water molecules near the surface of soil particles are so tightly bound to the particles that they are unavailable to plants. Water molecules that are often found in soil air spaces between soil particles are also considered unavailable for root absorption.

Soil water repellency can also reduce plant available water because water cannot be captured or stored in hydrophobic (water repellent) areas of the soil profile.

Water stress is characterized by the reduction of water content, turgor, total water potential, wilting and closure of stomata. Under extreme water deficit stress, one can expect an inhibition of various physiological and biochemical processes such as:

- Photosynthesis
- Respiration
- Metabolic activities
- Carbohydrate production
- Chlorophyll production
- Hormonal activity
- Cell production and growth

Whether you want to minimize water deficit stress, reduce your water consumption, increase watering intervals or optimize the efficiency of your plant production, it is imperative to properly manage subsoil moisture levels. This requires a program addresses the issues of soil water repellency and rootzone loss of moisture due to evaporation.

Soil Water Repellency

Humic Substances

The build-up of water repellent, non-polar organic coatings on mineral surfaces in the upper root zone has been identified by the general scientific community as the primary cause of soil hydrophobicity.

Many scientists point to humic substances as an example of organic polymer materials that will adopt conformational changes in order to facilitate their adsorption to the soil particle interface and ultimately form non-polar (water repellent) films. As a result, the surface of the soil particle surface can quickly be covered with adjoining sequences of these adsorbed, non-polar polymer chains.

Wet / Dry Cycles

Initially, very few sites on the humic substance polymer chain bind the molecule to the particle surface. However, if the system is allowed to dehydrate, such as occurs during cyclic wet/dry periods of irrigation, the humic substance's molecular structure collapses and flattens on the sand particle surface as oxygen and hydrogen atoms are removed from binding sites.

The dehydration process also causes polar sites at the humic substance water interface to lose their negative "charge" as hydrogen and oxygen are removed from the surface of the humic substance molecule.

As the dehydration process continues, non-polar sites on the humic substances surface increase and spaces between the layered humic substrates compress – rendering early stage films and later stage polymer layers of humic substances to become water repellent.

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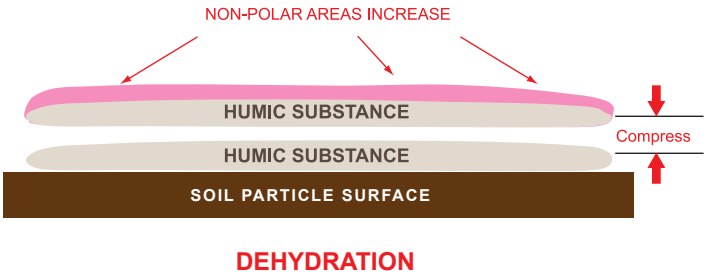
If water repellent conditions exist below the soil surface, non-polar surfaces will prevent adhesion, disrupt the wetting front, weaken capillarity and cause incomplete soil wetting and preferential flow. This ultimately can result in the reduction of plant available water (PAW) and contribute to poor distribution of water, fertilizer, pesticides, and other important amendments required to develop healthy plant growth conditions.



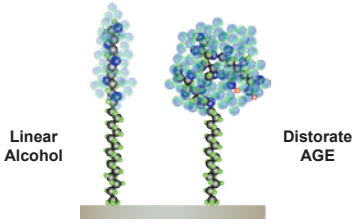
CISTERN Technology

Unlike many humectant products that utilize single surfactant technology or contain simple mixtures of different surfactants (polyblends), the development of CISTERN Soil Surfactant and Humectant Complex is driven by advances in surfactant and formulation technologies that offer superior product performance through the use of blends that contain new, highly effective chemistries that can be "tuned" to take advantage of their unique patterns of self-assembly and compatibility with other formulation components.

Disotrate AGE

The construction of the CISTERN Soil Surfactant and Humectant Complex formulation consists of two very different, high performance surfactant chemistries. The first constituent of CISTERN is **Disotrate AGE**, a new class of alkylpolyglucoside ester surfactants derived from natural, renewable raw materials.

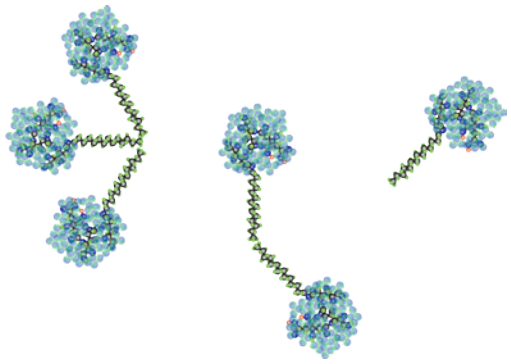
This new generation of sugar-based surfactants exhibits an improved hydration profile (head); better wetting and surface tension reduction properties; imparts electrolyte and hard water tolerance; and is readily or inherently biodegradable.



Graphic depiction of hydrated linear alcohol surfactant and the new generation Disotrate AGE alkylpolyglucoside ester surfactant. Note the larger, Improved hydration profile of the Disotrate AGE surfactant.

Depending on its concentration in water, the Disotrate AGE surfactant chemistry is quite capable of dynamically reconfiguring its molecular arrangement between its non-aggregated state (linear arrangement) and a complex aggregated state (micelle arrangement).

At low concentrations, such as found in irrigation water treated with CISTERN, Disotrate AGE surfactants usually exist as monomers and very small aggregates (dimers and trimers) at the soil interfaces.

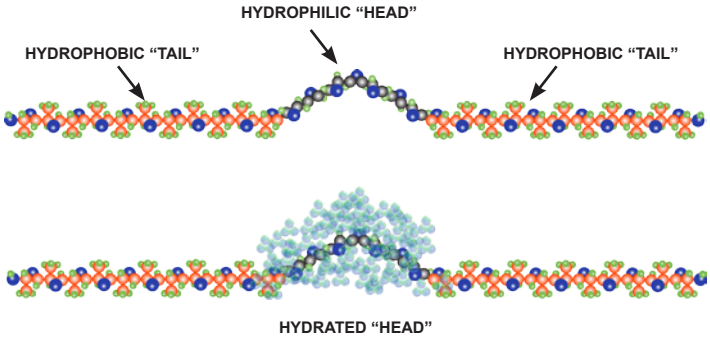


Examples of various self-assembly configurations of Disotrate AGE surfactant under low concentrations at soil interfaces.

Tri-Block Copolymer

The second constituent in the CISTERN surfactant blend is a tri-block copolymer. It was chosen for its exceptional ability to establish or restore adhesion sites (negative sites) on water repellent surfaces. In addition, this tri-block copolymer is proven to promote uniform vertical and lateral movement of water and solutes into and through the soil profile.

While the tri-block surfactant component used in the CISTERN surfactant blend is not capable of self-assembly into micelles, it does self-assemble into configurations that contain multiple non-polar attachment sites.



Graphic of tri-block surfactant used in CISTERN formulation.

The tri-block surfactant in the CISTERN formulation is capable of forming unique polymer networks that can attach to Disotrate monomers or micelles via non-polar attachment mechanisms. For this reason, as a co-surfactant, it can be used to promote networks assemblies of surfactant constructions and multiple anchor states for itself as well as its Disotrate AGE co-surfactant (in monomer or micelle configurations).

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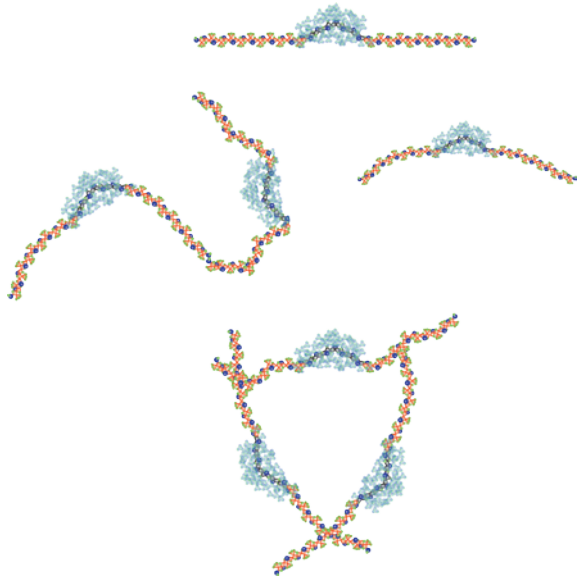


Examples of various self-assembly configurations of tri-block surfactant found in CISTERN surfactant complex.

Humectant and Hygroscopic Components

The CISTERN formulation also contains a mixture of hydrophilic humectants and hygroscopic compounds that in combination with CISTERN's blend of surfactants, will enhance rootzone hydration characteristics and plant tolerance to water deficit stress and drought conditions. These humectants molecules attract water molecules from air spaces within the soil profile and when required by the plant, make these water molecules "available" for uptake by the plant root system.

Because plants are able to obtain water that was previously unavailable, golf course superintendents and production managers should experience improved rootzone moisture conditions and improved water conservation.

The humectants and hygroscopic compound complex in the CISTERN formulation works in concert with CISTERN's surfactants to provide a comprehensive approach to dealing with plants suffering from heat or water deficit stress conditions caused by water loss due to soil hydrophobicity, runoff or evaporation.

Since moisture retention is improved with the application of CISTERN, one should observe improvements in irrigation efficiency, uniformity and the retardation of water repellency.

Mode-of-Action

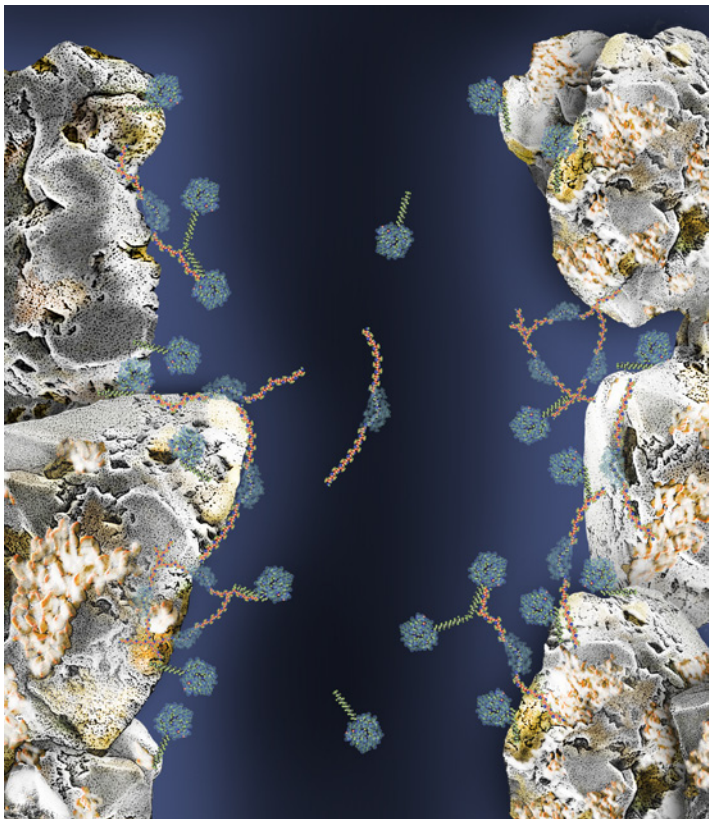
Penetration, Hydration & Uniform Movement of Water

Penetration of water, hydration of soil surfaces and uniform movement of water are usually governed by two forces: gravity and capillary action). Capillary forces are the combination of adhesive and cohesive forces that hold films of water around soil particles. Capillarity is the primary force that enables the soil to retain water, as well as to regulate its movement. It holds water in the soil profile against the force of gravity.

When soil profiles become hydrophobic, the storage and retention of water by soils is interrupted because the attractive forces between the solid and liquid phases is weak or non-existent.

As CISTERN-treated water penetrate into sub-surface layers of the soil profile, its blend of surfactants migrate from the bulk solution to soil interfaces. It is at these interfacial zones where surfactant concentrations begin to increase and micelle formation and cross linking of the surfactants are enhanced.

Both the Disotrate and tri-block surfactants attach to non-polar sites via their non-polar "tails." Attachment of Disotrate molecules can be on the soil surface or within a polymer network created by the tri-block surfactant. Their hydrophilic "heads" now are exposed to the liquid (water) phase. Water molecules are attracted to the polar heads of the surfactant and continue to build on these sites -- providing a water source to satisfy plant requirements.



Graphic depiction of hydrated Disotrate and tri-block surfactant molecules attaching to hydrophobic sites on soil particles. These hydrated surfactants provide an important source of water to roots and as free water molecules are removed due to gravity and evaporation, they serve as a feedstock for humates in the CISTERN formulation.

A humectant complex has been added to the CISTERN formulation primarily to harvest and retain ambient water in the soil profile. These humectants are a mixture of several short-chained sugar alcohols (polyols) and longer chained polysaccharides that both contain several hydrophyllic (water loving hydroxyl groups) sites. Because the equatorial positions of the hydroxyl groups (−OH) protude laterally along the polyol molecule, they are readily available to attract and bond with water -- making them excellent humectants.

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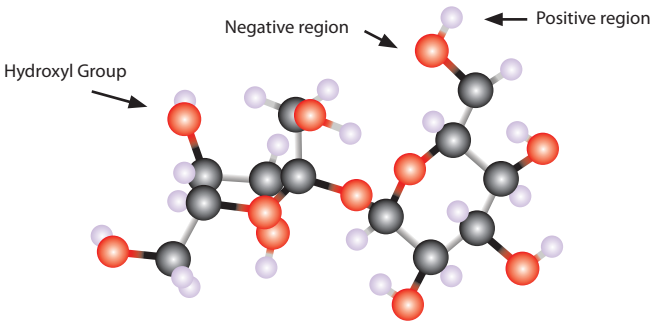
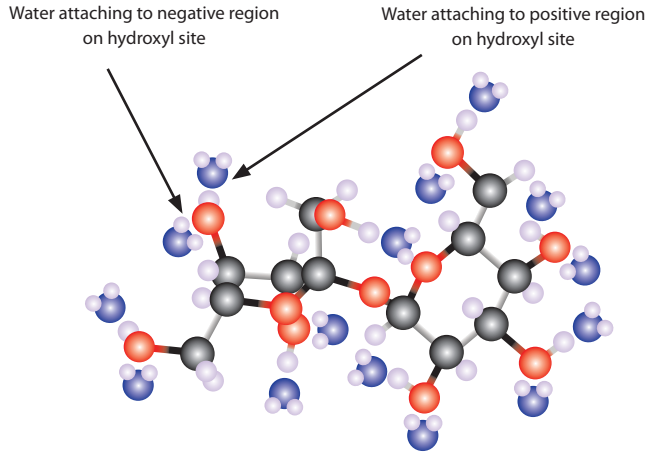
Because water is a polar molecule, its positive region is attracted to the negative region (oxygen) of the hydroxyl group and the negative region of the water molecule are attracted to the positive regions (hydrogen).

The polar nature of most sugar alcohols and polysaccharides allow them to absorb microscopic amounts of free water found in the pores of soil rootzones.

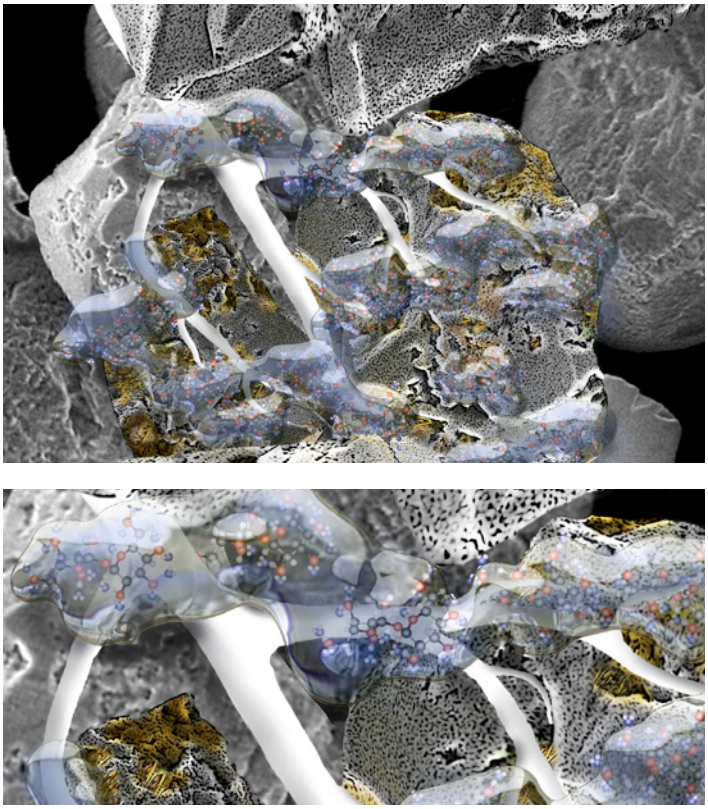


Example of protruding hydroxyl groups on simple sugar humectant

Since the water molecules are not held "tightly" to the humectant compounds, roots can take up this new source of available water through osmosis. This is a net gain for the plant since without the humectant "bridge," this microscopic water would be unavailable and eventually lost through evaporation.



Example of water molecules attaching to positive and negative regions of hydroxy groups on simple sugar humectant



Graphic depictions of hydrated humate molecules providing a unique source of water to fine root. Lower graphic has been enlarged to show molecular architecture.

The CISTERN blend of chemistries results in a multi-functional soil amendment with a range of chemical and physical properties that will address the demand by turfgrass and production managers for a water management product to that will:

- Overcome problems with water repellency on soil particles
- Increase infiltration rates and reduce runoff
- Improve wetting and promote uniform water movement into and throughout the soil profile
- Increase irrigation effectiveness and efficiency
- Reduce stress conditions and improve recovery from stress
- Be safe and not burn target plants
- Reduce watering requirements
- Improve seed germination and minimize transplant loss

APPLICATION RATES:

Greens & Tees, Fairways, Bunker Faces, Collars, Sports Turf and Parks/ Recreations Areas

General Application: Apply CISTERN at 6–8 oz. (180–235 ml.) per 1000 sq. ft. (100 sq. meters) in 2 gallons (8 liters) of water. For best results, apply every 2-4 weeks as required. A light watering-in after application is recommended.

Sodding, Overseeding and Sprigging: Apply CISTERN at 6–8 oz. (180–235 ml.) per 1000 sq. ft. (100 sq. meters) in 2 gallons (8 liters) of water. For best results, apply every 2-4 weeks as required. A light watering-in after application is recommended.

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