PASSAGE
SPRAYABLE SOIL SURFACTANT

TECHNICAL INFORMATION BULLETIN

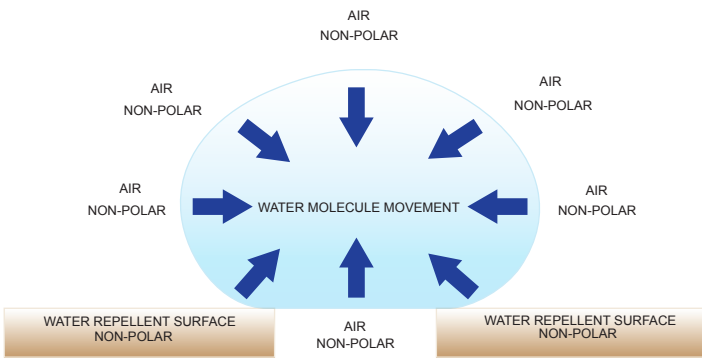
PASSAGE is an sprayable soil surfactant designed to overcome problems with the infiltration and penetration of water from rainfall or irrigation events into and through soil profiles that exhibit water repellency at or near the soil surface. Many surfactant products focus solely on correcting problems with surface run-off of irrigation water. PASSAGE goes beyond just correcting conditions found on the soil surface. The chemical properties of its multi-functional soil surfactants have been carefully "tuned" so their components work together to address additional hydrophobic conditions in the subsurface layers of the soil profile –conditions that may reduce infiltration capacity, create uneven hydration, reduce capillarity and disrupt the uniform distribution of water in turfgrass rootzones.

Problems with Infiltration and Water Repellency

Many superintendents find that regardless of how uniform the application of water, optimum efficiency is not ensured. Applied water may have difficulty moving through thatch, soil litter and the soil surface that have become water repellent. Even if applied water is successful in infiltrating the soil surface, it may find further difficulty penetrating and moving uniformly through hydrophobic subsurface layers.

Infiltration is defined as the initial process of water movement into an unsaturated zone through the soil surface. On highly maintained turfgrass, water repellency (hydrophobicity) is often commonplace on thatch/mat, surface litter and soil particle surfaces found on, at or near the soil surface (0 – 2 inches).

When water comes in contact with these hydrophobic (non-polar) surfaces, the water molecules on the air and water repellent surface boundaries will rotate and move inward – away from the non-polar interfaces and towards interior water molecules. This inward movement by boundary water molecules increases surface tension and causes water to "bead."



Water droplets with high surface tension often have difficulty moving through spaces or openings in thatch, surface litter and the soil surface. The inability of water to infiltrate through the soil surface can result in:

- Excessive runoff and evaporation
- A significant reduction in the amount of water that will enter the soil

Infiltration Capacity. Infiltration is the initial process of water movement into an unsaturated zone through the soil surface. However, what many professional turfgrass managers consider more important, is the soil's infiltration capacity. Infiltration capacity is defined as the maximum rate that water will move into the soil profile. It is highly influenced by capillary action. As capillary forces diminish, infiltration capacity decreases.

In hydrology, capillary action describes the attraction of water molecules to soil particles (adhesion). Adhesion (water-to-soil surface attraction) and cohesion (water attraction to water) are required to "wet" or hydrate the soil and to provide the tension for capillary suction ("pull") of water (vertically and horizontally) through pores in the soil matrix.

Adhesion occurs as water molecules at the wetting front attach to negative sites on the soil surface. When a soil particle becomes water repellent (hydrophobic), areas on its surface no longer carry a charge (non-polar). Water molecules cannot attach to these non-polar surface environments. If water repellency is widely distributed, the infiltration capacity of the soil can be reduced to the point where the amount of water that can move into the soil matrix is severely limited.

Uniform Flow. Ideally, turfgrass managers want applied water to move uniformly through the soil profile (particularly in the root zone). Uniform flow (matrix flow) is dependent on maintaining a uniform wetting front as water flows into and through the soil profile. Capillarity, a function of adhesion and cohesion (water molecules attracting to other water molecules), contributes to the retention and lateral movement of water as it moves through the soil profile.

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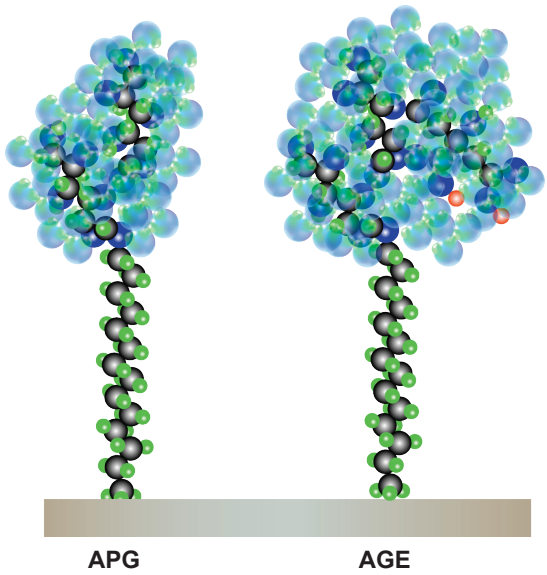
If water repellent conditions exist below the soil surface, non-polar surfaces will prevent adhesion and disrupt the wetting front, weaken capillarity and cause incomplete soil wetting and preferential flow. This can result in poor distribution of water, fertilizer, pesticides, and other important amendments required for healthy turfgrass conditions.

PASSAGE Technology

Unlike many injectable soil surfactants that utilize single surfactant technology or contain simple mixtures of different surfactants (polyblends), the development of PASSAGE Sprayable Soil Surfactant 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 co-surfactant compatibility.

Disotrate AGE

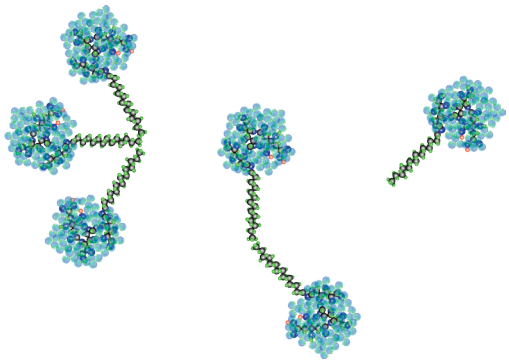
The construction of the PASSAGE formulation consists of two very different, high performance surfactant chemistries. The first constituent of PASSAGE is **Disotrate AGE**, new class of alkylpolyglucoside ester surfactants derived from natural, renewable raw materials. This new generation of sugar-based surfactants exhibits improved wetting and surface tension reduction properties; imparts electrolyte and hard water tolerance; and is readily or inherently biodegradable.



Graphic depiction of hydrated sugar-based surfactant (APG) and the new generation Disotrate AGE alkylpolyglucoside 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 PASSAGE, Disotrate AGE surfactants usually exist as monomers and very small aggregates (dimers and trimers) at the soil interfaces.

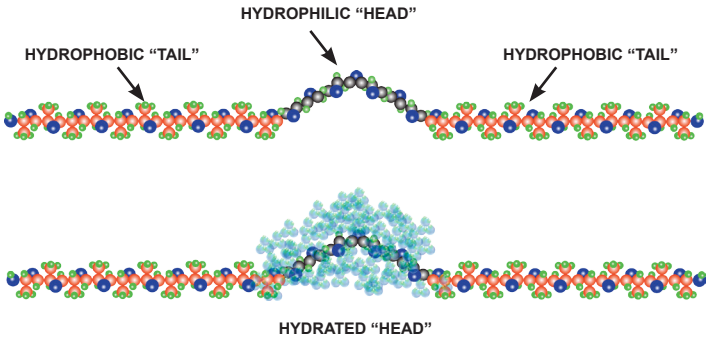


Examples of various self-assembly configurations of Disotrate AGE surfactant under low concentrations at soil interfaces.

Tri-Block Copolymer

The second constituent in the PASSAGE formulation 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 PASSAGE formulation 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 PASSAGE formulation.

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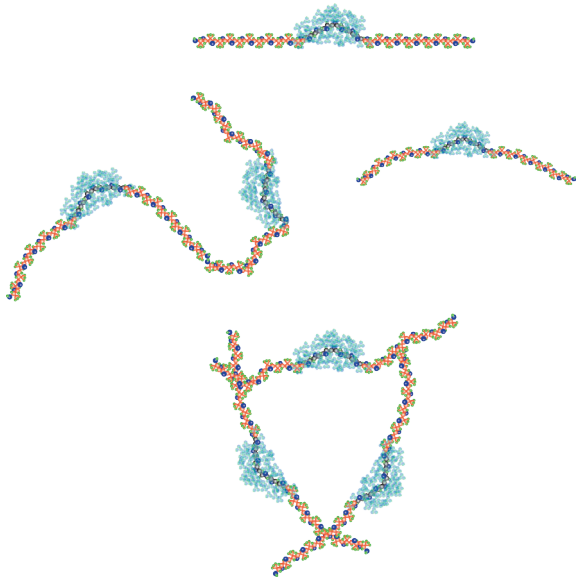


Examples of various self-assembly configurations of tri-block surfactant found in PASSAGE formulation.

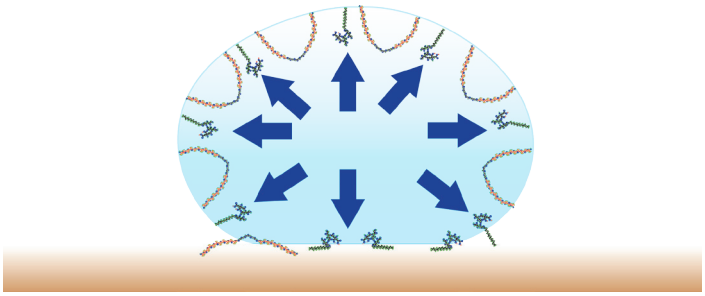
The tri-block surfactant in the PASSAGE formulation is capable of forming unique polymer networks that can attach to Disotrate monomers or micelles via non-polar attachment mechanisms. For this reason, as a co-surfactant, it can be used to promote networks assemblies of surfactant constructions and multiple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

Mode-of-Action

Infiltration. The infiltration of water into water repellent soils is dependent on the degree to which surfactants reduce the surface tension of water drops on hydrophobic surfaces. Reducing surface tension of water drops is very molecule dependent.

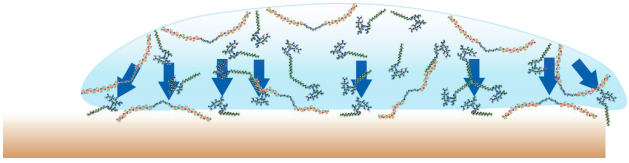
The Disotrate surfactant chemistry makes a significant contribution to the infiltration performance of the PASSAGE formulation because of the large size and repulsion to water by its non-polar "tail" and the large size and attraction to water by its polar "head."

When water containing the Disotrate AGE and the tri-block chemistries are applied to a hydrophobic surface, the large "tail" end of their molecules have a tendency to be pushed outward (towards the air/water interface).



Water molecules "pushing" tails of surfactant outward

At the same time, the polar "heads" of Disotrate AGE and its tri-block co-surfactant attract water molecules inside the liquid. These combined "push-pull" forces cause the Disotrate / tri-block surfactants to reduce the water's surface tension.



Disotrate AGE and tri-block surfactant "heads" pulling water molecules toward surface

As the "tails" attached to hydrophobic surfaces, "beading" of water is replaced with a film-like "coating" that will spread and infiltrate through cracks and pores on the soil surface. Disotrate chemistry has been shown to perform better than conventional surfactants including APG surfactants in its ability to reduce surface tension.

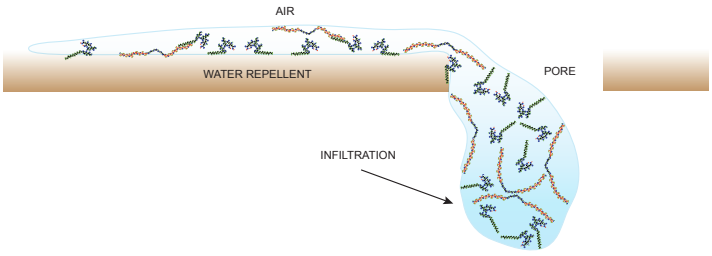


Illustration of water molecules being drawn into sublayers of soil profile by gravity and capillary forces.

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 PASSAGE-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.

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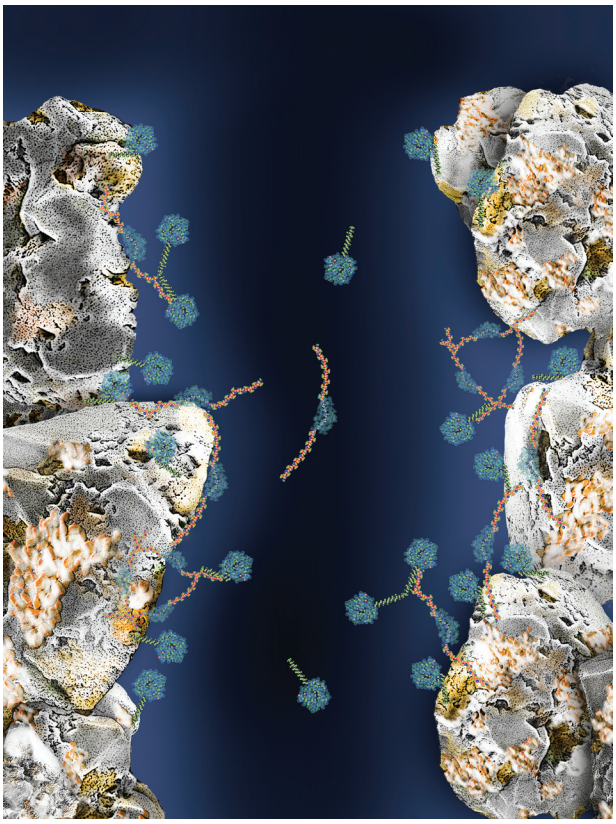

USE DIRECTIONS

DIRECTIONS FOR GENERAL TURF USE

GREENS, TEES, FAIRWAYS, LAWNS AND SPORTS TURF

A. Spray Application:

Tank mix PASSAGE at 8 - 16 fl. oz. /100 gal of spray solution per acre. Apply every 1-2 weeks. PASSAGE DOES NOT NEED TO BE WATERED-IN FOLLOWING APPLICATION.

B. For localized dry spots and turfgrass suffering under non-uniform growing conditions:

Apply PASSAGE at 6 to 8 oz. per 1000 sq. ft. in 2 gallons of water – apply every 2 to 4 weeks as required. A light watering-in is recommended after application to facilitate PASSAGE movement into the soil profile. PASSAGE is safe – NO BURN.

It is highly recommended that PASSAGE Soil Surfactant be applied prior to the development of environmental conditions that promote plant stress and water repellency on thatch and soil particle surfaces.

Disotrate AGE and its tri-block co-surfactant both contribute to preventing disruption of the wetting front by creating sites for water attachment (reducing surface tension). The larger, more complex tri-block surfactant also promotes downward and lateral movement of water (matrix flow).

The PASSAGE blend of chemistries results in a multi-functional surfactant solution with a range of chemical and physical properties that will address the demand by turfgrass managers for a surfactant solution that will:

- Offer exceptional penetration of applied or natural irrigation events through thatch, litter, and mineral particle fines on the soil surface
- Increase infiltration rates and reduce runoff
- Improve wetting and 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 turfgrass

Isn't it time for you to consider the use of PASSAGE in your irrigation protocol?

As both the quality and quantity of irrigation water is becoming a limiting factor in turfgrass management, studies have shown that use of surfactants in irrigation systems can reduce water requirements by as much as 50%. Further, the volumetric water content of soil profiles has also shown significant improvement with the use of surfactants in irrigation systems.

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