The Role of Silicon in Sustainable Turfgrass Management

Improvement in professional turfgrass sustainability requires both effective turf management as well as the optimal use and management of soil fertility and soil physical properties. The major challenges involved in sustainable turfgrass management are the development of practices that professionally manage both areas of the soil-plant equation.

Making the transition to 21st century sustainable turfgrass management is an evolving process. It involves consideration of new multifaceted programs that ensure healthy and vigorous turf under demanding expectations without compromising the long term interest of the environment and communities.

CrossOver™ Turf, a silicon-rich soil amendment and soil conditioner is well suited for use within modern turfgrass practices designed to establish sustainable turf-ecosystems.

Scientists, government officials and growers throughout the world now recognize silicon's contribution towards the improvement of sustainable practices, particularly its ability to enhance the effectiveness and efficiency of soil profiles and its significant contribution to improved turfgrass tolerance to a number of abiotic stresses.

**Sustainable Soil Management**

Managing healthy and vigorous turf requires the successful integration of many factors. Growers must successfully manage renewable and nonrenewable assets -- including the soil. There is general agreement that any successful approach to sustainable turfgrass management must include effective soil management strategies directed at improving, maintaining and stabilizing soil health and physical properties.

**SOIL STRUCTURE AND STABILITY**

Soil structure is an important, yet often misunderstood component of the function and dynamics of turf ecosystems. How important is it? It affects how water penetrates, infiltrates, drains and moves through the soil profile. Soil structure determines how efficient and sustainable the supply, storage and release of nutrients and pollutants are to the turf.

The mechanical stability of the soil profile is therefore, a main factor in sustaining an effective and efficient turf ecosystem.

Declines in soil structure can set in motion the onset of a number processes that will reduce or inhibit turfgrass ability to grow and thrive under seasonal stress. Any sustainable approach to turf management must strive to protect environmental resources -- including soil.

CrossOver™ Turf is a highly refined, calcium and magnesium silicate amendment in pelletized form. Silicate anions and calcium cations released into the soil profile following CrossOver applications are particularly effective in treating soils exhibiting poor structure and stability -- establishing soil surface complexes that improve flocculation and agglomeration of dispersed clay particles and formation of unique soil binders that lead to increased particle aggregation, structural strength and long term stability.

CrossOver Turf functions as a highly efficient and effective soil conditioner.

When compared to calcium, gypsum and limestone products, CrossOver's mineral constituents offer a significantly better and more comprehensive set of geochemical solutions to correct chemical imbalances, nutrient deficiencies, structural instability (deflocculation) and ion toxicity issues associated with low pH, salt-affected and high pH sodic soils.

**Soil structure modification**

Application of CrossOver Turf initiates the release of monosilicic acid in the soil solution. As concentrations of monosilicic acid increase, polymerization reactions result in unique silicon-rich inner-sphere complexes being adsorbed at soil surfaces. These silicate-based soil surface complexes that improve flocculation and agglomeration of dispersed clay particles.

Illustration of strong inner-sphere silicate ligand complexes at exchange sites on surface of soil particle. Soil modification by flocculation and aggregation is significantly improved over calcium bonds and are less susceptible to desorption.
**Long-Term Strength and Stability**

Long term soil stabilization occurs in soils when calcium ions chemically react with soluble silica (monosilicic acid) and alumina to form calcium-silicate-hydrates (CSH) and calcium-alumino-hydrate (CAH) polymer gels that function as “binders” between soil particle surfaces.

These reactions are called “pozzolanic reactions.” Of the two, calcium silicate hydrates produce the strongest mechanical strength.

\[
\text{Ca(OH)}_2 + \text{H}_2\text{SiO}_4 \rightarrow \text{Ca}^{2+} + \text{H}_2\text{SiO}_4^{2-} + 2 \text{H}_2\text{O} \rightarrow \text{CaH}_2\text{SiO}_4 \cdot 2\text{H}_2\text{O}
\]

Soils treated with CrossOver demonstrate longer term improvement in shear strength, swell behavior, aggregate formation, porosity and cation exchange.

**Phosphorus Fixation and Metal Toxicity**

Improved phosphorus availability and immobilization of toxic metal contaminants in the soil are two very important processes associated with the activity of silicate ligand exchange adsorption processes. These are addressed in separate CrossOver Information Bulletins.

**CrossOver Turf**

**Sustainable Soil Management**

Soil benefits realized from the application of CrossOver Turf are primarily associated with the release of soluble silicon species into the bulk soil solution that result in a multifunctional menu of geochemical reactions proven to be highly efficient and effective at managing and correcting a number of problems associated with soil structure and stability, sodic soils, phosphorus fixation and metal toxicity.

**Sustainable Turfgrass Management**

For decades, the professional turf industry has focused on reducing poor turf quality and losses from stress caused by biotic factors such as diseases, insects, weeds and other living organisms. Significant use of chemical pesticides have been used to accomplish control of yield-robbing pests.

It is understandable that under most sustainable turfgrass guidelines, considerable attention has been given to strategies designed to promote replacement or reduction of chemical pesticides in favor of “organic solutions”

**Paradigm Shift**

Most sustainable crop and turfgrass management guidelines have not, however, considered that during the last decade, agricultural multi-national agricultural chemical manufacturers and leading researchers have actively shifted from targeting biotic pest problems using curative chemical products to developing solutions that enable crops and turfgrass to better tolerate abiotic factors such as heat cold, drought, salinity and nutrient availability. What caused the shift?

Recent studies have confirmed that environmental stresses (abiotic stresses) significantly impact world agriculture and turf. These studies clearly show that abiotic stresses cause much higher yield losses and poor quality turf than biotic stresses.

A key focal point for successful turf management programs in the future will certainly include the need to incorporate strategies that address issues of abiotic stress.

**ABIOTIC STRESS**

Plants may experience physiological stress when an abiotic factor is excessive or deficient (such as the lack of water of certain nutrients or the lack of heat (often referred to as an imbalance). Research shows that abiotic stressors are most harmful when they occur in combination (such as heat and drought).
Reactive Oxygen Species

Reactive oxygen species (ROS) in plants are produced as normal by-products of many metabolic pathways, including photosynthesis. The production of ROS is also an unavoidable outcome of aerobic respiration.

Under steady state conditions (normal metabolism), plant cells have evolved a complex system of enzymatic and non-enzymatic antioxidants which serve to maintain a delicate equilibrium between Reactive Oxygen Species (ROS) production and their conversion to non-harmful molecules (scavenging).

Common enzymatic antioxidants include superoxide dismutase (SOD), ascorbate peroxidase (APX), glutathione peroxidase (GPX), glutathione-S-tranferase (GST), and catalase (CAT). Examples of non-enzymatic low molecular metabolites include ascorbic acid (ASH), glutathione (GSH), a-tocopherol, carotenoids and flavonoids.

Many “symptoms” of stress such as weakened plants and diminished turf quality caused by abiotic factors (drought, heat, salts, chilling, heavy metals, ultraviolet rays and light) are for the most part, actually indicators of oxidative stress.

In order for plants to remain healthy and productive under stress, its net accumulation of ROS must be kept within a tolerable range. A significant challenge to successful agricultural, turf and horticultural management today is coping with oxidative stress associated with damaging levels of ROS created by plant abiotic stresses.

**DEALING WITH ABIOTIC (ENVIRONMENTAL) STRESSES**

While a wide variety of chemical options are available to control biological stresses, options for the management of abiotic stresses have been overlooked or absent. Successful turfgrass management is often compromised by an increased occurrence of severe weather events. It is not surprising therefore, that a major target for sustainable turfgrass is to improve tolerance to abiotic stresses.

A major target for sustainable agriculture is to improve tolerance to abiotic stresses. Genetic research and breeding programs promise development of turfgrass capable of stress tolerance in the future. Silicon incorporated within sustainable turfgrass programs offers solutions that make turfgrass tolerance to many abiotic stresses available today.

Genetic research and breeding programs promise development of turfgrass capable of stress tolerance in the future. Silicon incorporated within sustainable agriculture programs offers solutions for turfgrass tolerance to abiotic stress available today.

Most turfgrasses have developed a predisposition for the uptake and use of silicon to boost their tolerance to abiotic stresses. Improved plant tolerance to stress conditions with silicon can be seen as a quicker and more efficient response at the onset of stress and enhanced recovery once the stress has abated.

There is a clear need for multi-functional soil amendments containing silicon that can enhance plant tolerance to abiotic stress conditions. A soil amendment that meets these desirable characteristics is available now — CrossOver Turf.

**CROSSOVER AND ABIOTIC STRESS**

CrossOver Turf helps turfgrasses stand up to stress.

CrossOver Turf is truly unique, inasmuch as it behaves as a functional hybrid. As silicon released from CrossOver is absorbed by the plant, it “crosses over” from its involvement in soil geochemical reactions, becoming an active participant in numerous complex plant biological processes that enhance the plant's ability to resist and tolerance abiotic stresses and further regulate metal toxicity.

Silicon released from CrossOver Turf is not inert. It has been found to be a biologically active element, participating in highly complex interactions with key components of the plant’s defense response system.

It is well documented and recognized that silicon plays a key role in activating processes that enhance and improve the efficiency and effectiveness of plant response systems under abiotic stress conditions – effectively increasing plants' tolerance to environmental (abiotic) stress.

Silicon is known to effectively mitigate various abiotic stress factors such as salinity, drought, heat, chilling and freezing stresses and manganese, aluminum and other metal toxicities.

Silicon’s biochemical properties enable it to interact with a host of enzymes, proteins and hormones and act as a modulator influencing the amplitude, timing and duration of stress transmission signals and protein activated plant defense response pathways.

**Graphic showing increased production of ROS under influence of abiotic/abiotic stress conditions. Note that ROS also participates in plant defense mechanisms by triggering sensors/receptors in signal pathways that produce plant defense responses.**

**Unfortunately in many plants such as turfgrass, their antioxidant systems, which are tuned to maintain steady state levels, are insufficient to counteract increased production of ROS due to abiotic stresses, particularly under multiple stress conditions.**

**Oxidative Stress**

Overproduction of ROS is often the result of plants subjected to abiotic stress and frequently results in oxidative stress. Oxidative stress occurs when the production of ROS overwhelms the plant's ability to maintain ROS at steady state levels.

**Graphic showing increased production of ROS under influence of abiotic stress.**

**Illustration of signal pathways being modulated by the presence of silicon, acting as a potentiator of plant defense responses or as an activator of strategic signaling proteins.**

**Toxic Metal Ions**

The hydroxyl radical (•OH) is one of the most reactive and destructive reactive oxygen species known to chemistry. It is believed to be the major free radical responsible for destructive modifications of membranes and cellular structures such as lipid peroxidation.

Evidence indicates that •OH radicals are generated in a Fenton-type Haber-Weiss reaction in plants. The Fenton reaction requires a catalytic free metal for the decomposition of hydrogen peroxide (H₂O₂).

**Fenton Reaction**

\[
\text{Metal}^{2+} + \text{H}_2\text{O}_2 \rightarrow \text{Metal}^{3+} + \text{OH}^- + \cdot\text{OH}
\]
Silicon-mediated alleviation of metals in planta

Under stress conditions, plants often increase their absorption of silicon (monosilicic acid) molecules. As the monosilicic molecules come in contact with free metals, they are capable of forming complexes with the metals.

For example, monosilicic acid will react with metal and form a metal silicate molecule.

As monosilicic acid complexes with metal molecules, the metal silicate product attaches to the extracellular walls of the apoplast or deposits as a precipitate. These complexed metals are rendered non-exchangeable, and therefore do not engage in chemical reactions that produce reactive oxygen species.

This co-deposition process effectively removes metal ions from entering the Fenton equation. Silicon therefore indirectly contributes to a decrease in -OH production by decreasing the availability of many free cationic metals – preventing the Fenton reaction from acquiring required metal catalysts.

Fenton Reaction

\[
\text{Metal}^2+ + H_2O_2 \rightarrow \text{Metal}^3+ + OH^- + OH
\]

Silicon has also been found to stimulate the production of flavonoid-phenolics (i.e. catechin and quercetin) that have a strong metal-chelating ability and may provide metal tolerance in plants.

In research work with aluminum toxicity in plants, significantly higher concentrations of malic and formic acids were observed in the plants grown in the presence of added silicon and aluminum. These organic acids are involved in the detoxification of highly toxic soluble aluminum.

Silicon Improves Photosynthetic Activity

The accumulation of silicon in epidermal cells and cell walls of plants produces more erect leaf blades with improved light interception characteristics and increased photosynthetic activity.

Application of silicon as a soil amendment has been reported to result in elevated concentrations of chlorophyll per unit area of leaf tissue, resulting in improved photosynthetic efficiency.

Silicon Promotes Balanced Nutrient Availability and Transport

Once silicon is absorbed by the plant, it continues to actively contribute to a balanced state of nutrient availability through uptake processes and micro-distribution of mineral ions as well as compartmentalization of metal ions.

Silicon Adds Structural Strength to Plants

Silicon is absorbed by plant roots and moves upward in the transpiration stream to sites of strong evapotranspiration in epidermal regions of stems and leaves. In these areas, the silica forms solid, hydrated gels between the cuticle and the cell walls.

Silicon is also deposited within cell walls where it improves cell wall strength, plant rigidity, root development, linear growth, water efficiency and presents barriers to environmental stresses.

CrossOver™ Turf – Addressing Today’s Turf Management Problems With Silicon-based Solutions

- Elevates abiotic stress tolerance
- Helps prevent sodium toxicity
- Increases photosynthesis
- Improves nutrient availability
- Increases phosphorus availability
- Reduces metal toxicity
- Improves soil structure
- Enhances soil stability
- Increases flocculation
- Increases aggregation
- Novel silicate-based soil binders

It’s what’s been missing in your sustainable turfgrass management programs

Purchase Information for CrossOver is available at:

NUMERATOR TECHNOLOGIES, INC.
P.O. Box 868
Sarasota, Florida 34230
941.807.5333
WWW.NUMERATORTECH.COM

Silicon (Si) is now designated as a “plant beneficial substance” by the Association of American Plant Food Control Officials (AAPFCO). Silicon formulations that contain measurable soluble silicon rather than silica can now be listed on fertilizer labels with the new designation backed by an established protocol for product quality, production, and accurate labeling for commercialization of silicon fertilizers.