



Product Information Bulletin

DEALING WITH BICARBONATES

*Bicarbonates are often not addressed until their levels significantly affect pH, the structure or stability of turfgrass soils or water movement through the soil profile. **The fact that the bicarbonate ion itself is highly toxic to the roots of plants and potentially has a strong negative physiological effect on plant health and photosynthesis is often overlooked.***

Bicarbonate related, direct physiological damage to the turfgrass on on golf courses may become far more severe than the geochemical damage to soil structure and stability that may occur as the result of its presence in the soil profile.

To properly address bicarbonates today, given their increased presence due to effluent water use, it is important for turfgrass managers to consider acidifiers whose chemistries are formulated to efficiently and effectively address both the geochemical issues of bicarbonates in the soil as well as the physiological issues of bicarbonates absorption in the plant.

Throughout the United States, many state and local governments place restrictions on the use of potable water for irrigating turfgrass landscapes. For many golf course superintendents, use of reclaimed, or other secondary water sources is the now the norm. Unfortunately, much of the recycled water used for irrigation contains high concentrations of bicarbonates (HCO_3) and carbonates (CO_3) that often precede the loss of soil structure and crusting of soil surfaces resulting from the effects of high levels of sodium, bicarbonate and carbonate salts.

Historically, treatment guidelines dealing with high levels of bicarbonates focused primarily on treatment of the irrigation water with acid to evolve the bicarbonates off as CO_2 gas plus water. Treatments with acid products are usually triggered when water analysis reveal that bicarbonate levels have exceeded 150 ppm (150 mg/L).

Influence of Bicarbonates on Plant Health

Bicarbonates are strongly implicated in decreased growth of plants. It has been shown that bicarbonate reduction of plant biomass is related to lowered fibrous root growth and density, which in turn, leads to reduced water and nutrient uptake. Impairment of an adequate root system decreases the root's ability to take up water as well as important nutritional cations (including Ca, Mg and K) as well as micronutrients, especially Mn and Fe. More importantly, bicarbonate damage to root systems are likely to increase water-related abiotic stress with declines in photosynthesis an expected consequence.

Bicarbonate Toxicity

When bicarbonate is absorbed by root cells, increases in the organic acid content of root cytoplasm frequently occur. Large increases in the organic acid content may have profound negative effects on the normal metabolism of the cells.

Researchers have found that Malate is often a product of acid bicarbonate induced acid increase. Under normal conditions, root cells would normally maintain a chemical balance of Malate in the cytoplasm (stoichiometry) by "storing" excess amino acids such as Malate in vacuoles. Vacuolar sequestration accounts both for metabolic unavailability and or stoichiometry.

However, when high levels of bicarbonates are present, it is generally accepted that the inhibitory effect of bicarbonate absorption on root growth is the result of over accumulation organic acids (such as Malate) in the cytoplasm and insufficient compartmentation of organic acids in vacuoles in the root cells.

Excessive accumulation of organic acids in the cytoplasm has been found to inhibit fine root elongation as well as promoting impairment of new root initiation. These effects can impact various parameters of growth including plant height, root and shoot measurements, nutrient composition of tissues and nutrient uptake.

The Need for Advanced Analytical Practices

Dealing with management practices applicable to bicarbonate toxicity in plants (versus traditional practices that deal with bicarbonate effects on soil profiles) can be a baffling exercise.

Although bicarbonate levels are routinely provided in source point irrigation water analysis, it is far more important to determine the bicarbonate level in the soil solution at root zones depths to provide useful information as to its potential for plant toxicity.

The bicarbonate concentration of the soil solution is significantly influenced by the moisture content of the soil as well as iron, phosphorus, calcium, gypsum and lime content. Bicarbonate analysis on the saturation extract of soils would likely provide a better aid in field problem diagnosis, but it is rarely selected for analysis.

Information from tissue analysis could be valuable, but processing samples would alter bicarbonate concentrations. However, advanced analytical practices such as the use of multi-spectral radiance cameras used by satellites and now available in drones, appears to offer golf course superintendents and researchers with a means to analyze turf grass canopies to include information regarding their general condition, relative amount of biomass (density), water and nitrogen uptake and other growth parameters such as photosynthesis.

Such information will provide additional information needed to assemble more comprehensive data sets that will assist in the evaluation of potential bicarbonate toxicity problems as well as assessments of bicarbonate management practices.

The use of remote sensing data produced through the use of multi-spectral radiance cameras can increase golf course management since remote sensing removes human bias in visual stress severity evaluation that can be highly variable among individuals.

Two analytical methods currently in wide use for agricultural-related data collection and analysis are the Normalized Difference Vegetation Index (NDVI) and the Green Normalized Difference Vegetation Index (GNDVI).

Normalized Difference Vegetation Index (NDVI)

It is well known that net photosynthesis is directly related to the amount of photosynthetically active radiation that plants absorb. Sunlight is made up of many different wavelengths. Certain wavelengths of sunlight are absorbed and other wavelengths are reflected.

The chlorophyll pigment in plant leaves strongly absorbs visible light for use in photosynthesis.

The cell structure (including water content) of leaves, strongly reflects near-infra-red light. The more vegetation in the area

captured by the spectral camera, the more wavelengths of light are represented. By comparing visible and infrared light, it is possible to determine the relative amount of vegetation.

Vegetation indices have been developed to quantify the density of plant growth captured by the multi-spectral radiance camera. This formula is called the Normalized Difference Vegetation Index (NDVI). This formula is:

$$NDVI = (NIR - VIS) / (NIR + VIS)$$

$$NDVI = (\text{Near-Infrared minus Visible light}) / (\text{Near-Infrared} + \text{Visible light})$$

Heavy vegetation absorbs most of the visible light that it is exposed to and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light.

Values below 0.33 depicted in red and deep orange, would represent dead or unhealthy plant material. Values above 0.33 depicted in light green to dark green would represent healthy to very healthy plant material.

Value	Indication
<0	Inanimate / dead material, e.g. roads, buildings, soil or dead plants
0 to >0.33	Unhealthy plant material
0.33 to > 0.66	Healthy plant Material
> 0.66	Very healthy plant material



The NDVI is a standardized index that allows for the generation of an image displaying vegetation or relative biomass. This information has been found to be correlated to leaf area index general plant health and a general look at the condition of the area captured. Coupled with other information and observations, it can provide clues as to areas needing additional management.

In the case of bicarbonates, NDVI can serve as a possible indication of water stress caused by bicarbonate damage to root systems.

Green Normalized Difference Vegetation Index (GNDVI)

The Green Normalized Difference Vegetation Index (GNDVI) is an index of photosynthetic activity and is one of the most commonly used vegetation indices to determining water and nitrogen uptake into the crop canopy.

GNDVI is a modified version of NDVI that is more sensitive to chlorophyll concentration and is more efficient than the red spectral band to discriminate nitrogen.

Scientists have found that water stress can be assessed and differentiated using chlorophyll reading and reflectance data when transformed into spectral vegetation indices.

Reduced chlorophyll content in plants is directly related to water stress leading to change in chlorophyll to carotenoid ratios and *chlorophyll a* to *chlorophyll b* ratios that are an indicator of water stress.

Water deficiency also causes alteration in leaf pigment composition, concentration, and cell structure by changing the properties of connections between air spaces and cell walls, cell wall composition and structure or cell size and shape.

GNDVI may also offer a better method to detect and quantify the impact of plant stress compared to visual techniques because a vegetative unit can be repeatedly, objectively, and non-destructively examined in a fast, robust, accurate, and inexpensive way.

Effective Treatment of Carbonate-Affected Turfgrass with pHAcid



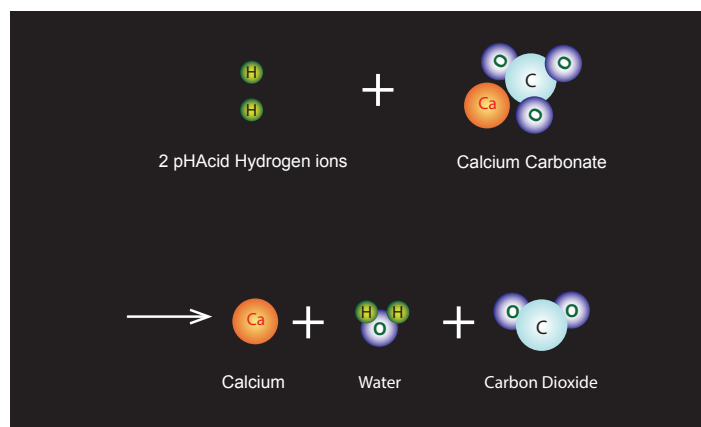
When high levels bicarbonates are present in irrigation water and analysis of turfgrass conditions suggest the bicarbonate threat should be reduced, acidification of the irrigation water or problem area with pHAcid Injectable and/or pHAcid Sprayable is recommended to remove excess carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions in the irrigation water and/or soil solution, neutralize pH, release Ca from calcium carbonate deposits and improve infiltration of applied or rain even water.

pHAcid is a unique combination of a blend of acidifying agents combined with a multi-purpose, high molecular weight surfactant.

This combination of complementary technologies is designed to be applied through irrigation and/or used as a tank spray to provide the superintendent with a highly flexible, proactive approach to:

- Neutralize the negative effects of high bicarbonate and carbonate levels in irrigation water and in the soil solution
- Lower pH of irrigation water and soil water
- Maintain the solubility of Ca and Mg in irrigation and soil water
- Dissolve calcium carbonate and magnesium carbonate salts on the surface (crusts) and in the soil profile
- Improve the ability of soil-applied Ca-based amendments to produce soluble Ca
- Flocculate dispersed colloidal-sized clay particles

The acidification/neutralization of bicarbonates by the acid component of the pHAcid formulation is straightforward. Protons from pHAcid's acid component combine with bicarbonates to form carbon dioxide and water.



Acidification of identified problem areas also promotes precipitation of Na salts from the root zone.

pHAcid Surfactant

The non-ionic, proprietary “block” surfactant used in pHAcid was chosen for its exceptional ability to enhance infiltration, percolation and drainage characteristics of the soil profile as well as its ability to significantly improve the movement and coverage of the acid constituent of pHAcid to the turfgrass rootzone.

Once in the rootzone, pHAcid neutralizes bicarbonates present in this area and prevents damaging bicarbonate absorption by fine roots of the turfgrass. Failure of acid treatments to reach the rootzone can expose turfgrass to significant water deficit and nutritional stress conditions as a result of the impact of bicarbonate toxicity on turfgrass root systems.

The pHAcid surfactant also facilitates “leaching” of sodium and carbonate salts from the rootzone. Leaching of these salts is fundamental in the treatment of alkaline soils.



USE DIRECTIONS

We strongly recommend that water and soil samples be taken and analyzed on a routine basis in order to develop and maintain a comprehensive management plan to correct bicarbonate-affected soils.

Any soil receiving irrigation water with high sodium (Na) and bicarbonate levels should be amended with a soluble source of calcium in addition to the pHAcid spray program.

pHAcid Injectable irrigation water program:

1. Apply pHAcid INJECTABLE at the rate of 1 to 2 gallons per 20,000 to 30,000 gallons of irrigation water every month if the bicarbonate levels are less than 150 PPM.
2. Inject pHAcid INJECTABLE at the rate of 1 to 2 gallons per 20,000 to 30,000 gallons of irrigation water every two weeks if the bicarbonate levels are greater than 150 PPM.

pHAcid Sprayable application program: 32 to 64 ounces per acre in a 1 to 2 gallon spray solution per 1000 ft² (24 ml per 100 sq. meters). Apply sufficient water to move product into the soil profile.

A good seasonal and annual monitoring program is recommended.

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