Gypsum Injections into Vineyard Drip Systems

It seems that one of the most common components of a vineyard irrigation system in the Western United States is the "Gypsum Machine", which consists of a tank with agitation paddles and an injection pump. Finely ground gypsum (calcium sulfate) is mixed with water to form a slurry within the machine and injected into the irrigation system. When the slurry mixes with the irrigation water, all of the gypsum dissolves into calcium and sulfate ions, which pass through the irrigation system and into the soil with the irrigation water. That is the theory and the theory is quite sound. It is the practice that presents the challenges.

Before we delve into these challenges, let’s take a look at the reasons for injecting gypsum in the first place. There are three generally recognized agronomic reasons for injecting gypsum:

1. Calcium is considered a secondary plant nutrient, and plays an important metabolic role in cell division and photosynthesis. In certain crops, such as apples and tomatoes, high levels of calcium are required prior to harvest and it becomes a management challenge supplying sufficient quantities. Magnesium ions can tend to compete with calcium uptake into plants so there is also some concern with the calcium-magnesium ratio, which can be favorably influenced with gypsum applications.

2. In irrigated viticulture perhaps a more important role is played by the calcium ion in the soil structure. The soil colloids possess a number of negatively charged sites, which attract and bond to positively charged ions (cations) in the soil-water solution. The structure of the soil is largely determined by the relative ratio of the calcium, magnesium and sodium cations that are bonded to these sites. If these "cation exchange sites" are mostly occupied by sodium ions, the soil colloids tend to pack in tightly together. This reduces the pore spaces between the colloids, making it difficult for water and air to infiltrate the soil. Exchanging most of the sodium ions with calcium ions tends to separate the soil colloids, thus providing larger pore spaces, better water penetration and improved soil texture.

   The cation balance of the soil tends to come into equilibrium with the cation balance of the irrigation water, so irrigating with high sodium water, for example, can lead to "sodic soils" and poor water infiltration. The cation balance of the irrigation water is expressed as the Sodium Adsorption Ratio (SAR), and is a common laboratory analysis. Irrigation water high in sodium (SAR above 6) can be modified through the addition of calcium, either through the water, or applied directly to the soil.

3. The infiltration rate of irrigation water that is very low in total salts can also be a problem with run-off under the emitters. This is due to the high surface tension of pure water. The

addition of *any* salt will tend to reduce this surface tension, and increase water infiltration rates. Gypsum is a very common choice for this application.

Well! These are certainly three good reasons for injecting gypsum! But what about those practical challenges? They all revolve around plugging up the drip system. The most immediate incidence of gypsum plugging occurs when either more gypsum is injected than can be dissolved into the irrigation stream or not enough time is allowed between the injection of the slurry and its arrival at the system filter. In either case undissolved gypsum coats the filter and plugs it. This can be overcome by reducing the concentration rate of the injection and moving the injection point farther upstream from the filter, if possible. In some cases growers have moved the injection point below the filter, which can lead to severe problems of plugged emitters if the injection stream is not adequately pre-filtered.

A second challenge presented when injecting gypsum is the fact that the mineral is often ground finer than the mesh size of the irrigation filters, and the insoluble (non-gypsum) fractions can pass into the system. In many cases, these will pass through the emitter without causing any plugging problems. But often, because of their density, they settle out in areas of the irrigation system where the velocity of the water is low. This can occur in large mainlines as well as in the emitters themselves. Over time these silt-like deposits can build up and affect the system performance. These deposits become difficult to remove, especially if allowed to remain over long periods of time. Because of this, it is recommended to frequently flush all mainlines and hose laterals with sufficient velocity to prevent these deposits from building up into a chronic plugging problem.

Perhaps the most common plugging problem associated with gypsum injections is lime scale formation. Lime scale (calcium carbonate) is formed when calcium ions (either naturally present in the source water or added as calcium sulfate in gypsum) combine with naturally occurring bicarbonates in the water. As described in the article ***Formation of Lime Scale in Drip Irrigation Systems*, PWV March/April 1998**, calcium ions are often the limiting factor in a source water's ability to deposit lime scale. When we dissolve gypsum into water that contains appreciable amounts of bicarbonates with pH 7.0 or greater, we are setting up a system to actively precipitate calcium carbonate (lime scale). When dealing with waters of a high potential for lime scale formation, (high Total Alkalinity), it may be most cost effective to seek alternative methods of applying calcium to the vineyard.

If the irrigation water has a high sodium adsorption ratio (SAR), there may be a need to supply calcium to the soil to prevent developing "sodic soils". Soil applications are very successful in correcting this problem. The product you use depends upon the pH of the soil, and whether or not there is any limestone (calcium carbonate) already present in the soil. If the soil is acidic, the addition of limestone will supply calcium and tend to raise the pH of the soil. If the soil is neutral or basic, the addition of gypsum (calcium sulfate) will supply the needed calcium with little effect on the pH. Banding the gypsum underneath the emitters will be as effective as injecting the material into the water, without the plugging potential. Soil applications also have the advantage of using natural rainfall to carry calcium into the soil. If the soil contains limestone (also called "free lime"), then soil applications of elemental sulfur or sulfuric acid will react with the calcium carbonate to release calcium ions. Sulfur and sulfuric acid will lower the pH of the soil as well.

If the crop requires high levels of calcium, increasing the total amount of calcium in the soil through applications of gypsum, limestone or soil sulfur, as described above is a good start. Often the calcium requirements of the crop are greater than the plant’s ability to "mine" it out of the soil. At these times, foliar applications of calcium may be required. There has also been some success in fertigating with calcium chelate to providing nutritional calcium during the critical development stages of some crops.

If the irrigation water is very low in Total Dissolved Solids (TDS) or Electro-Conductivity (EC), water infiltration may be a problem. Applying a band of gypsum or limestone (or a combination of the two, depending upon soil pH) underneath the emitters is as effective as injecting gypsum into the irrigation system. Another option is the use of "water penetrants" or "surfactants", which decrease the surface tension of the water, allowing for better infiltration. There are many products on the market formulated specifically for this application. Promoting cultural practices that increase the organic content of the soils will also help improve soil texture and water infiltration.

Another common occurrence on irrigated soils in the arid Western United States is surface crusting underneath the drip emitters. In many cases this is caused by the formation of lime scale where evaporation causes the salts in the water to concentrate beyond their solubility point, and calcium carbonate is deposited as a thin layer of concrete. Increasing the calcium content through the injection of gypsum will only worsen this situation. Removal of this surface scale can be accomplished by adding acid either through the irrigation water or the microbial oxidation of soil sulfur.

Because Lime Scale (calcium carbonate) is formed by the combination of calcium and bicarbonates at an elevated pH, injecting Gypsum (calcium sulfate) frequently provides the "missing ingredient" (calcium) to the batch of concrete (another name for calcium carbonate) that we are mixing in our drip system. If the alternatives to gypsum injections are not feasible in a given vineyard and we *must* inject gypsum, how do we avoid the potential plugging caused by chronic lime scale formation?

First of all obtain a valid water quality analysis from a reputable independent water laboratory. Before pulling the sample, contact the lab and tell them that you want to know what quantity of gypsum you can add to the water before lime scale starts to precipitate. Also tell them how much gypsum you would *like* to add to the water. Should lime scale begins to precipitate, ask them to determine how much acid you need to add to prevent the lime scale from forming. They will be able to instruct you on how to sample and preserve the water so their test will be valid. These analyses should be relatively inexpensive…less than $100.00.

Gypsum may be injected without the worry of lime scale formation if the pH and the bicarbonate (often expressed as Total Alkalinity) levels of the water are low enough. If the natural water is too high in either of these two factors, it can be modified with the injection of sulfuric acid prior to the gypsum injection point, effectively reducing the Total Alkalinity and pH. An available option to replace the acid injections is the use of "Lime Scale Inhibitors". These compounds have been around for years in "spotless" dishwasher detergents and the steam-generating industry, and several have been registered for use in agricultural irrigation systems. Because of their cost effectiveness and inherent safety factors the Lime Scale Inhibitors are becoming quite popular alternatives to acid injections.

In summary, the addition of soluble calcium to the vineyard has many agronomic benefits. There is a high potential that adding calcium to the irrigation water will cause emitter-plugging lime scale to form, which will affect the uniformity of the water and nutrient applications. There are many viable alternatives to gypsum injections and there are ways to modify the irrigation water to prevent lime scale formation during gypsum injections. Many vineyard managers are finding that soil applications every four or five years require less of their management time than does constantly dealing with gypsum machines and acid injectors.

Lizanne E. Wheeler and Patrick D. Brown are independent irrigation design consultants, specializing in developing management and bilingual training programs for micro irrigation systems. They may be contacted through Vineyard Water Systems, 521 Lucerne Road, Cayucos, CA 93430, (805) 995-0587. Reprints of their recent publications are available at www.vineyardwater.com.

Sources of Calcium

Calcium carbonate, Lime, ($CaCO_3$), is not soluble in water. It will tend to increase the pH of the water to above 8. Lime is what we attempt to remove from irrigation systems, and is not an appropriate source of calcium for injection.

Calcium magnesium carbonate, Dolomite Lime, is not soluble in water. It is used to increase the soil pH where magnesium is also required. It is not an appropriate material for fertigation.

Calcium chloride ($CaCl_2$) is a very soluble source of calcium, but its use in agriculture is limited because of the chloride content.

Calcium ammonium nitrate is a mixture of the calcium and ammonium salts of the nitrate ion. It is commonly available as CAN-17, which contains 17% N by weight. This is an excellent source of nitrate nitrogen and calcium ions.

Calcium nitrate ($Ca(NO_3)_2$) is an excellent source of nutritional calcium, and is extensively used in the hydroponics industry. It has good solubility, approximately 10 pounds per gallon (1200 grams per liter), and is widely available. The prills are almost always wax-coated. This wax needs to be skimmed off of the top of the solution tank prior to injection.

Calcium polysulfide (lime sulfur) is an excellent source of calcium and soil sulfur, but it is not stable in neutral and acidic environments, precipitating out elemental sulfur. It is not recommended for use in micro irrigation systems.

Calcium sulfate, Gypsum ($CaSO_4$), is a popular product for injecting into irrigation systems, which is surprising when one considers its extremely limited solubility, 0.02 pound per gallon (2.41 grams per liter). It is available in various grades, each having varying amounts of insoluble minerals.