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Chemicals for Fertigation

by

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BACKGROUND

There are numerous considerations in deciding what chemicals to fertigate. Because nitrogen fertilizer is injected more widely than any other nutrient, special attention is given to it in this presentation.

CATION-ANION BALANCE

The concept of cation-anion balance in plants is a useful mechanism to discuss nitrogen uptake by plants. This concept simply means that the total number of nutrient cations (positively charged ions) in a plant must equal the total number of nutrient anions (negatively charged ions) in a plant. If this were not true, the plant would become electrically charged.

The ammonium ion (NH_4^+) will be in competition with other cations for uptake. Plants may take up primarily ammonium if a nitrification inhibitor is applied, or if the soil is so strongly acidic that nitrification is inhibited. The nitrate ion (NO_3^-) will be in competition with other anions for uptake.

A plant receiving nearly all of its nitrogen in the form of ammonium may result in a low to deficient level of potassium (K^+), calcium (Ca^{2+}), and/or magnesium (Mg^{2+}). The plant will compensate the positive charge by absorbing more phosphate ($H_2PO_4^{-)}$ and sulfate (SO_4^{2-}) than normal. In addition, a plant which takes up primarily ammonium nitrogen will produce a more acidic root environment because the roots release H^+ ions to balance the charge from taking up NH_4^+ ions.

SELECTING THE CORRECT NITROGEN FORM

If the ammonium is needed in the root system, it will be used in the roots before any ammonium will be translocated to the stems and leaves. Nitrate is taken up by roots, and is immediately moved upward in the plant to the stems and leaves. In order for the nitrogen to be used by the plant for growth, the plant must convert the nitrate to ammonium, which it does with nitrate reductase enzymes. That conversion is done in the stems and leaves.

Young plants (less than 3 weeks of age) have not developed the nitrate reductase enzyme yet, so there is a preference for ammonium uptake. This is why many growers use fertilizer combinations with ammonium early in the season.

Once plants get older, there is generally a quicker visual response to nitrate applications because of the immediate movement of nitrate into the leaves. Also, the nitrate moves more freely in the soil solution than ammonium, making it easier to get into the roots.

A balance of nitrate and ammonium nutrition is recommended for optimal plant growth. In general, ammonium should not exceed 50% of the total nitrogen supply, and nitrate should not exceed 60% of the total nitrogen supply. There is considerably more to learn about this ratio.

Urea is generally converted to ammonium carbonate within a few hours or days after application into the soil, so its action is similar to that of ammonium in terms of nutrition. Ammonium which is not taken up by plant roots (or volatilized) is eventually converted to nitrate.

FERTILIZER SOLUBILITY

GENERAL

The solubility of various fertilizers must be considered when they are used for injection into irrigation systems.

DRY FERTILIZER CONDITIONERS

In California very few dry solid fertilizers are used for fertigation. Perhaps the main exception is potassium sulfate, which is sometimes injected via gypsum injection machines (described later).

Most dry solid fertilizers are manufactured by coating them with a special conditioner to keep the moisture from being absorbed by the fertilizer pellets. To avoid having these materials create plugging problems, it is best to prepare a small amount of the mix to observe if the coating agent settles to the bottom of the container, if it forms a scum at the surface, or if it remains in suspension.

When using dry fertilizers as ingredient sources, only 100% water soluble dry fertilizer materials should be used to prepare fertilizer solutions. Several dry fertilizer products used for making fertilizer solutions are marketed with or without a protective conditioner. Whenever possible, the “SOLUTION GRADE” form of these products should be purchased to avoid having to deal with the conditioners and the potential plugging problems they can cause.

Most dry solid nitrogen fertilizers will absorb heat from the water when they are mixed. Consequently, it may be difficult to dissolve as much fertilizer as expected. Dry fertilizer products that significantly lower the temperature of the water in which they are dissolved, include urea, ammonium nitrate, calcium nitrate, and potassium nitrate.

FERTILIZER COMPATIBILITY

THE JAR TEST

A "jar test" involves putting some of the fertilizer solution into a jar of irrigation water, and watching for any precipitate or milkiness which may occur within one to two hours. If cloudiness does occur, there is a chance that injection of that chemical will cause line or emitter plugging. If different fertilizer solutions are to be injected simultaneously into the irrigation system, mix the two in a jar. When testing the compatibility or acceptability of any fertilizer solution or combination of solutions, use the approximate dilution rate that would be expected when the products are injected into the irrigation system.

BASIC MIXING RULES

Some of the basic mixing rules of compatibility include the following:

1. ***Always*** fill the mixing container with 50 – 75% of the required water to be used in the mix if mixing dry, soluble fertilizers.
2. ***Always*** add the liquid fertilizer materials to the water in the mixing container before adding dry, soluble fertilizers. The additional fluid will provide some heat in case the dry fertilizers have the characteristic of making solutions cold.
3. ***Always*** add the dry ingredients slowly with circulation or agitation to prevent the formation of large, insoluble or slowly soluble lumps.
4. ***Always* put acid into water, not water into acid.**
5. When chlorinating water with chlorine gas, ***always*** add chlorine to water, and not vice versa.
6. ***Never* mix an acid or acidified fertilizer with chlorine**, whether the chlorine is in the gas form or liquid form such as sodium hypochlorite. A toxic chlorine gas will form. *Never* store acids and chlorine together in the same room.
7. ***DO NOT*** attempt to mix either anhydrous ammonia or aqua ammonia directly with any kind of acid. The reaction is violent and immediate.
8. ***DO NOT*** attempt to mix concentrated fertilizer solutions directly with other concentrated fertilizer solutions.
9. ***DO NOT*** mix a compound containing sulfate with another compound containing calcium. The result will be a mixture of insoluble gypsum.
10. ***Always*** check with the chemical supplier for information about insolubility and incompatibility.
11. Be extremely cautious about mixing urea sulfuric fertilizers (e.g., N-pHURIC®) with most other compounds. Urea sulfuric is incompatible with many compounds.
12. Many incompatibility problems tend to disappear if chemicals are spoon fed.
13. ***DO NOT*** mix phosphorus containing fertilizers with another fertilizer containing calcium without first performing the jar test.
14. Extremely hard water (containing relatively large amounts of calcium and magnesium) will combine with phosphate, neutral polyphosphate or sulfate compounds to form insoluble substances.

NITROGEN - LIMING EFFECT WITH AMMONIA FERTIGATION

When anhydrous ammonia or aqua ammonia fertilizers are injected into irrigation water, the ammonium is quite water soluble. However, the pH of the water is raised, and some of the ammonia will escape and volatilize into the atmosphere. In addition, the high pH of the irrigation water will cause the calcium and magnesium ions in the water to precipitate as calcium and magnesium hydroxides and carbonates (e.g., $Ca(OH)_2$, $CaCO_3$). This occurs

frequently in the NW portions of Mexico, Arizona, and Imperial Valley, where aqua ammonia and anhydrous ammonia are commonly injected.

This precipitate is lime in a very finely divided form. The harder the water is, the more lime precipitates. This precipitate will clog drip lines and filters, as well as valves, gates, and sprinklers. In addition, this fine precipitate will tend to clog soil pores over time, reducing the water intake rate into the soil.

This precipitation effect is commonly overcome by using long-chain linear polyphosphate water conditioners, such as rose-stone (Calgon®) and other products marketed for this purpose. These products are added to the water upstream to the point of ammonia fertilizer injection.

PHOSPHORUS SOLUBILITY

Monoammonium (MAP) phosphate 12-61-0, diammonium phosphate DAP21-53-0, monobasic potassium phosphate 0-52-34, phosphoric acid, urea phosphate, liquid ammonium polyphosphate 10-34-0, and long chain linear polyphosphates represent several water soluble or water miscible phosphate fertilizers. Nevertheless, they can still have precipitation problems when injected at high application rates into hard irrigation water.

Many farmers who inject phosphorus through drip and microirrigation systems should use acidic forms of phosphorus fertilizers rather than neutral forms. Phosphoric acid injection will be effective only as long as the pH of the fertigated water remains very low. As the pH rises (due to dilution with the irrigation water) the phosphate precipitates with the calcium and magnesium. Some growers supplement phosphoric acid injections with urea sulfuric acid to insure that the irrigation water pH will remain low (3.0 or lower). Caution should be exercised with either of these practices because low pH values (below 5.5) can increase corrosion of metal hardware, increase toxicity of certain micronutrients, or damage plant roots.

POTASSIUM

All potassium fertilizers are water soluble. Potassium sulfate (K_2SO_4) can be run through various gypsum injecting machines by itself, but it might form a mealy substance if it is run together with the gypsum in high calcium waters.

Potassium thiosulfate (KTS) is compatible with urea and ammonium polyphosphate solutions in any ratio. Potassium thiosulfate should not be mixed with acids or acidified fertilizers. When blended with UAN solution, a jar test is recommended before mixing large quantities. Under certain mixing proportions, particularly when an insufficient amount of water is used in the mix, potassium in KTS can combine with nitrates in the mix to form potassium nitrate crystals. If this happens, adding more water should bring the crystals back into solution.

TRENDS IN FERTILIZER USE

The type of fertilizer applied in the irrigation water varies depending on region and crop. For the most part, the most popular fertilizers for fertigation are CAN-17, AN-20, UN-32, urea sulfuric acid, and specialty formulations.

Complete fertilizers (i.e., 8-8-8, 4-10-10, 5-15-5) are popular for applications on vegetable crops, fruit, tree, and vine grown in some areas of California. With the added concern about crop quality, growers are also using more complicated formulations which often include micronutrients. For example, some lettuce growers in the Salinas Valley are applying zinc, manganese, iron, and copper on lettuce to improve yields, increase head uniformity, and increase head size. Some fertilizer dealers blend their own specialty mixes, thus providing special blends at competitive prices. Other dealers are selling "Concentrated Water Soluble Fertilizers" which vary in grade (15-10-30 or 6-30-30). These fertilizers are completely water soluble and are similar to Miracle Grow™. Because they are completely water soluble, they are quite expensive. Their use is limited to a variety of specialty crops such as produced by nurseries. Because nitrogen fertilizers are the most commonly applied fertilizers in fertigation, some notes are given below regarding the most popular forms of nitrogen fertilizers.

ANHYDROUS AMMONIA (82-0-0)

NH_3 (82-0-0) is a liquefied gas which must be handled with special equipment to maintain the high pressure required to keep it in liquid form. It is a colorless gas with a very pungent smelling odor. Ammonia injected into irrigation water will increase the pH of the water significantly. Anhydrous ammonia is no longer sold for fertigation in many areas of California, due to the potential of safety hazards. It should never be used in drip or sprinkler systems, nor in high calcium waters unless treated with long chain polyphosphates or acidification.

AQUA AMMONIA (20-0-0)

$NH_3 \cdot H_2O$ is a liquid fertilizer (20-0-0) sold in some areas of California, but safety hazards in handling this product limit its use. It is a low pressure ammonia solution. That is, it is a solution containing both gaseous ammonia and ammonium hydroxide (NH_4OH). The lid must always remain securely over the tank because the ammonia gas can quickly volatilize. The tank should be of the type to hold pressurized liquids and should be fitted with a pressure relief valve to avoid over-pressurization of the tank. It should never be used in drip or sprinkler systems.

AMMONIUM NITRATE SOLUTION OR AN-20 (20-0-0)

$NH_4NO_3 \bullet H_2O$ is ammonium nitrate fertilizer dissolved in water. It has a density of 10.5 pounds per gallon. This product is commonly used for fertigation in California. *Under no conditions should concentrated AN-20 be mixed with concentrated urea sulfuric acid, concentrated sulfuric acid, concentrated hydrochloric acid, or concentrated phosphoric acid.*

UREA-AMMONIUM NITRATE SOLUTION OR UN-32 (UAN-32) (32-0-0)

$(NH_2)_2CO \bullet NH_4NO_3$: Urea-ammonium nitrate solutions are marketed as 32% nitrogen solutions in warmer agricultural climates; and as 28% nitrogen solutions in cooler agricultural areas. Urea-ammonium nitrate solutions should not be combined with CAN-17 or solutions prepared from calcium nitrate. A thick, milky-white insoluble precipitate forms, presenting a serious potential plugging problem.

CALCIUM AMMONIUM NITRATE OR CAN-17 (17-0-0-8.8CA)

$Ca(NO_3)_2 \bullet NH_4NO_3$: This specialty nitrogen fertilizer is high in nitrate-nitrogen, low in ammonium-nitrogen, and supplies calcium. It is used on crops that have a high calcium

requirement. Moreover, certain crops such as pepper, strawberry, tomato, and eggplant appear to produce higher yields of higher quality fruit when fertilized with predominantly nitrate-nitrogen fertilizer programs. CAN-17 fulfills this requirement. CAN-17, however, should not be applied as a major source of calcium since the crop will be fertilized with excessive amounts of nitrogen. CAN-17 can be combined with ammonium nitrate, magnesium nitrate, potassium nitrate, and muriate of potash (0-0-60), and should not be combined with any products containing sulfates or thiosulfates.

UREA SOLUTION (23-0-0)

Urea is sold as 46-0-0 dry fertilizer or as a liquid 23-0-0 urea solution. Generally, growers purchase urea solution for fertigation, although they can make their own solution by dissolving solid urea in water. Urea makes solutions extremely cold when it is being dissolved. Urea is noncorrosive.

UREA SULFURIC ACID (VARIOUS)

Urea sulfuric acid ($CO(NH_2)_2 \bullet H_2SO_4$) is an acidic fertilizer which combines urea and sulfuric acid. By combining the two materials into one product, many disadvantages of using these materials individually are eliminated. The sulfuric acid decreases the potential ammonia volatilization losses from the soil surface and ammonia damage in the root zone that can occur with the use of urea alone. Urea sulfuric acid is safer to use than sulfuric acid alone.

Urea sulfuric acid is used as follows:

1. To add nitrogen to the soil. This application can be used as a general fertilizer strategy.
2. To acidify the irrigation water, thus reducing the amount of carbonates and bicarbonates in the water. This application can be used as a maintenance strategy to keep drip lines and emitters clear of calcium carbonate deposits.
3. To clean irrigation lines. Once lines have been plugged, urea sulfuric acid can be injected to clean the irrigation lines as a reclamation strategy.
4. To acidify the soil, thus increasing the solubility, availability and mobility of several nutrients.
5. To increase the availability of calcium in soils with free lime.
6. To prevent soil crusting, thus improving germination and soil structure.

This product is commonly sold under various names, such as N-pHURIC® by Unocal. The nitrogen and sulfuric acid contents of these products vary depending on their specific formulation.

GYPSUM INJECTION

Gypsum injection is quite common in many areas of California for the following purposes:

1. Improve water penetration in soils, in conditions of very pure irrigation water.
2. Improve water penetration in soils, in conditions of high Mg/Ca ratios in irrigation water.
3. Improve calcium nutrition in plants, where there is a lack of calcium in the soil and/or water, or an excess of magnesium in the soil or water.

Gypsum is the most readily available bulk source of soluble calcium. Commercial equipment has been readily available for injecting gypsum since the late 1980's.

High quality bulk and sacked gypsum is available from a number of companies, and the quality and form of the gypsum will vary depending upon the natural deposits which are

mined by those companies. Most companies will only guarantee 92% gypsum purity, leaving a potential 8% of other compounds such as clay or $CaCO_3$.

There are two forms of gypsum: (i) natural dihydrate gypsum ($CaSO_4 \cdot 2H_2O$, molecular weight 172.2) and (ii) the natural anhydrite ($CaSO_4$, molecular weight of 136.1, also called anhydrous calcium sulfate). The dihydrate dissolves more rapidly because of the attached water molecules.

There are (broadly speaking) two types of gypsum machines; (i) those which have an agitator that helps to dissolve gypsum, and (ii) those which force water through a tank of gypsum, thereby dissolving the gypsum. At this time, the agitator-type is most common in California. There is a major potential problem with these machines - one so great that some farmers will no longer use them. It can be solved with proper management, however. The agitator-type units tend to inject a slurry of suspended (not dissolved) particles into the irrigation water, with the objective of having everything dissolved before it reaches the emitters or microsprayers. With a good grind, manufacturers expect about 90% of the slurry to be dissolved within a minute, with 100% dissolution within five minutes. If hard particles remain in suspension (i.e., are not dissolved) by the time they reach the first emitters or microsprayers, there is a potential for abrasive damage to the equipment. Such damage has been observed with microsprayers, with the greatest damage closest to the pump (where suspended particles did not have sufficient contact time to dissolve) and less damage with an increased distance from the pump.

The following tentative guidelines are provided to minimize problems. ITRC emphasizes that field testing must be done to ensure local compatibility:

1. The anhydrite form of gypsum is a very hard crystal. It dissolves, but not as quickly as the dihydrate form. There may be some advantage to purchasing gypsum with a higher percentage of dihydrate.
2. The gypsum should have a very fine grind. Some specialists recommend that 98% of the material should pass through a 200 mesh screen, and 100% through a 100 mesh screen. Gypsum is available with a 99.4% passage through a 200 mesh screen. A good grind should minimize problems with dissolving differences between anhydrite and dihydrate forms.
3. Always locate the injector prior to the filtration equipment. MANY installations inject gypsum downstream of filters because the installers know that the filters will plug up with gypsum injection. Such an observation should be considered a blessing - it should tell farmers that something is wrong with the rate of injection, the injection material, or the injection machine.
4. Obtain a laboratory analysis of the material to determine which impurities exist. For example, calcium carbonate impurities are hard and fairly insoluble, and may cause abrasion problems even if the gypsum dissolves. Silicate impurities may also cause abrasion. The presence of some trace elements such as boron, even in low percentages, can cause plant toxicity problems.
5. Purchase a good injection machine which provides a thorough mixing.
6. Do not inject gypsum at excessively high rates which exceed the solubility limit of gypsum in water. In theory, one could dissolve up to about 2400 ppm of 100%

pure dihydrate gypsum (1900 ppm of pure anhydrite). In the field, 1000 ppm of dissolved gypsum is a very high application in pure water.

1000 ppm anhydrite
= 1265 ppm dihydrate
= 14.7 meq/L of calcium
= 2720 pounds of pure anhydrite per acre-foot
= 3440 pounds of dihydrate per acre-foot

Keep in mind that gypsum is a salt, and will increase the salinity of the water. Also, gypsum won't dissolve in water that is already saturated with gypsum.

There is a fairly unanimous opinion in the field that gypsum application must be continuous in order to be effective. Occasional injections may show little if any benefits. This is because the gypsum is a water treatment, rather than a soil treatment. Once the treatment is stopped, pure water can quickly reseal a soil surface. In practice, a continuous maintenance injection rate of 2 – 2.5 meq/L may be sufficient to prevent future pure water infiltration problems.

There is some uncertainty over the dosage of gypsum which is needed for the initial treatments. A field which has been irrigated with pure water for some time will have an established permeability problem. Some field personnel believe that unless high dosages of gypsum are used during the initial treatments, there will be little benefit derived from the gypsum injection.

Note: This information was extracted from the following ITRC publication, which is available for purchase through the ITRC: FERTIGATION. 1995. Burt, C.M., K. O'Connor, and T. Ruehr. ISBN 0-9643634-1-0. 295 p.