

Fertigation Chemicals

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by

Charles M. Burt, P.E., Ph.D.
Professor and Director
Irrigation Training and Research Center (ITRC)
California Polytechnic State University (Cal Poly)
San Luis Obispo, CA 93407
(805) 756-2379
e-mail: cburt@rubens.artisan.calpoly.edu

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FERTIGATION. 1995. Burt, C.M., K. O'Connor, and T. Ruehr. ISBN 0-9643634-1-0. 295 p.

BACKGROUND

When deciding what chemicals to inject, there are numerous considerations to be made. This paper addresses some of the more common factors which should be considered, but which are often overlooked. Because nitrogen fertilizer is injected more widely than any other nutrient, special attention is given to it.

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.

Table 1. Plant composition as influenced by the type of nitrogen nutrition in order to maintain charge balance.

Source of Nutrition	Plant Composition	
	Cations	Anions
NH ₄ ⁺	8 NH ₄ ⁺	
	4 K ⁺	9 H ₂ PO ₄ ⁻
	1 Ca ²⁺	3 SO ₄ ²⁻
	1 Mg ²⁺	1 Cl ⁻
	Sum of Charges	16 +
NO ₃ ⁻		8 NO ₃ ⁻
	8 K ⁺	5 H ₂ PO ₄ ⁻
	2 Ca ²⁺	1 SO ₄ ²⁻
	2 Mg ²⁺	1 Cl ⁻
	Sum of Charges	16 +

In the above example, a plant receiving nearly all of its nitrogen in the form of ammonium will result in a low to deficient level of potassium (K⁺), calcium (Ca²⁺), and/or magnesium (Mg²⁺). The plant will compensate the positive charge by absorbing more phosphate (H₂PO₄⁻) and sulfate (SO₄²⁻) 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 NH₄⁺ 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.

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.

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.

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. Table 2 provides useful information for some of the most commonly injected fertilizers and agricultural minerals.

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 with the use of gypsum injection machines.

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.

Table 2. Solubility information on various fertilizer compounds commonly used to prepare fertilizer solutions and/or for application through irrigation water. (California Fertilizer Association, 1980)

	Grade	Form	Temp °F	Solubility gm/100 ml	Solubility pounds/gal
<u>Nitrogen Fertilizers</u>					
Ammonium Nitrate	34-0-0	NH ₄ NO ₃	32	18.3	9.87
Ammonium Polysulfide	20-0-0	NH ₄ S _x		high	high
Ammonium Sulfate	21-0-0	(NH ₄) ₂ SO ₄	32	70.6	5.89
Ammonium Thiosulfate	12-0-0	(NH ₄) ₂ S ₂ O ₃		v. high	v. high
Anhydrous Ammonia	82-0-0	NH ₃	59	38.0	3.17
Aqua Ammonia	20-0-0	NH ₃ H ₂ O/NH ₄ OH		high	high
Calcium Nitrate	15.5-0-0	Ca(NO ₃) ₂	62	121.2	10.11
Urea	46-0-0	CO(NH ₂) ₂		100.0	8.34
Urea Sulfuric Acid	28-0-0	CO(NH ₂) ₂ • H ₂ SO ₄		high	high
Urea Ammonium Nitrate	32-0-0	CO(NH ₂) ₂ • NH ₄ NO ₃		high	high
<u>Phosphate Fertilizers</u>					
Ammonium Phosphate	8-24-0	NH ₄ H ₂ PO ₄		moderate	moderate
Ammonium Polyphosphate	10-34-0	(NH ₄) ₅ P ₃ O ₁₀ & others		high	high
Ammonium Polyphosphate	11-37-0	(NH ₄) ₇ P ₅ O ₁₆ & others		high	high
Phosphoric Acid, green	0-52-0	H ₃ PO ₄		45.7	high
Phosphoric Acid, white	0-54-0	H ₃ PO ₄		45.7	high
<u>Potash Fertilizer</u>					
Potassium Chloride	0-0-60	KCl	68	34.7	2.89
Potassium Nitrate	13-0-44	KNO ₃	32	13.3	1.10
Potassium Sulfate	0-0-50	K ₂ SO ₄	77	12	1.00
Potassium Thiosulfate	0-025-17S	K ₂ S ₂ O ₃		150	12.5
Monobasic Potassium Phosphate	0-52-34	KH ₂ PO ₄		33	2.75
<u>Micronutrients</u>					
Borax	11% B	Na ₂ B ₄ O ₇ • 10H ₂ O	32	2.10	0.17
Boric Acid	17.5% B	H ₃ BO ₃	86	6.35	0.53
Solubor	20% B	Na ₂ B ₈ O ₁₃ • 4H ₂ O	86	22	1.84
Copper Sulfate (acidified)	25% Cu	CuSO ₄ • 5H ₂ O	32	31.6	2.63
Cupric Chloride (acidified)		CuCl ₂	32	71	5.93
Gypsum	23% Ca	CaSO ₄ • 2H ₂ O		0.241	0.02
Iron Sulfate (acidified)	20% Fe	FeSO ₄ • 7H ₂ O		15.65	1.31
Magnesium Sulfate	9.67% Mg	MgSO ₄ • 7H ₂ O	68	71	5.93
Manganese Sulfate (acidified)	27% Mn	MnSO ₄ • 4H ₂ O	32	105.3	8.79
Ammonium Molybdate	54% Mo	(NH ₄) ₆ Mo ₇ O ₂₄ • 4H ₂ O		43	3.59
Zinc Sulfate	36% Zn	ZnSO ₄ • 7H ₂ O	68	96.5	8.05
Zinc Chelate	5% – 14% Zn	DTPA & EDTA		v. sol.	v. sol.
Manganese Chelate	5% – 12% Mn	DTPA & EDTA		v. sol.	v. sol.
Iron Chelate	4% – 14% Fe	DTPA, HOEDTA & EDDHA		v. sol.	v. sol.
Copper Chelate	5% – 14% Cu	DTPA & EDTA		v. sol.	v. sol.
Zinc Lignosulfonate	6% Zn	Lignosulfonate		v. sol.	v. sol.
Manganese Lignosulfonate	5% – 14% Mn	Lignosulfonate		v. sol.	v. sol.
Iron Lignosulfonate	6% Fe	Lignosulfonate		v. sol.	v. sol.
Copper Lignosulfonate	6% Cu	Lignosulfonate		v. sol.	v. sol.

Dry fertilizer products that significantly lower the temperature of the water they are being dissolved in are 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. For example, injecting both calcium nitrate and ammonium sulfate fertilizers into the same

- irrigation water will cause the formation of calcium sulfate (gypsum)—calcium sulfate has a very low solubility. Although the calcium nitrate is very soluble and the ammonium sulfate has good solubility, they create problems when mixed together in the same container or when poured together from separate mixing tanks. Gypsum crystals will form and can clog drip emitters or filters.
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. Since fertilizer solutions are applied in very small dosages, and if injected at separate locations in the irrigation line, many incompatibility problems tend to disappear. The jar test is essential when it comes to deciding if solutions can be simultaneously injected into the irrigation system.
 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., $\text{Ca}(\text{OH})_2$, CaCO_3). This occurs frequently in the NW portions of Mexico, 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 (DAP) 21-53-0, 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.

SPECIFIC FERTILIZERS AND AGRICULTURAL MINERALS

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. ITRC conducted a limited survey of major fertilizer dealers in different areas of California regarding the extent of fertilizer sales for *fertigation*. Table 3 summarizes the findings.

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.

Table 3. A summary of the fertilizers sold specifically for fertigation in California according to a 1994 ITRC survey conducted of major fertilizer dealers.

Fertilizer	Grade	Cost Range (\$)	Unit	Number of Dealers Responding Relative amount sold for fertigation			
				V. Much	Avg.	Little	None
Ammonium Bisulfate*	8-0-0-11	170	ton			2	5
Ammonium Molybdate							7
Ammonium Nitrate	34-0-0	200	ton		1		6
Ammonium Nitrate Solution	20-0-0	160 – 210	ton	2	1	1	3
Ammonium Phosphate	8-24-0					1	6
Ammonium Polyphosphate	10-34-0	250 – 400	ton	1	4	2	
Ammonium Polyphosphate	11-37-0						7
Ammonium Polyphosphate	7-21-7					7	
Ammonium Polysulfide	20-0-0-45					1	6
Ammonium Sulfate	21-0-0	170	ton		1	15	
Ammonium Thiosulfate	12-0-0-26	168 – 220	ton	1	2	2	2
Borax							7
Boric Acid							7
Calcium Ammonium Nitrate	17-0-0	173 – 300	ton	5	1		1
Calcium Nitrate	15.5-0-0	200 – 351	ton	2		2	3
Calcium Polysulfide		270	ton		1		6
Concentrated Super Phosphate	0-45-0						7
Copper Sulfate		1.50	lb			1	6
Cupric Chloride							7
Diammonium Phosphate	18-46-0						7
Gypsum	0-0-0	121	ton		1	1	5
Iron Sulfate	0-0-0	251	ton			1	6
Lime Sulfur	0-0-0	230	ton		1	1	5
Long Polyphosphate Chain							7
Magnesium Sulfate	0-0-0	0.47	lb			1	6
Manganese Sulfate	0-0-0						7
Monoammonium Phosphate	11-48-0						7
Monoammonium Phosphate	11-55-0						7
Phosphoric Acid (white)	0-54-0	1,000	ton			1	6
Phosphoric Acid (green)		600	ton			1	6
Potassium Chloride	0-0-60	100 – 137	ton		1	2	4
Potassium Nitrate	13-0-44	570 – 607	ton			2	5
Potassium Phosphate	0-10-6-14.5						7
Potassium Sulfate	0-0-50	354	ton			1	6
Potassium Thiosulfate (KTS)	0-0-25-17	491	ton			1	6
Sodium Molybdate	0-0-0						7
Solubor	0-0-0	1.40	lb			2	5
Sulfur Dioxide Gas	0-0-0						7
Sulfuric Acid	0-0-0	110	ton			1	6
Superphosphoric Acid	0-68-0						7
Urea	46-0-0	220 – 300	ton		2	1	4
Urea Ammonium Nitrate	32-0-0	200 – 270	ton	5	2		0
Urea Phosphate	17-44-0						7
Urea Phosphate	10-34-0						7
Urea Solution	20-0-0	190	ton			1	6
Urea Sulfuric Acid	10-0-0-18	300	ton	1			6
Urea Sulfuric Acid	15-0-0-49	183 – 240	ton	1	2	1	3
Urea Sulfuric Acid	28-0-0-9						7

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.

AQUA AMMONIA (20-0-0)

$\text{NH}_3 \cdot \text{H}_2\text{O}$ 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)

$\text{NH}_4\text{NO}_3 \cdot \text{H}_2\text{O}$ 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)

$(\text{NH}_2)_2\text{CO} \cdot \text{NH}_4\text{NO}_3$: 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)

$\text{Ca}(\text{NO}_3)_2 \cdot \text{NH}_4\text{NO}_3$: 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 ($\text{CO}(\text{NH}_2)_2 \cdot \text{H}_2\text{SO}_4$) 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 well suited for fertigation and can be used for other purposes.

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 (Table 4).

Table 4. Summary and constituents of N-pHURIC[®] products.
(Unocal, 1993)

Product	Density pounds/gal	Nitrogen %	Sulfuric Acid %	Sulfur %
N-pHURIC 10/55	12.8	10	55	18
N-pHURIC 15/49	12.7	15	49	16
N-pHURIC 28/27	11.8	28	27	9