Fertilizer efficiency for winegrape vineyards

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In the winegrape business, competition is more intense than ever before. Grape growers, through their winery customers, are feeling the pressure of imported wine. Just as real, but less often considered, is the competition among U.S. growers producing grapes for wines at the same price-point.

The only reasonable response to competition, and the only way for a vineyard enterprise to prosper, is to farm smarter. This includes capturing the greatest possible return on operating expenditures, such as fertilizers. This article addresses fertilizer efficiency for winegrape vineyards.

Fertilizer efficiency

Fertilizer efficiency represents fertilizer performance per unit cost, not fertilizer cost alone or nutrient content. Fruit yield is the most common measure of performance, but balanced growth and fruit quality are increasingly important to winegrape growers. For researchers, fertilizer efficiency can be the amount of fertilizer nutrient that is taken up by the plant.[24]

Perfect fertilizer efficiency involves the exact amount of mineral nutrient, in the right form, in the correct place, at the proper time to be entirely taken up and used by grapevines. In reality, perfect fertilizer efficiency is not possible due to technological, environmental, and grapevine constraints.

Technological factors that influence fertilizer efficiency include application rate and timing, placement, and formulation. Due to several technological advances that have greatly improved fertilization efficiency, fertilizer technology is often the least limiting of the factors affecting fertilizer efficiency in vineyards.

Table I. Liquid fertilizers commonly used for winegrape vineyard fertigation[1].

Name	Analysis (2)	Effect on Soil pH
Urea Ammonium Nitrate or UAN-32	32-0-0	Acidifying
Calcium Nitrate or CN-9	9-0-0-11(Ca)	Basic
Calcium Ammonium Nitrate or CAN-17	17-0-0-8.8 (Ca)	Mildly acidifying
Ammonium Polyphosphate	10-34-0	Acidifying
Phosphoric Acid	0-54-0	Acidifying
Potassium Sulfate or ESP	1-0-8-2.5(S)	Neutral
Potassium Chloride	0-0-10-8(Cl)	Neutral

[1] Sources: Burt (1998), Christensen (1995), Farm Chemical Handbook (2001), Mid Valley Agricultural Services (2002), Western Fertilizer Handbook (1998).

Fertilizer efficiency is optimized when application timing or availability in the soil coincides with periods of high nutrient demand and uptake. For example, potassium fertilizer efficiency is often greater in early to mid-summer when soils have warmed, roots are highly active, and berries are rapidly growing than earlier in the growing season. For most nutrients, less value is captured from fertilizer applied during the winter when vines are dormant. (For more information regarding fertilizer application timing, refer to ***PWV*** May/June2002).[6]

In general, several low-rate applications are more efficient than infrequent high-rate applications. Exceptions include phosphorus- and potassium-deficient vineyards, which usually require large applications to satisfy both the nutrient absorption capacity of the soil and grapevine needs. In all circumstances, application rates that greatly exceed vine needs and uptake capabilities are inefficient.

Placing fertilizer in or on the soil near active roots is much more efficient than placing it where there are no roots. Placement of dry fertilizer to correct phosphorus and potassium deficiency is particularly critical. In these vineyards, fertilizer is most effective when placed in a concentrated band on or below the soil surface adjacent to the vine row.[4,6,21] Such placement saturates the soil's absorption capacity and leaves the remaining fertilizer nutrients available for vine use.

Fertilizer formulation is critical, because it determines solubility, the requirement for conversion by microbes within the soil, the likelihood of fixation within the soil, relative ease of uptake by vine roots, the potential for loss from the soil, and the potential for undesirable side effects on soil chemistry.

Improper use and poor maintenance of application equipment degrade the value of fertilizer technology and erode fertilizer efficiency. Proper use of ground application equipment includes correct calibration. Spray applications are optimized when the equipment ground speed is correct and consistent as possible, droplets are of the appropriate size, and a minimum amount of spray misses the target.

When the target is the grapevine canopy, optimization includes complete coverage with minimum run-off. Proper applications into irrigation water involve full charging of irrigation systems before fertilizer injection, sufficient runtime for uniform fertilizer distribution, and a flushing period after injection of sufficient duration to completely flush the system.

Several plant factors affect fertilizer efficiency. One such factor is grapevine nutrient demand. Potential fertilizer efficiency is highest during or shortly before periods of high nutrient demand. For example, pre-bloom and bloom foliar zinc applications provide greater fruit set benefit and economic return than applications made at other times.[4]

Root system condition has a significant impact on fertilizer efficiency. Younger roots (and leaves) absorb fertilizer nutrients more readily than older tissues.[14] Limited root system distribution and extensiveness will limit access to soil-applied fertilizers, thereby decreasing efficiency.

For example, vines with root systems limited by soil-borne pests (*Phylloxera* and nematodes) have greater difficulty in taking up fertilizer nutrients. Under such circumstances, a comprehensive soil management program involving organic soil amendments, fertilizers, and frequent irrigation can enhance root growth and extensiveness, thereby improving potential fertilizer efficiency.

Rootstocks influence mineral uptake and movement within a grapevine, as well as root system distribution and extensiveness. For example, Freedom rootstock is highly effective in acquiring phosphorus.[7]

Similarly, leaf characteristics, such as amount of pubescence vary with winegrape variety and, as a result, so do capabilities to take up mineral nutrients from foliar-applied fertilizers. Clearly, some scion-rootstock combinations are inherently more efficient fertilizer users than others.

In soils, several possible fates await a recently applied fertilizer nutrient. The best possible outcome, and the most efficient, is uptake by a grapevine root. However, direct uptake is limited for some fertilizer formulations, such as urea-nitrogen. These molecules are normally converted to a form more readily taken up by vine roots (mostly nitrate).[21] Alternatively, a fertilizer nutrient may be precipitated as an insoluble compound, trapped between clay layers, adsorbed on the exterior of a soil particle, or otherwise fixed by the soil and made unavailable to vines.

Grapevines have sources of competition for mineral nutrients other than the soil reactions mentioned above. Mineral nutrients already present in the soil solution may compete with a particular fertilizer nutrient for uptake by grapevines (such as magnesium competing with potassium).[21] Soil microbes also compete for nutrients, and their numbers and nutrient-consumption temporarily swell after a nitrogen-fertilizer application.[21] Weeds are very effective competitors that can greatly diminish the value of a fertilizer application.

Adverse soil conditions that impair root function and health will limit the uptake and efficiency of applied fertilizer nutrients. These include excessive moisture, compaction, low temperatures, and high salinity.

Vine leaves absorb foliar-applied nutrients most effectively when fertilizers dry slowly and fertilizer efficiency suffers during hot, dry, or rainy weather. Sunlight also promotes foliar nutrient uptake.[14]

Losses to the environment are the last major factor limiting fertilizer efficiency. Some fertilizer formulations (such as ammonia) readily volatilize and may be lost to the atmosphere without careful management.[21] Other highly soluble nutrients (such as nitrate) are prone to leaching from the root zone.[2,21] Another avenue to loss is surface run-off, which carries nutrients attached to soil particles.

Table II. Recently developed fertilizer products commonly available in California for winegrape vineyard fertigation.

Product	Fertilizer Formulation	Analysis	Vineyard Uses	Manufacturer
K-MEND	Potassium thiosulfate	0-0-25-17(S)	Rapid K uptake, fertilizer mixes, alkaline soils	Best Sulfur Products
K-Thio	Potassium thiosulfate	0-0-25-17(S)	Rapid K uptake, fertilizer mixes, alkaline soils	Na-Churs Alpine
KTS	Potassium thiosulfate	0-0-25-17(S)	Rapid K uptake, fertilizer mixes, alkaline soils	Tessenderlo Kerley
Thiocal	Calcium thiosulfate	0-0-0-10(S)-6(Ca)	Rapid Ca uptake, alkaline soils	Best Sulfur Products
CaTs	Calcium thiosulfate	0-0-0-10(S)-6(Ca)	Rapid Ca uptake, alkaline soils	Tessenderlo Kerley
MagThio	Magnesium thiosulfate	0-0-0-10(S)-4(Mg)	Rapid Mg uptake, fertilizer mixes, alkaline soils	Tessenderlo Kerley
pHighter-K	Potassium carbonate	0-0-28-3(org. acids)	K for acid soils & high sulfur soils	Actagro
0-0-30	Potassium carbonate	0-0-30	K for acid soils & high sulfur soils	Na-Churs Alpine
Organocal	Calcium carbonate & organic acids	1.2-0-0-20(Ca)-2(org. acids)	Ca for acid soils & high sulfur soils	Actagro
Mainstay Calcium	Calcium carbonate (encapsulated)	0-0-0-20 (Ca)	Ca for acid soils & high sulfur soils	Redox Chemical
Mainstay Magnesium	Magnesium carbonate & magnesium hydroxide	0-0-0-20 (Mg)	Mg for acid soils & high sulfur soils	Redox Chemical
Structure	Nitrogen & phosphorus organic acid complexes	7-21-1-7(org. acids)	Fertility programs emphasizing N & P	Actagro
Cache	Nitrogen, phosphorus, & potassium organic acid complexes	4-6-10-3(org. acids)	Fertigation programs emphasizing N, P, & K	Acatagro
Monarch	Nitrogen,phosphorus, & potassium organic acid complexes	2-20-15-3(org. acids)	Foliar fertilization	Actagro

Fertilizer industry's technological advances

Soil amendments (organic wastes and mined mineral materials) and leguminous cover crop residues are the traditional inputs for managing vineyard mineral nutrient supplies. These materials can serve as effective fertilizers, but have the disadvantages of bulk, low nutrient content, and slow and somewhat unpredictable nutrient release that frequently is not in synchrony with vine requirements.[17]

For this reason, they often fail to provide sufficient nutrients to avoid deficiencies in grapevines, especially in soils with very low quantities of available nutrients, soils that absorb large quantities of applied nutrients, and for vineyards with a very large nutrient need (such as high-density plantings and vineyards with large crops). Even under the best circumstances, the fertilizer efficiency of soil amendments and cover crop residues is usually low in winegrape vineyards.

While organic amendments may not be highly efficient fertilizers, repeated applications can increase soil organic matter. Soil organic matter serves several functions critical to sustained productivity in vineyards, including contributing to a soil's cation exchange capacity (CEC) or ability to retain positively-charged nutrients like potassium, calcium, and magnesium. As supplies of these nutrients in the soil solution are depleted, nutrients held by organic matter reenter the soil solution and buffer the nutrient supply available to vines. By this action, organic matter increases fertilizer nutrient residence time in the soil, the opportunity for uptake by vines, and the benefit of the fertilizer.

A few types of refined and manufactured fertilizers have been available since the late 19th century, but they did not become widely used until after World War II.[1,17,21] For the most part, these fertilizer products are inorganic salts (such as ammonium phosphate). Compared to soil amendments, they are concentrated and release nutrients rapidly and predictably. These characteristics allow them to saturate a soil's absorption capacity and meet very large nutrient needs. In spite of these advantages, refined and manufactured fertilizers are still subject to inefficiencies. These include application timing and placement limited by tractor-pulled equipment, and for some fertilizers, slow solubility in soil moisture.

Research reports of foliar fertilization of grapevines first appeared in the 1950's.[25] The technique was quickly adopted for correcting micronutrient deficiencies.[4] The foliar technique supplies nutrients more rapidly than techniques involving the roots, but benefits are shorter lived.[14] The efficiency of foliar fertilizer application is limited by the low capacity of foliar organs to absorb mineral nutrients. In general, there is greater flexibility in in-season fertilizer application timings with foliar compared to other ground based application methods.

Chelation

Chelation is an innovation that increases availability of certain mineral nutrients and, thereby, potential fertilizer efficiency. A chelate is a compound involving a mineral nutrient and a surrounding, protective organic molecular structure.[2,21] Chelates are expensive to produce and, for this reason, are usually cost-effective only for mineral nutrients required in small quantities.[2] Chelates of zinc, manganese, iron, and copper have become standard products for foliar application in many vineyards. Chelate efficiency is reduced in soils by salinity and acidity, and some chelates are better adapted to certain soil conditions than others (for example, diethyleneaminepentaacetic acid [DPTA] works better in alkaline soils than ethylenediaminetetraacetic acid [EDTA]).[2]

Amino acid chelation is a recent technology that has further enhanced nutrient-uptake and foliar-fertilizer efficiency.[10,11,12] Amino acids are components of proteins found in all organisms. In fertilizers, amino acid chelates possess a pseudo-natural structure that is small, rounded, highly-soluble, neutral in charge, and therefore, readily taken up and used by foliar grapevine tissues (leaves, stems, and clusters).[23] Amino acids contain a small amount of nitrogen that has fertilizer value. Some amino acid chelate fertilizers are approved by the Organic Materials Review Institute (OMRI) for organic vineyards.

Fertigation

Perhaps the most important innovation leading to improved fertilizer efficiency is not a fertilizer technology, but rather the irrigation technology known as micro- or drip irrigation. Using a drip-irrigation system, a winegrape grower can apply fertilizer any time, and place it where grapevine roots are most numerous and active.[2,17,21] In other words, drip irrigation overcomes the timing and placement limitations of tractor-pulled application equipment. Actually, it eliminates the need for tractors, application equipment, and tractor drivers, allowing most of the fertilizer application costs to be absorbed as irrigation costs.

Fertigation is the practice of applying fertilizers with irrigation water. In addition to greater flexibility in application timing and optimal placement, fertigation increases the rate of nutrient uptake and predictability of vine response to fertilization compared to broadcast and band applications.[2,18,20] Consequently, it is normally the most efficient fertilizer application method.

Fertigation is evolving along with grower's understanding of soils and grapevines. The total seasonal nutrient need of a vineyard can be estimated based on yield, vigor, and soil conditions. This is used to create a schedule of nutrient applications to meet specific needs of particular developmental stages (pre-bloom, post-bloom, ripening, and post-harvest). These balanced fertigation strategies optimize nutrient availability and avoid nutrient imbalances (deficiencies and excess), greatly increasing fertilizer efficiency.[6]

Fertigation is especially valuable mid-season, after moisture stored from winter rains has been depleted and the active root zone is maintained under the vine row where water is being periodically applied. In this limited volume of soil, chemical changes are much more rapid than in the surrounding soil, including nutrient depletion by vine roots.[6,16] Just as rapidly, the nutrient supply can be efficiently restored through careful fertigation. The key operative is careful, because careless fertigation is not efficient and can produce undesirable side effects, including soil acidification, salinization, loss of soil structure, greatly diminished microbial activity, and pollution of the environment.

Fertilizers suitable for fertigation fall into two categories: highly soluble solid (solution grade) fertilizers and clear liquid fertilizers.[2] Many conventional fertilizers, such as potassium sulfate, have been adapted to fertigation through refining and reformulation (Table I). Micro-nutrients, such as zinc chelates, are also effectively applied by fertigation.[21]

Fertilizers for fertigation

In recent years several innovative, highly soluble fertilizers have been developed expressly for fertigation. These include the thiosulfates, carbonates, hydroxides, and organic acid complexes (Table II). Some of these materials have characteristics that lend themselves to specific soil conditions, while others are suitable for a wide range of soils. Most of them have been available for a relatively short period – so short that little research information about them is available. Some of them remain to be fully tested under field conditions.

Potassium and calcium thiosulfate are more soluble than sulfate based fertilizers. They also appear more efficient than sulfate and chloride-based fertilizers.[9,5]

Potassium thiosulfate, compared to other potassium fertilizers, has the dual advantages of high potassium content (about 2.5 lb K per gal) and low soil salinization potential. It also contains more sulfur and results in greater sulfur uptake than liquid potassium sulfate.[8]

In 2005, magnesium thiosulfate became available as a liquid alternative to magnesium sulfate. Like other thiosulfates, it can be mixed with other fertilizers to make nutrient blends suitable for balanced soil fertility programs.[2] All thiosulfate fertilizers have one characteristic that is disadvantageous under some circumstances — they tend to acidify soils. Potassium thiosulfate has the greatest capacity for soil acidification among the three fertilizers discussed.

Some soils are not amenable to thiosulfate fertilizers. For example, certain soils have an overabundance of sulfur, but require potassium, calcium, and/ or magnesium. Also, most strongly acid soils require potassium, calcium, and magnesium, but responsible management of these soils precludes the use of acidifying fertilizers, no matter how slight their effect. The soil under the emitters in most vineyards becomes acidic over time due to the leaching of minerals and application of acidifying fertilizers, including N-P-K blends used in balanced soil fertility programs.

Fortunately, a few fertilizers neutralize soil acidity. Perhaps the best known of the alkalinizing fertilizers is calcium nitrate, which is a highly efficient source of calcium, but calcium nitrate applications are limited by the adverse side-effects of excess nitrogen on vine vigor and fruit quality. Liquid formulations of calcium carbonate are an effective supplemental source of calcium under these conditions. Acid soils are usually low in potassium and magnesium and liquid formulations of potassium and magnesium-carbonate and hydroxide are adapted to them.[19,21]

It is important to note that the fertilizers described above will have a limited effect on soil pH because they are applied at low rates. They are not substitutes for agricultural lime or dolomite to raise the pH of an acid soil. They must be injected slowly into high calcium and magnesium irrigation water to avoid clogging of drip emitters.

Humic substances are a complex group of large, stable organic molecules found in very old deposits.[13,16] Mineral nutrients complexed (lightly-bonded) with humic substances can be highly effective fertilizers.[22] They act similarly to chelates by improving availability of the mineral nutrient, but unlike chelates, plants can absorb them in their entirety.[3] In this way, they act as a nutrient delivery system. Also unlike chelates, they are comparatively inexpensive to produce and are cost-effective for soil, as well as foliar application of both macronutrients and micro-nutrients.

In addition, organic acids increase the solubility of some mineral nutrients under acid and alkaline conditions.[16] There are several formulations of organic acid-complexed fertilizers with various mineral nutrients. Some organic-complexed fertilizers are OMRI-approved.

Conclusion

There is ample opportunity to optimize the efficiency of fertilizer use in your vineyard, regardless of your production goals. Keep in mind that efficiency is measured by performance per unit cost, not fertilizer cost alone or nutrient content. Use the combination of technologies that renders the greatest return on your fertilizer investment within the constraints of your scion-rootstock and vineyard environment. ■

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