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Application of the "4R" Nutrient Stewardship Concept to Horticultural Crops: Selecting the "Right" Nutrient Source

Mark Gaskell[1,3] and Tim Hartz[2]

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SUMMARY. Nutrient management practices must be tailored to the crop, environment, and production system if nutrient efficiency and environmental water quality protection are to be achieved. This requires consideration of fertilizer choice, placement, application rate, and timing. These factors have been characterized as the "4Rs" of nutrient stewardship—right material, right placement, right rate, and right timing. The factors affecting the choice of fertilizer material have been described previously for agronomic crops, and include plant nutritional requirements, soil conditions, fertilizer delivery issues, environmental risks, product price, and economic constraints. Although those factors are applicable to all crops, the unique features of intensive horticultural production systems affect their interactions. This article discusses fertilizer choice as it affects productivity, profitability, sustainability, and environmental impact of intensive horticultural crop production. Diverse fertilizer materials are available for specialized application to provide nitrogen, phosphorus, potassium, and other plant nutrients for different horticultural needs. These fertilizer sources can be formulated as dry or liquid blends, but increasingly higher solubility materials are used to target plant growth needs even in field operations. Composts can have useful applications—particularly for certified organic production—but their high cost, bulk, and relatively low efficiency limit their use. Profitability can be affected by fertilizer cost—typically a relative small percentage of overall costs in intensive production systems—and the improved efficiency of these specialized materials often improves profitability. There are also sustainability issues with the manufacture, transport, and efficient use of different fertilizer sources. Such factors as soil chemical reaction changes, effects on soil salinity, and loss of organic matter also can adversely affect sustainability, but systems are available to maintain soil quality while using more efficient fertilizer sources.

The multiple factors affecting the choice of fertilizer material source can include plant nutritional requirements, soil and climate conditions, fertilizer delivery issues, environmental risks, and economic constraints (Mikkelsen et al., 2009). Intensive horticultural production systems involve a wide range of management options that affect interactions among these factors. Nitrogen (N) is available in the form of urea, ammonium (NH_4), or nitrate (NO_3), or as combinations of these forms; anhydrous ammonia is seldom used on horticultural crops. A large body of hydroponic research has documented a general improvement in plant growth when nutrient solutions contain more NO_3-N than NH_4-N; most hydroponic production is now accomplished with nutrient solutions containing predominately or solely NO_3-N. Another reason for favoring NO_3-N in nutrient solutions for the production of fruiting crops [tomato (*Solanum lycopersicum*), pepper (*Capsicum annuum*), etc.] is the suppression of blossom end rot (BER); NH_4-N can reduce calcium (Ca) uptake and induce the disorder (Bar-Tal et al., 2001).

In field production, the choice of N form is more complicated. Urea and NH_4 fertilizers are readily converted to NO_3 through hydrolysis and nitrification reactions, at least at soil temperatures above 68 °F (Havlin et al., 2005). Regardless of fertilizer N form applied, NO_3-N concentration usually exceeds that of NH_4-N in well aerated, temperate soils (often by an order of magnitude), and NO_3-N represents the majority of crop N uptake (Haynes, 1986). In colder soils nitrification is slower, and NO_3-form fertilizer may provide more rapid plant N uptake. Although the use of NO_3-N during fruit development is a common recommendation for field-grown tomato and pepper to prevent BER, documentation linking NH_4-N application and BER severity in field production is less compelling than in greenhouse culture.

The various forms of ammonium phosphates comprise the majority of phosphorus (P) fertilizers used in horticultural production. High purity mono and diammonium phosphate and potassium mono and diphosphate are commonly used for nutrient solutions and specialty fertilizers for the greenhouse and ornamental industries. Ammonium phosphates or polyphosphates dominate the market for soil-applied P. Phosphoric acid also has specialty uses in both greenhouse and field production; for example, it can be injected into drip irrigation systems where other P sources may form precipitates with Ca in the irrigation water. Since all these fertilizers supply P in PO_4^- form, the choice of product for a particular purpose is based on factors such as cost, solubility, companion ions supplied, or effect on soil or solution pH.

Potassium chloride and potassium sulfate constitute the overwhelming majority of potassium (K) fertilizer use on horticultural crops, with potassium nitrate and potassium thiosulfate used more sparingly. Potassium chloride, the least expensive K source, is avoided by growers of chloride-sensitive crops [e.g., strawberry (*Fragaria* ×*ananassa*)], some tree fruits, and ornamentals (Maas, 1984). Potassium thiosulfate offers higher solubility than potassium sulfate and an acid soil reaction, but at considerably higher price. Potassium carbonate has a basic soil reaction, but also at a higher price.

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[1]Farm Advisor, University of California Cooperative Extension, 2156 Sierra Way, San Luis Obispo, CA 93401

[2]Extension Vegetable Specialist, Department of Plant Sciences, University of California, Davis, CA 95616-8780

[3]Corresponding author. E-mail: mlgaskell@ucdavis.edu.

Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
1.1209	lb/acre	$kg \cdot ha^{-1}$	0.8922
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32