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SL315

UF UNIVERSITY of FLORIDA
IFAS Extension

Principles of Sound Fertilizer Recommendations[1]

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Introduction

This document provides an integrated discussion of all the components that must be considered when making an appropriate fertilizer recommendation. The recommendation should produce the desired crop increase in yield and/or quality, yet avoid associated pitfalls of fertilizer mismanagement resulting in potential degradation of the environment. These processes require field research and not just testimonials or non-statistical measurements. The first step is to keep the fertilizer in the root zone and available to the crop through water management. Nutrients can be moved from the field by poor water management, despite the best intentions of the grower.

While a soil-test result might reflect the likelihood of a positive crop response to applied fertilizer, determination of the amount of fertilizer requires that the soil test be both calibrated and interpreted for the specific crop.

After soil-test calibration and water management, an understanding of the philosophy associated with fertilizer recommendations is an essential element of a fertilizer recommendation. The conceptual approach to fertilization, the philosophy, is important because concepts originating in other areas of the country with fine-textured soils and considerably less rainfall are impractical for Florida growing conditions.

To approach these and other important considerations discussed in this document that result in a sound fertilizer recommendation, one has to use scientific methods, which are partially discussed in the document and in more detail in related EDIS documents. The political situation surrounding fertilizer use often distorts fertilizer recommendations. Some argue that fertilizers have caused considerable environmental damage, while others laud the use of fertilizers because of the improved yield and quality that can be achieved with their use. In fact, both views are correct. The only way to document and decide on appropriate fertilizer recommendations is through a strong scientific approach so that the concerns and issues by both political camps are addressed and explained with correctness.

1. This document is SL315, one of a series of the Soil and Water Science Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date February 2010. Visit the EDIS Web Site at http://edis.ifas.ufl.edu.
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History of Fertilizer Use in Vegetable Production

Crop production until the early part of the 20th century depended on native soils and their inherent fertility. Certain minerals, e.g., rock phosphate, sodium nitrate, potassium silicate, etc., were found to increase productivity, and organic nutrient sources, such as animal manures, were added to the soils. These materials supplied nutrients not available from the native soil, or supplied certain nutrients in amounts greater than supplied from the soil to meet crop nutrient needs. In the early to mid 20th century, chemical and synthetic nutrient sources came into wide use. These fertilizers could be manufactured in large amounts and were inexpensive to use, given the positive crop responses that resulted. Synthetic fertilizers soon replaced organic nutrient materials for providing needed nutrients to crops.

Fertilizers are applied in crop production to improve crop productivity and quality. Fertilizers have played a significant role in increasing crop productivity in the world and increasing farming profitability. Fertilizer use has led to more productivity on fewer acres and helped maintain U. S. food costs at the lowest levels in the world.

Scientific research played a role in ushering in the fertilizer age in crop productivity during the mid 20th century. Research that was conducted mainly in crop fields provided guidelines for the amount of fertilizer to use and how to apply it to the crop. Scientific methods were used to develop the means for efficiently using fertilizers, including soil testing methodologies, application technologies, and new fertilizer materials. Fertilizer recommendations during most of the 20th century focused on crop productivity and economics.

Environmental Considerations in Fertilizer Use

In the latter part of the 20th century, scientists expressed concerns about nutrient enrichment of surface water bodies and ground water. Fertilizer recommendations began incorporating stronger references to managing fertilizers for crop productivity in the context of protecting the environment. Today, fertilizer recommendations must consider both farm-scale economics and society's sometimes competing objectives to maintain a safe, affordable food supply and a healthy environment.

The Link Between Farming and the Environment: Best Management Practices (BMPs)

At the national level, nutrients from all human activities and sources can enter water bodies and cause pollution. Agricultural fertilizer use and management became an issue in the late 1960s and early 1970s. A portion of the nutrients used to aid crop production and quality may leave the farm through non-point source runoff and enter adjacent water bodies. Increasing concentrations of nutrients from human sources has led to algae blooms, much lower dissolved oxygen in the water column resulting in dying or distressed fish and other aquatic life, and unpleasant odors from affected waters.

The federal Clean Water Act of 1972 requires states to identify impaired waters and establish load limits, called Total Maximum Daily Loads (TMDLs), for the pollutants of concern. The 1999 Florida Watershed Restoration Act (FWRA) provides the framework for the state's TMDL program. As a part of the FWRA, FDEP establishes TMDLs and may adopt Basin Management Action Plans (BMAPs) to implement them. Agricultural operations within a BMAP area are required to implement FDACS-adopted BMPs or monitor their water quality to show compliance with the TMDLs. (For more information see: *Total Maximum Daily Loads and Agricultural BMPs in Florida* http://edis.ifas.ufl.edu/AE388). Accordingly, FDACS-adopted BMPs are designed to produce water quality benefits along with some water conservation benefits. The adopted BMPs are based on research and typically consist of the University of Florida IFAS Extension nutrient management recommendations. The Extension recommendations for vegetables are based on more than 50 years of experimentation, often including tests conducted on commercial farms.

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Water Management: A Crucial First Step in a Fertilizer Recommendation

Before addressing the other important components of the fertilizer recommendation, water for both irrigation and drainage must be efficiently managed. Any fertilizer recommendation is of little use if water is not managed correctly. Environmental problems occur when movement of nutrients from the field is facilitated by water. In effect, water is the vehicle or mode of transport that can move nutrients off of the farm. If a grower adequately manages water, then nutrients will be available for improved yield and quality, greatly improving the efficiency of the applied fertilizer and minimizing the possibility of adverse environmental consequences. Please see the "For More Information" section for documents addressing water management.

Philosophies of Fertilization

While concern for the environment has influenced fertilizer research and the resulting recommendations, not all recommendations are based on the same philosophical approach concerning fertilizer use, soil interactions, and nutrient movement. In fact, for Florida soils, some fertilization philosophies work against environmental protection, and also increase production costs. Philosophies largely differ based on their approach to fertilizing the soil versus fertilizing the crop. The following section describes philosophies that are influencing soil testing and fertilizer recommendations in commercial use within Florida today. This discussion focuses on P and K. The University of Florida does not recommend soil testing for nitrogen because N is mobile in Florida's largely sandy soils.

Build-Up and Maintenance

This philosophy has been applied since the 1940s, mostly by commercial soil testing laboratories. This philosophy claims that nutrient concentrations can be built up and maintained in the soil. This approach assumes that fertilizer additions will increase the soil-test value in time; however, increasing soil nutrients is really only possible in areas of the country where evapotranspiration exceeds rainfall and fine-textured soils are found. This philosophy is one of three of the main philosophies that are based on the principle of *fertilizing the soil,* rather than that of fertilizing the plant. During the build-up phase, fertilizer is added to supply nutrition to the crop plus some extra to contribute directly to increase the soil-test value. The assumption is that the built-up fertilizer will stay in the soil (presumably in the root zone) and will not be lost to leaching or run-off. Once a critical soil-test value is reached, fertilizer is added to maintain the soil-test at or slightly above the critical value (i.e., some fertilizer for the crop and some extra to maintain the soil-test level.)

With this philosophy, a grower rarely omits fertilization of the soil in any season. In Florida rainfall and/or excessive irrigation of our coarse-textured sandy soils can often cause nutrients to leach. Hence, this philosophy increases the cost of fertilizer, usually does not result in the expected increase of soil-test values, and exposes adjacent water bodies to fertilizer nutrients. While soil testing for P may show annual changes, considerable P could be leached or lost to run-off, resulting in poor nutrient use by the plant and increased costs for the grower. When considering this philosophy for K, this nutrient is so mobile in our sandy soils that any significant buildup is impossible. Florida just does not have the type of soils or environment to employ the build-up and maintenance philosophy without much higher production costs and environmental penalties.

Basic Cation Saturation

The basic cation saturation philosophy assumes that the amounts of cations on clay and organic particles in the soil (the cation exchange capacity of the soil) can be manipulated with the addition of fertilizers to achieve an ideal ratio of nutrients at the exchange sites. This approach to fertilization is another philosophy considered to be *fertilizing the soil* rather than the plant. Further, in the quest to achieve and maintain the ideal ratio, the farmer must also fertilize the soil every season.

In addition to the problems mentioned for the build-up and maintenance philosophy above, the basic cation saturation philosophy erroneously assumes that plants will do best at some specific ratio

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of the cations. Most Florida soils do not contain appreciable amounts of clays and humus that provide cation exchange sites. There are soils with more clay (panhandle) and organic matter (Everglades), but the majority of vegetable soils are mostly sands. Specifically for Florida's soils, the cation exchange capacity found in sands is quite low and unlikely to supply nutrients throughout the growing season, especially when leaching events occur. As with the build-up and maintenance philosophy, basic cation saturation is not appropriate for Florida conditions, and is likely to result in higher fertilizer costs with increased environmental risk.

Hydroponics

In the hydroponics philosophy, soils are not considered to supply any nutrition whatsoever to the crop. Thus, all nutrition required by the crop must come from fertilizer sources. Although our soils do not hold large amounts of nutrients such as N and K, they do hold some; our soils are not devoid of nutrients in their native (unfertilized) state. For example, even largely sandy soils may have soil horizons with more clay or minerals that will hold certain nutrients, and sandy soils may also contain appreciable amounts of calcium and phosphate precipitates. Sandy soils, such as the Spodosols, have a clay/organic layer that can retain nutrients, such as phosphorus. Although there may be situations where nutrients can be held in sandy soils, for the bulk of the soil, there is little nutrient-holding capacity in the majority of the root zone. Like the philosophies discussed above, the hydroponics philosophy is based on *fertilizing the soil* rather than the crop. By supplying all of the nutrition from fertilizers, this practice potentially over-fertilizes the crop, which may expose the fertilizer to leaching and increase the cost of production for the grower.

Percent Sufficiency Concept (CNR)

The percent sufficiency philosophy is called the Crop Nutrient Requirement (CNR) in Florida. The assumptions underlying this philosophy are that the soil does contribute nutrition to the crop (often significant in the case of P, Ca, Mg, S, micronutrients, and sometimes K); the soil's contribution can be measured by a calibrated soil test; and the nutritional amount not supplied by the soil can be determined and added to fertilize the plant. This approach takes into account the nutrient-supplying capacity of the soil, the nutrient requirements for the plant, and the potential for supplying fertilizer in appropriate amounts to satisfy the Crop Nutrient Requirements. This philosophy has proven to be valid with respect to Florida's sandy soils for many commercial crops, and is the approach used by the University of Florida in making fertilizer recommendations.

The Foundations of Fertilizer Recommendations

Each philosophy described above must rise or fall on the basis of sound research conducted on various soils in farm-production conditions. Economical and environmentally sound fertilizer recommendations are best based on research that is properly conducted and reported in peer-reviewed scientific journals. These publications provide the foundation for making recommendations and defending or modifying the recommendations, if needed. Fertilizer research must follow accepted scientific principles of hypotheses testing, randomly applying treatments, replication, statistical analyses, and unbiased interpretation of results.

Ideally, fertilizer research should be conducted with the aid of public funds, since the public benefits from economical crop production as well as from the best management practices that protect the environment. Unfortunately, public funding for fertilizer research has been severely reduced in the last few decades, due to reductions in state and federal budgets. The funding burden for this research must now be picked up by the agricultural industry. Sometimes private funding of research is viewed as potentially leading to biased results in favor of the funding entity. Where economic, environmental, and societal benefits are concerned, researchers must take great care to ensure the unbiased nature of their research.

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The Importance of Grower Involvement, Demonstrations, and Input on Philosophies of Fertilization

In all fertilizer research, there should be a grower or on-farm component to the work. On-farm or field testing of fertilizer research is important for several reasons. Most significantly, the scale-up nature from small plot to field scale trials allows the researcher to test the results from research plots in a farm environment with *real-world* practices. Secondly, on-farm work allows the growers to view the research within the context of their own farming management systems and conditions. Thirdly, farm-scale testing allows valuable economic cost analyses with *real-world* inputs.

A fertilizer recommendation is the research-based set of guidelines, or management practices, for supplying fertilizer to the crop to achieve yield and quality goals (economic) in a manner that minimizes nutrient losses to the environment. A typical fertilizer recommendation consists of guidelines for:

- The rate: specifying how much fertilizer is needed to supplement the nutrients supplied from the soil;
- The types or forms of fertilizers to use: soluble, dry granular, fluid, controlled-release, etc.;
- Fertilizer sources to supply specific nutrients, for example, nitrogen may be supplied from urea, ammonium sulfate, calcium nitrate, ammonium nitrate, etc.;
- Placement method: ground or foliar; broadcast or band; preplant, side-dressing in the season; and
- Timing: at planting, according to certain growth cycles or growth stages in the season

Specific Recommendation Components

Economics

Fertilizer typically comprises about 10% of the total production costs for most vegetables. Fertilizer costs have risen sharply during the first decade of the century. Nitrogen fertilizer costs are closely tied to fossil fuel prices. Other nutrients are tied to scarcity of supply and the costs of mining and refining. All fertilizer prices are affected by the increasing demand for fertilizer in developing countries. Fertilizer expenses on the farm can be controlled by paying close attention to the science-based recommendations and BMPs. Nutrients that are applied but unused by the crop represent lost money and profits. Nutrients lost to the environment also create environmental pollution and lead to expensive clean-up programs. In contrast, capturing and using nutrients on the farm contributes to the economic, social, and environmental sustainability of the state.

Irrigation Management

Irrigation is the most important management tool to control fertilizers properly. Optimum irrigation management is an important part of a fertilizer recommendation so nutrients are not leached or subject to runoff. Irrigation and fertilizer must be managed together to keep the water and nutrients in the root zone. Irrigation should be planned with knowledge of the root zone of the crop and the leaching/runoff potential of the soils being farmed. The goal of the irrigation program should be to keep the water and nutrients in the root zone until the nutrients can be absorbed by the plant. Irrigation frequency and run time are scheduled so that water and nutrients do not move below the root zone. There are several useful publications with information on irrigation management in the literature list at the end of this publication.

Fertilization Rate

The IFAS-recommended rate of fertilizer is based on the CNR. The CNR is the total amount of a nutrient needed for profitable crop production. The CNR can be met, in whole or in part, from the

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nutrients in the soil with supplemental applications (fertilizer) as needed.

For most Florida crop production areas, fertilizer nutrients fall in two general categories, those nutrients that are highly mobile in the soil and those that are not highly mobile. For example nitrogen is mobile in Florida soils, therefore The University of Florida Extension does not make N recommendations based on a soil test. Growers receive a nitrogen recommendation based on field research that determined the crop nitrogen requirement. Potassium is mobile in sandy soils, and for some crops, such as potato, there are ample research findings that have led Extension to discontinue making recommendations for K based on a soil test. For other vegetables, K recommendations are still based on a soil test until research disproves the need for the soil test. Soil testing can be used to determine the fertilizer needs for those nutrients, such as phosphorus (P), that are not mobile in the soil. For the mobile nutrients, such as nitrate-nitrogen, fertilizer rates are recommended based on the CNR, which is based on fertilizer rate field trials. A sound fertilizer recommendation includes not just the rate of fertilizer, but the management components as well. However, appropriate management components will vary from region to region and farm to farm.

The fertilizer rate component of an IFAS recommendation comes from years of research with a crop typically involving several varieties, production practices, and locations in the state. The recommended rate is tested on commercial farms to make sure that it will work given the range of farmer practices used in producing the crop. The rate is considered a recommendation that should work in most production situations because the rate has been tested in numerous production areas. The rate is provided as a guideline, therefore there may be situations where additional fertilizer is needed, as outlined below. However, to help minimize environmental impacts, growers are not encouraged to target higher-than-recommended rates at the beginning of the season. These greater-than-recommended rates may not result in greater crop yields, but rather leave nutrients in the soil to be leached to a water body.

Fertilizer BMPs allow the use of seasonal amounts of fertilizer greater than the recommended amount when:

- Leaching rains occur;
- There is a diagnosed nutrient deficiency; or
- The typical harvesting period needs to be extended beyond the period used to develop the recommendation.

Types or Forms of Fertilizer

Fertilizer can be supplied in solid granular, liquid, or suspension formulations. Some products are supplied in a single-nutrient formulation. Mixed fertilizers are formulated containing more than one nutrient.

Solid granular fertilizers can consist of materials varying in solubility, and they can come in controlled-release form. Controlled-release materials release nutrients with time depending on the release mechanism of the fertilizer material, often a coating on the fertilizer.

Liquid fertilizers are used when nutrients are injected in the irrigation system, such as with drip irrigation. Also, liquid fertilizers are used with certain side dress applications during the season. Nutrients stay uniformly mixed in liquids resulting in very uniform application.

Suspension formulations are useful for applying fertilizers as side dress applications in the season.

Other materials for supplying crop nutrients include animal manures, composts, bio-solids, reclaimed water, and various prepared products such as humates and hydrolyzed fish waste.

Nutrient Sources

Specific nutrients can be supplied from several chemical sources or salts. For example N can be supplied from urea, ammonium sulfate, ammonium nitrate, potassium nitrate, etc. Potassium can be supplied from potassium nitrate, potassium sulfate, potassium chloride, or potassium-magnesium-sulfate. Phosphorus can be supplied from phosphoric acid, superphosphate, and ammonium phosphates. Many

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of these sources can be manufactured into any of the forms, such as solid or liquid, mentioned above. The clear preponderance of research shows that the source of the nutrient is not important for crop yield and quality.

Timing

The best timing for fertilizer application is to match applications to the crop growth pattern and crop nutrient needs throughout the season. Apply fertilizer only when the plants are present and are most likely to absorb the nutrients, e.g., do not apply fertilizer far ahead of crop establishment. Use appropriate split applications in the growing season so that fertilizer is more likely to be used by the crop, e. g., split side-dressings, fertigation.

With some exceptions, application of extra fertilizer late in the season, or shortly before harvest, does not result in additional yield or quality, and is not an appropriate part of fertilizer recommendations. Late-applied nutrient is not taken up by the plant, transferred to the fruit, and incorporated into the fruit/vegetable tissue in time to make a significant difference. This process takes time, which is why late season or just-before-harvest fertilizer applications are unlikely to improve yield or quality. By the time harvest is near, most nutrients needed for production have been moved to the fruits. Further, plants re-translocate nutrients from the leaves late in the season preferentially to absorb nutrients. Late-season applications of extra fertilizer are not likely to enhance yields or fruit quality where the best management practice is followed.

Placement

Placement is an important part of a fertilizer recommendation, and crop-specific placement guidelines are provided with Extension production recommendations for each crop available in the EDIS database. The best placement of fertilizer is as close as possible to the roots for absorption, but not so close that the roots are damaged, either by the placement operation or by chemical burning from the fertilizer. In unmulched culture, the fertilizer is knifed into the side of the row during the growing season. In no-till production systems, the fertilizer is placed in bands on the soil surface or cut into the soil by a no-till coulter blade. A general guideline is to place the fertilizer where it will be most likely to be used by the crop and not likely to be out of reach of the roots or subject to runoff or leaching. Placement selection involves technology, but also practical knowledge and experience.

Mulching beds with polyethylene mulch (covering the beds with plastic) helps protect the fertilizer against leaching from rainfall. Using a production practice such as mulch to protect the fertilizer from leaching is a best management practice for those crops where mulch can be used economically. When polyethylene mulch is used, fertilizer is applied through a drip irrigation system or with a fertilizer injection wheel.

Summary

This publication describes components of science-based recommendations (best management practices) for fertilizer management in modern vegetable production.

Careful fertilizer management is important in today's crop production systems. Fertilizer is a costly input and continues to become more expensive. Further, fertilizer mismanagement can lead to nutrient losses to the environment, with potential negative impacts to water quality. A sound fertilizer recommendation is based on the accumulation of the best science available and takes into consideration profitable crop production and protection of the environment. A recommendation is not only comprised of the amount of a particular nutrient to use. Equally important are the guidelines for fertilizer placement, fertilizer application scheduling, and irrigation methods.

For More Information

Boman, B., and T. Obreza. 2008. Fertigation Nutrient Sources and Application Considerations for Citrus. edis.ifas.ufl.edu/CH185.

Clark, G. A., D. Z. Haman, and F.S. Zazueta. 2005. Injection of Chemicals into Irrigation Systems: Rates, Volumes, and Injection Periods. edis.ifas.ufl.edu/AE116.

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Daroub, S. H., O.A. Diaz, T.A. Lang, and M. Chen. 2008. Best Management Practices in the Everglades Agricultural Area: Soil Testing. edis.ifas.ufl.edu/SS445.

Hochmuth, G. J., and E. A. Hanlon. 2009. Calculating Recommended Fertilizer Rates for Vegetables Grown in Raised-Bed, Mulched Cultural Systems. edis.ifas.ufl.edu/SS516.

Hochmuth, G. J., and A. G. Smajstrla. 2003. Fertilizer Application and Management for Micro (Drip)-Irrigated Vegetables in Florida. edis.ifas.ufl.edu/CV141.

Hutchinson, C. H., and E. H. Simonne. 2003. Controlled-Release Fertilizer Opportunities and Costs for Potato Production in Florida. edis.ifas.ufl.edu/HS187.

Migliaccio, K. W., and B. J. Boman. 2009. Total Maximum Daily Loads and Agricultural BMPs in Florida. edis.ifas.ufl.edu/AE388.

Muñoz-Carpena, R., J. H. Crane, G. D. Israel, and T. Olczyk. 2009. Vegetable Growers' Water Use and Conservation Practices in Miami-Dade County. edis.ifas.ufl.edu/AE258.

Obreza, T., L. Parsons, and K. Morgan. 2009. Nitrogen Fertilizer Sources: What does the future hold for citrus producers? edis.ifas.ufl.edu/SS457.

Obreza, T. A., R. Rouse, and E. A. Hanlon. 2006. Advancements with Controlled-Release Fertilizers for Florida Citrus Production: 1996 -2006. edis.ifas.ufl.edu/SS463.

Shukla, S., E. A. Hanlon, F. H. Jaber, P. J. Stoffella, T. A. Obreza, and M. Ozores-Hampton. 2006. Groundwater Nitrogen: Behavior in Flatwoods and Gravel Soils Using Organic Amendments for Vegetable Production. edis.ifas.ufl.edu/AE400.

Sloan, D. R., G. Kidder, and R. D. Jacobs. 2003. Poultry Manure as a Fertilizer Source. edis.ifas.ufl.edu/AA205.

Simonne, E., D. Studstill, R. Hochmuth, T. Olczyk, M. Dukes, R. Munoz-Carpena, and Y. Li. 2003. Drip Irrigation: The BMP Era - An Integrated Approach to Water and Fertilizer Management for Vegetables Grown with Plasticulture. edis.ifas.ufl.edu/HS172.

Stanley, C. D., R. A. Clarke, B. L. McNeal, and B. W. Macleod. 2009. Impact of Agricultural Land Use on Nitrate Levels in Lake Manatee, Florida. edis.ifas.ufl.edu/SS428.

Wright, A. L., E. A. Hanlon, D. Sui, and R. Rice. 2009. Soil pH Effects on Nutrient Availability in the Everglades Agricultural Area. edis.ifas.ufl.edu/SS500.