UF IFAS Extension
UNIVERSITY of FLORIDA

Chapter 2. Fertilizer Management for Vegetable Production in Florida

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Best Management Practices

With the passage of the Federal Clean Water Act (FCWA) in 1972, states were required to assess the impacts of agricultural fertilizer use on surface and ground waters. The FCWA also requires states to identify impaired water bodies and establish the amount of fertilizer nutrient that can enter water bodies consistent with its intended use (swimming, fishing, or potable uses) called total maximum daily loads (TMDLs). Water quality TMDLs involving vegetable production are concentrations of nitrate, phosphate, and total dissolved solids. Best Management Practices (BMPs) are specific cultural practices aimed at reducing the load of specific fertilizer compounds entering ground and surface water, while maintaining or increasing economical yields. BMPs are intended to be economically sound, environmentally effective, and based on science. It is important to recognize that BMPs do not aim at becoming an obstacle to vegetable production. Instead, they should be viewed as a means to balance economical vegetable production with environmental responsibility.

The BMPs that will apply to vegetable production in Florida are described in the "Agronomic and Vegetable Crop Water Quality/Water Quantity BMP Manual for Florida" produced by the Florida Department of Agriculture and Consumer Services (FDACS). This manual was developed through a cooperative effort between state agencies, water management districts and commodity groups, and under the scientific leadership of the University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS). The manual was adopted by reference in 2006 and by rule in Florida Statutes (5M-8 Florida Administrative Code) and was revised in 2015 (http://www.floridaagwaterpolicy.com/ PDFs/BMPs/vegetable&agronomicCrops.pdf). Vegetable growers may get one-on-one information on 1) the benefits for joining the BMP program, 2) how to join it, 3) how to select the BMPs that apply to their operation and 4) record keeping requirements by getting in contact with their county extension agent.

The vegetable BMPs have adopted all current UF/IFAS recommendations; including those for fertilizer and irrigation management (see the new BMP manual on "Optimum Fertilizer Management"). At the field level, adequate fertilizer rates should be used together with proper irrigation scheduling techniques and crop nutritional status monitoring tools (leaf analysis, petiole sap testing). In the BMP manual, adequate fertilizer rates may be achieved by combinations of UF/IFAS recommended base rates and supplemental fertilizer applications added after leaching rainfall, when tissue analyses suggest a need for more fertilizer, or when the harvesting season is prolonged.

Soils

Vegetables are grown on more than 300,000 acres in various soil types throughout the state. These soil types include sandy soils, sandy loam soils, Histosols (organic muck), and calcareous marl soils. Sandy soils make up the dominant soil type for vegetable production in Florida. Vegetables are produced on sandy soils throughout the Florida peninsula and on sandy soils and sandy loams in the panhandle. Sandy soils have both advantages: ease of tillage; production of the earliest vegetable crops; timely production operations and disadvantages: leaching mobile nutrients such as nitrogen, potassium and even phosphorus by heavy rain or over irrigation. Therefore, sands must be managed carefully with regard to fertility programs and irrigation scheduling. Histosols, calcareous rock, and marl are also important for Florida's vegetable production. For more information, please see "Soil and Fertilizer Management for Vegetable Production in Florida" at <http://edis.ifas.ufl.edu/cv101>.

SOIL PREPARATION

A well-prepared planting bed is important for uniform stand establishment of vegetable crops. Old crop residues should be plowed down well in advance of crop establishment. A 6- to 8-week period between plowing down of green cover crops and crop establishment is recommended to allow the decay of the refuse. Freshly incorporated plant material promotes high levels of damping-off organisms such as *Pythium* spp. and *Rhizoctonia* spp. Turning under plant refuse well in advance of cropping reduces damping-off disease organisms. Land should be kept disked if necessary to keep new weed cover from developing prior to cropping.

Chisel plowing is beneficial in penetrating and breaking tillage pan layers in fields. If plastic mulch culture is practiced, debris and large undecayed roots will create problems in preparing good beds over which mulch will be applied. For information about soil preparation for commercial vegetable production see "Soil preparation and Liming for Vegetable Gardens" at <http://edis.ifas.ufl.edu/vh024>.

LIMING

Current UF/IFAS recommendations call for maintaining soil pH between 6.0 and 6.5 (Table 1); further discussion is in "Soil pH Range for Optimum Commercial Vegetable Production" at <http://edis.ifas.ufl.edu/hs1207>. If soil pH is too low, liming is needed. A common problem in Florida has been over-liming, resulting in high soil pH tying up micronutrients and phosphorus causing a restriction of their uptake by plants. Over-liming can also reduce the accuracy with which a soil test can predict the fertilizer component of the CNR. For more information about liming see "Liming of Agronomic Crops" at <https://edis.ifas.ufl.edu/aa128>. Liming can not only adjust soil pH but also provide calcium and magnesium if dolomite, i.e., calcium magnesium carbonate is used.

Irrigation water from wells in limestone aquifers is an additional source of liming material. The combination of liming and use of alkaline irrigation water has resulted in soil pH greater than 7.0 for many sandy soils in south Florida. To measure the liming effect of irrigation, have a water sample analyzed for total bicarbonates and carbonates annually, and the results converted to pounds of calcium carbonate per acre. Liming (Table 2), fertilization (Table 3), and irrigation programs are closely related to each other. To maximize overall production efficiency, soil and water testing in a critical BMP must be made a part of any fertilizer management program. Additionally, using ammoniacal fertilizers can neutralize alkalinity (Table 3) but nitrate fertilizers can increase pH in rootzone due to selective uptake of different ions by plants. Fertigation with ammonium-N (such as ammonium sulfate) is effective for decreasing soil pH.

BEDDING

Fields, where seepage irrigation is used or fields prone to flooding, should be cropped using raised beds. Beds generally range from 3 to 8 inches in height, with high beds of 6 to 8 inches preferred where risk of flooding is greatest. Raised beds dry faster than non-bedded soils. Raised beds promote early season soil warming resulting in somewhat earlier crops during cool seasons. Mulching requires a smooth, well-pressed bed for efficient heat transfer from black mulch to the soil. Adequate soil moisture is essential in forming a good bed for mulching using a bed press.

Fertilization

Nitrogen fertilization is needed for vegetable production in Florida. A new and innovative approach to BMPs for fertilizer known as **4R** nutrient stewardship defined as follows: the **RIGHT** fertilizer **SOURCE** is applied at the **RIGHT RATE** in the **RIGHT PLACE** and at the **RIGHT TIME** to a particular crop. More information about the 4Rs is available in “What is 4R nutrient stewardship?” at < https://edis.ifas.ufl.edu/hs1264>; “The Four Rs of Fertilizer Management” at <http://edis.ifas.ufl.edu/ss624>. For tomato production, more information is available in “Implementing the Four Rs (4Rs) in Nutrient Stewardship for Tomato Production” at < https://edis.ifas.ufl.edu/hs1269 >.

Right Rate

SOIL TESTING

Soil testing is a key BMP for nutrient management. There are 17 elements essential for plant growth (Table 4). Nickel is the 17^{th} element (see “Nickel Nutrition in Plants” http://edis.ifas.ufl.edu/hs1191). The crop nutrient requirement (CNR) for a particular element is defined as the total amount in lb/A of that element needed by the crop to produce optimum economic yield. The CNR can be satisfied from many sources, including soil, water, air, organic matter, or fertilizer.

The CNR for a crop has been determined from field experiments that test the yield response to selected levels of added fertilizer. The CNR is equivalent to the fertilizer rate above which no significant increases in yield is expected. The CNR values derived from such experiments take into account factors such as fertilizer efficiencies of the soils and cultural practices. Using the CNR concept will ensure optimum, economic yields and minimize both pollution from over-fertilization and loss of yield due to under-fertilization.

It is important to remember that nutrients are supplied to the crop from both the soil and fertilizer. The amounts are applied as fertilizers only when a properly calibrated soil test indicates very small extractable amounts of macronutrients (N, P, K, Mg, and Ca) and micronutrients present in the soil.

Table 2.1. A general guideline to crop tolerance of mineral soil acidity.[1]

Slightly tolerant (pH 6.8–6.0)			Moderately tolerant (pH 6.8—-5.5)			Very tolerant (pH 6.8–5.0)	
Beet	Celery	Muskmelon	Bean, snap	Cucumber	Pumpkin	Endive	Sweet potato
Broccoli	Chard	Okra	Bean, lima	Eggplant	Radish	Potato	Watermelon
Cabbage	Leek	Onion	Brussels sprouts	Kale	Squash	Shallot	
Cauliflower	Lettuce	Spinach	Carrot	Mustard	Strawberry		
			Collard	Pea	Tomato		
			Corn	Pepper	Turnip		

[1] From Donald N. Maynard and George J. Hochmuth, Knott’s Handbook For Vegetable Growers, 4th edition (1997). Reprinted by permission of John Wiley & Sons, Inc.

Table 2.2. Liming materials.

Material	Formula	Amount of material to be used to equal 1 ton of calcium carbonate[1]	Neutralizing value2(%)
Calcium carbonate, calcite, hi-cal lime	$CaCO_3$	2,000 lb	100
Calcium-magnesium carbonate, dolomite	$CaCO_3$, $MgCO_3$	1,850 lb	109
Calcium oxide, burnt lime	CaO	1,100 lb	179
Calcium hydroxide, hydrated lime	$Ca(OH)_2$	1,500 lb	136
Calcium silicate, slag	$CaSiO_3$	2,350 lb	86
Magnesium carbonate	$MgCO_3$	1,680 lb	119

[1] Calculated as (2000 x 100) / neutralizing value (%).

[2] The higher the neutralizing value, the greater the amount of acidity that is neutralized per unit weight of material.

Table 2.3. Effect of some fertilizer materials on soil pH.

Fertilizer material	Approximate calcium carbonate equivalent (lb)[1]	Fertilizer material	Approximate calcium carbonate equivalent (lb)[1]
Ammonium nitrate	-1200	Normal (ordinary) superphosphate	0
Ammonium sulfate	-2200	Potassium nitrate	+520
Anhydrous ammonia	-3000	Potassium sulfate	0
Diammonium phosphate	-1250 to -1550	Potassium-magnesium sulfate	0
Potassium chloride	0	Triple (concentrated) superphosphate	0
Sodium-potassium nitrate	+550	Urea	-1700
Nitrogen solutions	-759 to -1800		

[1] A minus sign indicates the number of pounds of calcium carbonate needed to neutralize the acid formed when one ton of fertilizer is added to the soil.

Decisions should be based on two common extractants used by commercial laboratories (Mehlich1 or Mehlich 3), however, Mechlich 3 provides better results for soils with a pH of 7 or greater. More information about Mechlich 3 is available in "Extraction of Soil Nutrients Using Mehlich-3 Reagent for Acid-Mineral Soils of Florida" at < https://edis.ifas.ufl.edu/ss620>. Based on such tests, the amount of fertilizer that is needed to supplement the nutrition component of the native soil can be calculated. The BMP program for vegetables requires the importance of calibrated soil test. More information about soil testing can be found in "Developing a Soil Test Extractant: The Correlation and Calibration Processes" at <http://edis.ifas.ufl.edu/ss622> and "Soil Testing for Plant-Available Nutrients—What Is It and Why Do We Use It?" at <http://edis.ifas.ufl.edu/ss621>.

PLANT TISSUE ANALYSIS

Analysis of plant tissues (e.g. leaves or petioles) for nutrient concentration provides a good tool to monitor nutrient management programs. There are basically two approaches to plant tissue testing: standard laboratory analysis and the plant sap testing procedures. Standard laboratory analysis involves analyzing the most-recently-matured leaf of the plant for an array of nutrients. The resulting analyses are compared against published adequate ranges for that particular crop. Laboratory results that fall outside the adequate range for that nutrient may indicate either a deficiency or possibly toxicity (especially in the case of micronutrients). The most-recently- matured leaf serves well for routine crop monitoring and diagnostic procedures for most nutrients. However, for the immobile nutrients such as Ca, B, and certain other micronutrients, younger leaves are generally preferred.

The second approach is use of plant sap quick test kits that have been calibrated for N and K for several vegetables in Florida. These testing kits analyze fresh plant sap for N and K. Quick tests can be a valuable tool for on-the-spot monitoring of plant nutrient status. Diagnostic information for leaf and petiole sap testing can be found in "Plant Tissue Analysis and Interpretation for Vegetable Crops in Florida," at <http://edis.ifas.ufl.edu/ep081> and "Petiole Sap Testing for Vegetable Crops" <http://edis.ifas.ufl.edu/cv004>.

Right Source

N, P, K, NUTRIENT RATES AND SOURCES

Nitrogen often is the most limiting nutrient in Florida's sandy soils. The amount of nitrogen required by vegetable plants must be applied each growing season because it leaches rapidly. Therefore crop nitrogen requirements vary among crops and are not dependent on soil test results (Table 5). Fertilizer rates of other nutrients must be applied based on soil test results (see soil test above) to follow BMPs. The interpretations of Mehlich 1 (very low, low, medium, high, and very high) and Mehlich 3 (low, medium, and high) are shown in Table 6. The soil test extractant used in UF/IFAS recommendations recently has changed to Mehlich 3. UF recommendations based on Mehlich 3 test include P_2O_5 and K_2O (Table 7) and nutrient management using fertigation (Table 8). More information on the change to Mehlich-3 can be found in "Extraction of Soil Nutrients Using Mehlich-3 Reagent for Acid-Mineral Soils of Florida" at <http://edis.ifas.ufl.edu/ss620>. Some private companies may use Mehlich 1 and recommendations include P_2O_5 and K_2O (Table 9) and micronutrients (Table 10).

The recommendations found in Tables 7 through 10 were determined in field rate studies considering a wide range of nutrient applications and various soil pH levels. Crop plant development, crop yield and vegetable quality were considered in determining the optimum nutrient levels for UF/IFAS recommendations.

Table 2.4. Nutrient elements required by plants.

	Nutrient	Deficiency symptoms	Occurrence
Macronutrients	Nitrogen (N)	Stems thin, erect, hard. Leaves small, yellow; on some crops (tomatoes) undersides are reddish. Lower leaves affected first.	On sandy soils especially after heavy rain or after over irrigation. Also on organic soils during cool growing seasons.
	Phosphorus (P)	Stems thin and shortened. Leaves develop purple color. Older leaves affected first. Plants stunted and maturity delayed.	On acidic soils or very basic soils. Also when soils are cool and wet.
	Potassium (K)	Older leaves develop gray or tan areas on leaf margins. Eventually a scorch appears on the entire margin.	On sandy soils following leaching rains or over irrigation.
Secondary nutrients	Calcium (Ca)	Growing-point growth restricted on shoots and roots. Specific deficiencies include blossom-end rot of tomato, pepper and watermelon, brown heart of escarole, celery blackheart, and cauliflower or cabbage tip burn.	On strongly acidic soils, or during severe droughts.
	Magnesium (Mg)	Initially older leaves show yellowing between veins, followed by yellowing of young leaves. Older leaves soon fall.	On strongly acidic soils, or on leached sandy soils.
	Sulfur (S)	General yellowing of younger leaves and growth.	On very sandy soils, low in organic matter, reduced especially following continued use of sulfur-free fertilizers and especially in areas that receive little atmospheric sulfur.
Micronutrients	Boron (B)	Growing tips die and leaves are distorted. Specific diseases caused by boron deficiency include brown curd and hollow stem of cauliflower, cracked stem of celery, blackheart of beet, and internal browning of turnip.	On soils with pH above 6.8 or on sandy, leached soils, or on crops with very high demand such as cole crops.
	Copper (Cu)	Yellowing of young leaves, stunting of plants. Onion bulbs are soft with thin, pale scales.	On organic soils or occasionally new mineral soils.
	Chlorine (Cl)	Deficiencies very rare.	Usually only under laboratory conditions.
	Iron (Fe)	Distinct yellow or white areas between veins on youngest leaves.	On soils with pH above 6.8.
	Manganese (Mn)	Yellow mottled areas between veins on youngest leaves, not as intense as iron deficiency.	On soils with pH above 6.4.
	Molybdenum (Mo)	Pale, distorted, narrow leaves with some interveinal yellowing of older leaves, e.g. whiptail disease of cauliflower. Rare.	On very acidic soils.
	Nickel (Ni)	Deficiencies very rare.	Usually only under laboratory conditions.
	Zinc (Zn)	Small reddish spots on cotyledon leaves of beans; light areas (white bud) of corn leaves.	On wet, cold soils in early spring or where excessive phosphorus is present.

Nitrogen (N) can be supplied in both nitrate and ammoniacal forms. Nitrate-nitrogen is generally the preferred form for plant uptake in most situations, but ammoniacal N can be absorbed directly or after conversion to nitrate-N by soil microbes. Since this rate of conversion is reduced in cold, fumigated, or strongly acidic soils, it is recommended that under such conditions 25% to 50% of the N be supplied from nitrate sources. This ratio is not critical for unfumigated or warm soils.

Phosphorus (P) can be supplied from several sources, including single and triple superphosphate, diammonium phosphate (DAP) and monoammonium phosphate (MAP), and monopotassium phosphate. All sources can be effective for plant nutrition. However, on soils that test very low in native micronutrient levels, DAP in mixtures containing micronutrients reduces yields when banded in large amounts. Initial soil reaction pH with DAP is about 8.5 which favors ammonia production and volatilization. This produced ammonia causes seedling injury and inhibits root growth. Adequate separation of seed and DAP is needed to eliminate any seedling damage. DAP should not be used on calcareous or high pH soils. MAP's reaction pH is 3.5 and doesn't have the above problems.

Potassium (K) can also be supplied from several sources, including potassium chloride, potassium sulfate, potassium nitrate, and potassium-magnesium sulfate. If soil-test-predicted amounts of K fertilizer are adhered to, there should be no concern about the K source or its relative salt index.

CA, MG, S NUTRIENT RATES AND SOURCES

The secondary nutrients calcium (Ca), magnesium (Mg), and sulfur (S), and have not been a common problem in Florida. Calcium usually occurs

Table 2.5. Target pH and Nitrogen (N) fertilization recommendations for selected vegetable crops in mineral soils of Florida.

Crops	Target pH	N (lb/acre)
Tomato, pepper, potato, celery, sweet corn, crisphead lettuce, endive, escarole, romaine lettuce and eggplant	6.0 (potato) and 6.5	200
Snapbean, lima bean and pole bean	6.5	100
Broccoli, cauliflower, Brussels sprouts, cabbage, collards, Chinese cabbage and carrots	6.5	175
Radish and spinach	6.5	90
Cucumber, squash, pumpkin, muskmelon, leaf lettuce, sweet bulb onion, watermelon and strawberry	6.0 (watermelon) and 6.5	150
Southernpea, snowpea, English pea and sweet potato	6.5	60
Kale, turnip, mustard, parsley, okra, bunching onion, leek and beet	6.5	120

Table 2.6. Mehlich-1 (double-acid) and **Mehlich-3** interpretations for vegetable crops in Florida.

	Mehlich-1 (double-acid) interpretations					Mehlich-3 interpretations		
	Very low	Low	Medium	High	Very high	Low	Medium	High
Nutrient	(parts per million soil)					(parts per million soil)		
P	<10	10–15	16–30	31–60	>60	≤25	26–45	>45
K	<20	20–35	36–60	61–125	>125	≤35	36–60	>60
Mg[1]	<10	10–20	21–40	41–60	>60	≤20	21–40	>40
Ca[2]	<100	100–200	201–300	301–400	>400			

[1] Up to 40 lbs/A may be needed when soil test results are medium or lower.

[2] Ca levels are typically adequate when > 300 ppm.

Table 2.7. Phosphorus (P, expressed as P_2O_5) and potassium (K, expressed as K_2O) fertigation recommendations for selected vegetable crops in mineral soils for Florida based on low, medium, and high soil test index using **MEHLICH 3 SOIL EXTRACATANT METHOD.**

	P_2O_5			K_2O		
	Low	Medium	High	Low	Medium	High
	(lb/A/crop season)			(lb/A/crop season)		
Celery	150-200	100	0	150-250	100	0
Eggplant	130-160	100	0	130-160	100	0
Broccoli, cauliflower, Brussels sprouts, cabbage, collards, Chinese cabbage, carrots, kale, turnip, mustard, parsley, okra, muskmelon, leaf lettuce, sweet bulb onion, watermelon, pepper, sweet corn, crisphead lettuce, endive, escarole, strawberry and romaine lettuce	120-150	100	0	120-150	100	0
Tomato	120-150	100	0	125-150	100	0
Cucumber, squash, pumpkin, snapbean, lima bean, pole bean, beet, radish, spinach and sweet potato	100-120	80	0	100-120	80	0
Bunching onion and leek	100-120	100	0	100-120	100	0
Potato	120	100	0	150	--	--
Southern pea, snowpea and English pea	80	80	0	80	60	0

in adequate supply for most vegetables when the soil is limed. Since we don't have an interpretation for Mehlich-3 soil Ca yet we still have Mehlich-1 soil Ca interpretation. If the Mehlich-1 soil Ca index is above 300 ppm, it is unlikely that there will be a response to added Ca. Maintaining correct moisture levels in the soil by irrigation will aid in Ca supply to the roots. Calcium is not mobile in the plant; therefore, foliar sprays of Ca are not likely to correct deficiencies. It is difficult to place enough foliar-applied Ca at the growing point of the plant on a timely basis.

Magnesium deficiency may be a problem for vegetable production; however, when the Mehlich-3 soil-test index for Mg is below 23 ppm, 30–40 lb Mg/A will satisfy the Mg CNR. If lime is also needed, Mg can be added by using dolomite as the liming material. If no lime is needed, then the Mg requirement can be satisfied through use of magnesium sulfate or potassium-magnesium sulfate. Blending of the Mg source with other fertilizer(s) to be applied to the soil is an excellent way of ensuring uniform application of Mg to the soil.

Sulfur deficiencies have seldom been documented for Florida vegetables. Sulfur deficiency would most likely occur on deep, sandy soils low in organic matter after leaching rains. If S deficiency has been diagnosed, it can be corrected by using S-containing fertilizers such as magnesium sulfate, ammonium sulfate, potassium sulfate, normal superphosphate, or potassium-magnesium sulfate. Using one of these materials in the fertilizer blends at levels sufficient to supply 30 to 40 lb S/A should prevent S deficiencies.

MICRONUTRIENT SOURCES

It has been common in Florida vegetable production to routinely apply a micronutrient package. This practice has been justified on the basis that these nutrients were inexpensive and their application appeared to be insurance for high yields. In addition, there was little research data and a lack of soil-test calibrations to guide judicious application of micronutrient fertilizers. Compounding the problem has been the vegetable industry's use of micronutrient-containing pesticides for disease control.

Copper (Cu), manganese (Mn), and zinc (Zn) from pesticides have tended to accumulate in the soil. This situation has forced some vegetable producers to over-lime in an effort to reduce availability and avoid micronutrient toxicities. Data have now been accumulated which permit a more accurate assessment of micronutrient requirements (Table 10). Growers are encouraged to have a calibrated micronutrient soil test conducted and to refrain from shotgun micronutrient fertilizer applications. It is unlikely that micronutrient fertilizers will be needed on old vegetable land, especially where micronutrients are being applied regularly via recommended pesticides. A micronutrient soil test every 2 to 3 years will provide recommendations for micronutrient levels for crop production.

MANURES AND COMPOSTS

Waste organic products, including animal manures and composted organic matter, contain nutrients for enhancing plant growth. These materials applied to the soil decompose releasing nutrients for vegetable crops to utilize. The key to proper use of organic materials as fertilizers comes in the knowledge of the nutrient content and the decomposition rate of the material. Growers contemplating using organic materials as fertilizers should have an analysis of the material before determining the rate of application. In the case of materials such as sludges, it is important to have knowledge about the type of sludge to be used. Certain classes of sludge are not appropriate for vegetable production, and in fact may not be permitted for land application. Decomposition rates of organic materials are rapid in warm sandy soils in Florida. Therefore, there will be relatively small amounts of residual nutrients remaining for succeeding crops. Usually application rates of organic wastes are determined largely by the N content. Organic waste materials can contribute to groundwater or surface water pollution if applied in rates in excess of the CNR for a particular crop. Therefore, it is important to understand the nutrient content and the decomposition rate of the organic waste material, and the P-holding capacity of the soil. For more information about using manure for vegetable production see "Using Composted Poultry Manure (Litter) in Mulched Vegetable Production" at <https://edis.ifas.ufl.edu/ss506> and "Introduction to Organic Crop Production" at <http://edis.ifas.ufl.edu/cv118>.

As a soil amendment, compost improves soil physical, chemical, and biological properties making soil more productive. To eliminate or minimize human and plant pathogens, nematodes, and weed seeds composting temperature must be kept in a range from 131 and 170°F for 3 days in an in-vessel or static aerated pile. N in compost is basically organic. Thus, compost N is not as readily bioavailable as synthetic N fertilizers before being mineralized. Compost N mineralization rate varies with feedstock, soil characteristics, and composting conditions. Generally speaking, compost N fertilizer releases only 5% to 30% bioavailable N to crops in the first year. On the contrary, compost P and K are as bioavailable as as chemical fertilizers. Composting converts raw organic materials to humus-stable forms and hence minimizes possibly adverse impacts on the environment.

Right Place

FERTILIZER PLACEMENT

Fertilizer rate and placement must be considered together. Banding low amounts of fertilizer too close to plants can result in the same amount of damage as broadcasting excessive amounts of fertilizer in the bed. Because P movement in most soils is minimal, it should be placed in the root zone. Banding is generally considered to provide more efficient utilization of P by plants than broadcasting. This is especially true on the high P-immobilizing calcareous soils. Where only small amounts of fertilizer P are to be used, it is best to band. If broadcasting P, a small additional amount of starter P near the seed or transplant may improve early growth, especially in cool soils. The modified broadcast method where fertilizer is broadcast only in the bed area provides more efficient use of fertilizer than complete broadcasting.

Micronutrients can be broadcast with the P and incorporated in the bed area. On the calcareous soils, micronutrients, such as Fe, Mn, and B, should be banded or applied foliarly. Since N and, to a lesser extent, K are mobile in sandy soils, they must be managed properly to maximize crop uptake. Plastic mulch helps retain these nutrients in the soil. Under non-mulched systems, split applications of these nutrients must be used to reduce losses to leaching. Here, up to one-half of the N and K may be applied to the soil at planting or shortly after that time. The remaining fertilizer is applied in one or two applications during the early part of the growing season. Split-applications also will help reduce the potential for fertilizer burn defined as leaf scorch resulting from over-fertilization.

When using plastic mulch, fertilizer placement depends on the type of irrigation system (seepage or drip) and on whether drip tubing or the liquid fertilizer injection wheels are to be used. With seepage irrigation, all P and micronutrients should be incorporated in the bed. Apply 10% to 20% (but not more) of the N and K with the P. The remaining N and K should be placed in narrow bands on the bed shoulders, the number of which depends on the crop and number of rows per bed. These bands should be placed in shallow (2- to 2 1/2-inch deep) grooves. This placement requires that adequate bed moisture be maintained so that capillarity is not broken. Otherwise, fertilizer will not move to the root zone. Excess moisture can result in fertilizer leaching. Fertilizer and water management programs are linked. Maximum fertilizer efficiency is achieved only with close attention to water management.

In cases where supplemental sidedressing of mulched crops is needed, applications of liquid fertilizer can be made through the mulch with a liquid fertilizer injection wheel. This implement is mounted on a tool bar and, using 30 to 40 psi pressure, injects fertilizer through a hole pierced in the mulch.

Right Time

SUPPLEMENTAL FERTILIZER APPLICATIONS AND BMPS

In practice, supplemental fertilizer applications when growing conditions require doing so, allow vegetable growers to stay within BMP guidelines while numerically apply fertilizer rates higher than the standard UF/IFAS recommended rates. The two main growing conditions that may require supplemental fertilizer applications are leaching rains and extended harvest periods. Applying additional fertilizer under the following three circumstances is part of the current UF/IFAS fertilizer recommendations and thus BMPs. Supplemental N and K fertilizer applications may be made if 1) grown on bare ground with seepage irrigation, a 30 lbs/A of N and /or 20 lbs/A of K_2O supplemental application is allowed after a leaching rain. A leaching rain occurs when it rains at least 3 inches in 3 days, or 4 inches in 7 days; 2) nutrient levels in the leaf or in the petiole fall below the sufficiency ranges. For bare ground production, the supplemental amount allowed is 30 lbs/A of N and/or 20 lbs/A of K_2O. For drip irrigated crops, the supplemental amount allowed is 1.5 to 2.0 lbs /A/day for N and/or K_2O for one week; or 3) for economic reasons, the harvest period has to be longer than the typical harvest period. When the results of tissue analysis and/or petiole testing are below the sufficiency ranges, a supplemental 30 lbs /A N and/or 20 lbs /A of K_2O may be made for each additional harvest for bare ground production. For drip-irrigated crops, the supplemental fertilizer application is 1.5 to 2.0 lbs/A/day for N and/or K_2O until the next harvest.

FERTIGATION

Common irrigation systems used for fertigation include drip, sprinkler, and pivot systems. Advantages of fertigation over conventional fertilizing methods are: 1) more efficient delivery of nutrients, 2) more precise localized application, 3) more flexible control of application rate and timing, and 4) lower application cost. Liquid and water soluble fertilizers are more commonly used for fertigation than dry fertilizers. The most common liquid N fertilizers for fertigation are ammonium nitrate (20-0-0), calcium ammonium nitrate (17-0-0), and urea ammonium nitrate (32-0-0). Complete fertilizers (e.g. 8-8-8 and 4-10-10) are also commonly used. To develop a more precise fertilizer application strategy, growers can request a custom blend at a local fertilizer dealer based on soil test results and crop nutrient requirements. For more information, consult "Fertigation Nutrient Sources and Application Considerations for Citrus" at <http://edis.ifas.ufl.edu/ch185>.

The basic components for a fertigation system include a fertilizer tank, an injector, a filter, a pressure regulator, a pressure gauge, and a backflow

Table 2.8. Fertigation[1] and supplemental fertilizer[1] recommendations on mineral soils testing low in potassium (K_2O) based on the **MEHLICH 3 SOIL EXTRACTION METHOD.**

	Preplant[2] (lb/A)	Injected[3] (lb/A/day)					Low plant content[4,5]	Extended season[4,6] (lb/A/day)
Eggplant								
Wk after transplanting[7]		1-2	3-4	5-10	11-13			
N	0-70	1.5	2.0	2.5	2.0		1.5-2.0	1.5-2.0
K_2O	0-55	1.0	1.5	2.5	1.5		1.5-2.0	1.5-2.0
Okra								
Wk after transplanting		1-2	3-4	5-12	13			
N	0-40	1.0	1.5	2.0	1.5		1.5-2.0	1.5-2.0
K_2O	0-50	1.0	1.5	2.0	1.5		1.5-2.0	1.5-2.0
Pepper								
Wk after transplanting		1-2	3-4	5-11	12	13		
N	0-70	1.5	2.0	2.5	2.0	1.5	1.5-2.0	1.5-2.0
K_2O	0-70	1.5	2.0	2.5	2.0	1.5	1.5-2.0	1.5-2.0
Strawberry								
Wk after transplanting		1-2	Sept.-Jan.	Feb.-Mar.	Apr.			
N	0-40	0.3	0.6	0.75	0.6		0.6-0.75	0.6-0.75
K_2O	0-40	0.3	0.5	0.75	0.6		0.6-0.75	0.6-0.75
Tomato[8]								
Wk after transplanting		1-2	3-4	5-11	12	13		
N	0-70	1.5	2.0	2.5	2.0	1.5	1.5-2.0	1.5-2.0
K_2O	0-70	1.5	2.0	2.5	2.0	1.5	1.5-2.0	1.5-2.0

1 A=7,260 linear feet per acre (6-ft. bed spacing); for soils testing "low in Mehlich 3 potassium (K2O), seeds and transplants may benefit from applications of a starter solution at a rate no greater than 10 to 15 lb/A for N and P2O5 and applied through the plant hole or near the seeds.

2 Applied using the modified broadcast method (fertilizer is broadcast where the beds will be formed only, and not over the entire field). Preplant fertilizer cannot be applied to double/triple crops because of the plastic mulch; hence, in these cases, all the fertilizer has to be injected.

3 This fertigation schedule is applicable when no N and K20 are applied preplant. Reduce schedule proportionally to the amount of N and K20 applied preplant. Fertilizer injections may be done daily or weekly. Inject fertilizer at the end of the irrigation event and allow enough time for proper flushing afterwards.

4 Plant nutritional status may be determined with tissue analysis or fresh petiole-sap testing, or any other calibrated method. The "low' diagnosis needs to be based on UF/IFAS interpretative thresholds.

5 Plant nutritional status must be diagnosed every week to repeat supplemental fertilizer application.

6 Supplemental fertilizer applications are allowed when irrigation is scheduled following a recommended method (see "Evapotranspiration-based Irrigation Scheduling for Agriculture at <http://edis.ifas.ufl.edu/ae457>). Supplemental fertilizations is to be applied in addition to base fertilization when appropriate. Supplemental fertilization is not to be applied 'in advance' with the preplant fertilizer.

7 For standard 13 week-long, transplanted tomato crop.

8 Some of the fertilizer may be applied with a fertilizer wheel through the plastic mulch during the tomato crop when only part of the recommended base rate is applied preplant. Rate may be reduced when a controlled-release fertilizer source is used.

prevention device. All of the components must be resistant to corrosion. In most situations, N and K are the nutrients injected through the irrigation tube. Split applications of N and K through irrigation systems offers a means to capture management potential and reduce leaching losses. Other nutrients, such as P, are usually applied to the soil rather than by injection. This is because chemical precipitation can occur with these nutrients and the high calcium carbonate content of our irrigation water in Florida.

Nutrient management through irrigation tubes involves precise scheduling of N and K applications. Application rates are determined by crop growth and resulting nutrient demand. Demand early in the season is small and thus rates of application are small, usually on the order of ½ to ¾ lb of N or K_2O per acre per day. As the crop grows, nutrient demand increases rapidly so that for some vegetable crops such as tomato the demand might be as high as 2 lb of N or K_2O per day. Schedules of N and K application have been developed for most vegetables produced with drip irrigation in Florida (Table 7).

FOLIAR FERTILIZATION

Foliar fertilization should be thought of as a last resort for correcting a nutrient deficiency (Table 11). The plant leaf is structured in such a way that it naturally resists easy infiltration by fertilizer salts. Foliar fertilization most appropriately applies to micronutrients and not to macronutrients such as N, P, and K. In certain situations, temporary deficiencies of Mn, Fe, Cu, or Zn can be corrected by foliar application. Examples include vegetable production in winter months when soils are cool and roots cannot extract adequate amounts of micronutrients and in cases where high pH (marl and Rockdale soils) immobilizes broadcast micronutrients. There is a fine line between adequate and toxic amounts of these nutrients. Indiscriminate application of micronutrients may reduce plant growth and restrict yields because of toxicity. Compounding the problem is the fact that the micro-nutrients can accumulate in the soil to levels which may threaten crop production on that soil.

THE 5TH R, RIGHT IRRIGATION

Fertilization and irrigation go hand in hand with fertilizers included in irrigation schedules and systems. Water is the solvent of all nutrients and the carrier of almost every pollutant. Keeping moisture and fertilizer primarily in the root zone by managing irrigation inputs and drainage minimizes nutrient-related impacts. Irrigating in excess of the soil's water-holding capacity or excessive drainage leads to increased runoff or leaching, and may results in higher production costs or lower marketable yields.

Table 2.9. Phosphorus (P; expressed as P_2O_5) and potassium (K; expressed as K_2O) fertilization recommendations for selected vegetable crops in mineral soils of Florida, using **MEHLICH 1 SOIL EXTRACTANT METHOD.** VL, L, M, H, and VH = very low, low, medium, high, and very high, respectively.

	P_2O_5					K_2O				
	VL	L	M	H	VH	VL	L	M	H	VH
	(lb/A/crop season)					(lb/A/crop season)				
Celery	200	150	100	0	0	250	150	100	0	0
Eggplant	160	130	100	0	0	160	130	100	0	0
Broccoli, cauliflower, Brussels sprouts, cabbage, collards, Chinese cabbage, carrots, kale, turnip, mustard, parsley, okra, muskmelon, leaf lettuce, sweet bulb onion, watermelon, pepper, sweet corn, crisphead lettuce, endive, escarole, strawberry and romaine lettuce	150	120	100	0	0	150	120	100	0	0
Tomato	150	120	100	0	0	225	150	100	0	0
Cucumber, squash, pumpkin, snapbean, lima bean, pole bean, beet, radish, spinach and sweet potato	120	100	80	0	0	120	100	80	0	0
Bunching onion and leek	120	100	100	0	0	120	100	100	0	0
Potato	120	120	60	0	0	150	--	--	--	--
Southern pea, snowpea and English pea	80	80	60	0	0	80	80	60	0	0

Table 2.10. Interpretations of **Mehlich-1** soil tests for micronutrients**.**

	Soil pH (mineral soils only)		
	5.5–5.9	6.0–6.4	6.5–7.0
	(parts per million)		
Test level below which there may be a crop response to applied copper.	0.1–0.3	0.3–0.5	0.5
Test level above which copper toxicity may occur.	2.0–3.0	3.0–5.0	5.0
Test level below which there may be a crop response to applied manganese.	3.0–5.0	5.0–7.0	7.0–9.0
Test level below which there may be a crop response to applied zinc.	0.5	0.5–1.0	1.0–3.0

When soil tests are low or known deficiencies exists, apply per acre 5 lbs Mn, 2 lbs Zn, 4 lbs Fe, 3 lb Cu and 1.5 lbs B (higher rate needed for cole crops).

Table 2.11. Some nutrients and fertilizer management for vegetable production in Florida.

Nutrient	Source	Foliar application (lb product/A)
Boron	Borax[1]	2 to 5
	Solubor	1 to 1.5
Copper	Copper sulfate	2 to 5
Iron	Ferrous sulfate	2 to 3
	Chelated iron	0.75 to 1
Manganese	Manganous sulfate	2 to 4
Molybdenum	Sodium molybdate	0.25 to 0.50
Zinc	Zinc sulfate	2 to 4
	Chelated zinc	0.75 to 1
Calcium	Calcium chloride	5 to 10
	Calcium nitrate	5 to 10
Magnesium	Magnesium sulfate	10 to 15

[1] Mention of a trade name does not imply a recommendation over similar materials.