BMPs are specific cultural practices that aim at reducing nutrient load while maintaining or increasing productivity.

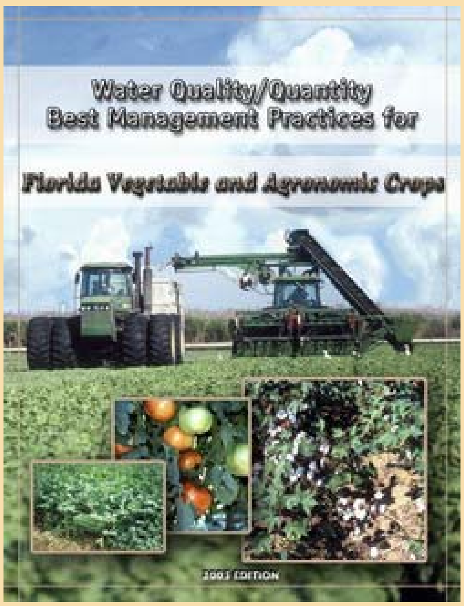


Figure 1. The BMP manual provides background on the state-wide BMP program for vegetables, lists all the possible BMPs, provides a selection mechanism for building a customized BMP plan, outlines record-keeping requirements and explains how to participate in the BMP program. It is available at:

www.floridaagwaterpolicy.com

The following section emphasizes the need for a balance between the nutrient and irrigation requirements for tomato and pepper production on one side, and the risks associated with fertilization and irrigation under the main production systems used in Florida on the other **(Table 1)**.

BEST MANAGEMENT PRACTICES:

As an effort to clean impaired water bodies, federal legislation in the 70's, followed by state legislation in the 90's and state rules since 2000 have progressively shaped the Best Management Practices (BMP) program for vegetable production in Florida.

Section 303(d) of the Federal Clean Water Act of 1972 required states to identify impaired water bodies and establish Total Maximum Daily Loads (TMDL) for pollutants entering these water bodies. In 1987, the Florida legislature passed the Surface Water Improvement and Management Act requiring the five Florida water management districts to develop plans to clean up and preserve Florida lakes, bays, estuaries, and rivers. In 1999, the Florida Watershed Restoration Act defined a process for the development of TMDLs. More recently, the "*Water Quality/Quantity Best Management Practices for Florida Vegetable and Agronomic Crops*" manual was adopted by reference and by rule 5M-8 in the Florida Administrative Code on Feb.9, 2006.

BENEFITS FOR GROWERS FOR HAVING A BMP PLAN:

Vegetable growers who elect to participate in the BMP program receive three statutory benefits:

1. Waiver of liability from reimbursement of cost and damages associated with the evaluation, assessment, or remediation of contamination of ground water [Florida Statutes 376.307].

2. A presumption of compliance with water quality standards [F.S 403.067 (7)(d)].

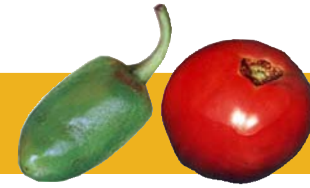
3. Eligibility for cost-share programs [F.S. 570.085 (1)].

Table 1. Levels of nutrient and irrigation management, and corresponding practices for tomato and pepper production.

Management Level	Nutrient management[z]	Irrigation management[z]
0-None	Guessing fertilizer application rates	Guessing irrigation rates
1-Very low	Soil testing and still guessing	Using the "feel and see" method or other empirical method
2-Low	Soil testing and implementing "a" recommendation	Using systematic irrigations (example: 2 hrs everyday from transplanting to harvest)
3-Intermediate	Soil testing, understanding UF/IFAS recommendations, and correctly implementing them	Using a soil moisture measuring tool to start irrigation
4-Advanced	Soil testing, understanding UF/IFAS recommendations, correctly implementing them, and monitoring crop nutritional status	Using a soil moisture measuring tool to schedule irrigation and apply irrigation amounts based on a water budget
5 - Recommended	Soil testing, understanding UF/IFAS recommendations, correctly implementing them, monitoring crop nutritional status, and practice year-round nutrient management and/or following BMPs	Using together a water use estimate based on the crop stage of growth, a measurement of soil moisture, and guidelines for splitting irrigations

For greater efficiency, fertilizer and irrigation schedules should be at the same level.
[z] Not all irrigation systems are suitable for high levels of nutrient and irrigation management.

Prepared by: Dr. Eric Simonne



***BMPs** cover all aspects of tomato and pepper production: pesticide management, conservation practices and buffers, erosion control and sediment management, nutrient and irrigation management, water resources management and seasonal or temporary farming operations.*

The main water quality parameters of importance to tomato and pepper production and targeted by the BMPs are nitrate, phosphate and total dissolved solids concentration in surface ground water. All BMPs have some effect on water quality, but nutrient and irrigation management BMPs have a direct effect on it **(Table 2)**.

Table 2. Best Management Practices Effectiveness summary (page A-4 of the BMP manual).

Best Management Practices	Resource Concerns							
	Surface Water Quality					Ground Water Quality		Relative Cost
	Nutrients	Sediments	Pesticides	BOD	Salinity	Nutrients	Pesticides	
Management Practices								
Irrigation Management	H	H	H	L	H	M	M	M
Nutrient Management	H	—	L	M	—	H	—	L
Pest Management	—	—	H	—	—	—	H	L
Springs Protection	M	M	M	M	—	H	M	L
Vegetative and Tillage Practices								
Conservation Crop Rotation	M	H	M	—	M	M	M	T
Conservation Tillage	M	H	M	L	—	—	—	M
Contour Farming	M	H	M	M	—	—	—	T
Cover Crops	M	M	M	L	—	—	L	M
Field Borders	M	M	M	M	—	—	—	L
Filter Strips	M	H	M	M	—	—	—	L
Grassed Waterways	M	M	M	L	—	—	—	H
Plasticulture Farming	M	1	M	—	—	M	M	H
Riparian Buffers	M	M	M	M	—	—	—	
Structural Practices								
Diversions Terraces	L	M	L	L	—	—	—	H
Grade Stabilization	L	M	—	L	—	—	—	H
Reservoirs, Ponds & Ditches	H	H	M	H	—	H	L	
Sediment Basins	M	H	M	M	—	—	—	M
Temporary Erosion Control	M	H	M	M	—	—	—	L/M
Water Table Control	M	H	M	H	—	—	—	M

H (high), M (medium), L (low), — (little to no effect), T (primary cost is time)
*Adapted from Ohio State University Extension Fact Sheet AEX-464-91 and Farming for Clean Water in South Carolina.
1 - Effects may be positive or negative depending on management techniques.

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SOIL TYPES AND PRODUCTION SYSTEMS:

From a management standpoint, tomatoes and peppers are grown in Florida on four types of soils: shallow loamy sands with an impermeable clay layer (mostly in the panhandle), deep sands (mostly north and central Florida), spodosols (east coast, central and south Florida **(Figure 2)**) and calcareous rock and marl soils (south Miami-Dade county).

In the karst topography of North Florida, the calcium carbonate bed rock lays below a 15 to 24 ft thick, uninterrupted layer of sand **(Figure 3)**. In contrast, spodosols are characterized by the presence of an impermeable spodic layer at the 3 to 4 ft depth.

In south Miami-Dade county, soils are characterized by very low nutrient and water holding capacity, an alkaline pH in the 7.4-8.4 range, and levels of calcium carbonate ($CaCO_3$) ranging from 30% to 94%. Soil profiles of rocky soils appear as an approximately 10 inch-thick layer of crushed limestone particles over the porous limestone bedrock **(Figure 4)**.

Figure 2. The profile of a sandy soil, typical of the Flatwoods in Florida. This soil happens to be a Myakka fine sand, which is the Florida state soil. Photograph by: UF/IFAS.

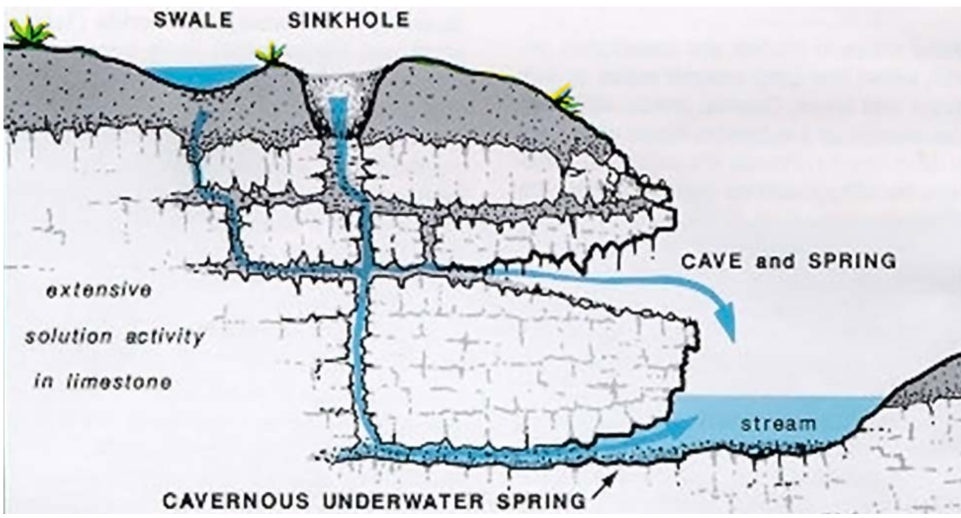

Figure 3. The Karst topography of North Florida: surface and ground water are connected through sinkholes, underground caves and springs. Diagram by: UF/IFAS.

On all these soils, tomatoes and peppers are grown on plastic-mulched, raised beds from transplants. Typical polyethylene mulch colors are black (in winter, for extra heat), white (in summer, for reflection) and silver (to reduce the risk of whitefly and aphid transmitted viruses). Bed widths vary from 24 to 36 inches, and standard bed spacing is 6-ft (7,260 linear bed feet of plastic per acre).

Tomatoes are staked, tied using the "Florida weave" and pruned. When peppers are staked, the stakes are placed on the bed shoulders. Strings (1 or 2) are used to keep the pepper plants from falling in the row middles. Production recommendations for tomato can be found in Olson (2005a) for sandy soils and in Li et al. (2006a) for calcareous soils. Recommendation productions for pepper can be found in Olson et al. (2005b) for sandy soils and in Li et al. (2006b) for calcareous soils.

Figure 4. Tomato grown on plasticulture in a calcareous soil. Note the gravelly soil texture visible through plant hole and the rebar stakes. Photograph by: Eric Simonne.

Prepared by: Dr. Eric Simonne

METHODS OF IRRIGATION:

Seepage (subsurface) and drip are the two methods of irrigation used for tomato and pepper production in Florida.

Seepage irrigation is used in areas where a perched water table can be maintained above an impermeable layer. Ground water is channeled by gravity to the field by a series of pipes and ditches. In the field, water moves laterally from the ditches and above the impermeable layer **(Figure 5)**. When water fronts from two adjacent ditches meet, the water moves upwards, thereby irrigating the crop from the bottom up. Typically, the water table is maintained between 18 and 24 inches below the top of the bed.

Seepage irrigation is the simplest, least expensive irrigation system, but it is the least efficient in terms of water usage.

With **drip irrigation**, water under pressure is delivered to the crops by a continuous set of pipes and tubes. Typical drip tape flow rates range from 16 to 27 gal/100ft/hr. Each tomato or pepper plant gets its water from a nearby emitter. Emitters are small holes in the drip tape placed 4 to 12 inches apart, that allow water to drip near the plant **(Figure 6)**. Because emitters have small diameters, they are prone to clogging **(Figures 7 & 8)**.

Drip irrigation requires preventative maintenance plan based on filtration, chlorination, acidification and flushing **(Table 3)** and periodic observation of the system to ensure proper operation and optimal efficiency **(Table 4)**.

Figure 5. In seepage irrigation, water moves laterally when it reaches the spodic layer on an Acona fine sand. Photograph by: Eric Simonne.

Figure 6. A drip emitter is a controlled leak. Photograph by Eric Simonne.

Typically, seepage and drip irrigation have application efficiencies of 20% to 70%, and 80% to 95%, respectively. Hence, drip irrigation requires **50% less** *water than seepage irrigation and provides uniformity.*

Table 3. Components of the prevention-is-best-medicine maintenance plan for drip irrigation systems.

Filtration: Removes solid particles from the water. Sand filters, disc filters, screen filters or centrifugal sand separators are used to remove precipitates and solid particles (200 mesh or equivalent for screen and disk filters).

Chlorination: Reacts with organic matter in the water and precipitate ions in solution by injecting hypochlorous acid (HOCl) in the water. A 1 ppm residual Cl concentration at the end of the drip line indicates complete reaction and is adequate.

Acidification: Reduces pH to around 6.5 to increase efficiency of chlorination.

Flushing: Increasing water velocity, forces solid particles and precipitates to leave the drip tape by ways other than the emitters usually the end of drip line.

Prepared by: Dr. Eric Simonne

Table 4. A check list for drip irrigation system maintenance during the growing season.

What to Check	Frequency	Compared to What	What to Look For	Possible Causes
Pump flow rate and pressures for each zone	Weekly	Design or benchmark flow rate and pressures	High flow and /or low pressure Low flow and/or high pressure	Leaks in pipelines Leaks in laterals Opened flush valves Opened ends of laterals Closed zone valves Pipeline obstruction Tape clogging Pump malfunction Well problems
Pressure difference across filter	Every irrigation	Manufacturer specifications	Exceeds or is close to maximum allowable	Filter becoming clogged Obstruction in filter
Operating pressures at ends of laterals	Monthly, unless other checks indicate possible clogging	Benchmark pressures	Pressure greater than expected Pressure lower than expected	Possible clogging High system pressure Obstruction in tape Broken lateral Leaks in lateral Low system pressure
Water at lateral ends & flush valves	Bi-weekly	Water source	Particles in water Other debris	Broken pipeline Hole in filter screen Tear in filter mesh Particles smaller than screen Filter problem Chemical/fertilizer precipitation Algae growth Bacterial growth
Pump station	Weekly	Leaks, breaks, engine reservoir levels, tank levels		
Injection pump settings	Weekly	Calibrated setting at startup	Discoloration at outlets or ends of laterals	Indicates possible build up of minerals, fertilizer, algae, and/or bacterial slime
Overall system	Weekly	System at start up	Leaks in tape Wilting crop	Pest or mechanical damage Tape off of fittings Tape blowout from high pressure Tape clogged, obstructed, or broken Crop may also be affected by pathogens

[z] Most benchmark and in-season values in this table are also BMP record keeping requirements

Figure 7. Poor uniformity caused by totally or partially clogged emitters. Photograph by: Eric Simonne.

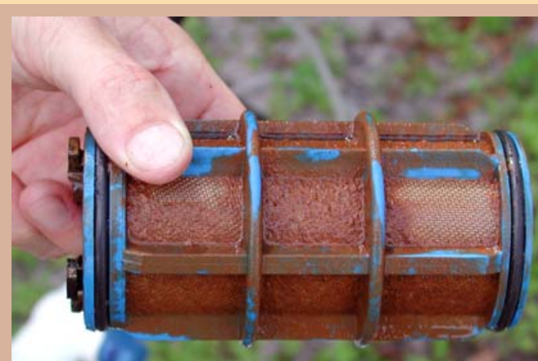

Figure 8. Dirty filters are common occurrences when no maintenance program for drip irrigation system is followed. Photograph by: Eric Simonne.

From a BMP standpoint, irrigation management is as important as fertilizer application rates because soluble nutrients move with water in the soil.

Figure 9. With subsurface (seepage) irrigation, water levels in the field are controlled by removable boards. Photograph by: Eric Simonne.

The most vulnerable period for nutrient leaching is early in the season when plants are small, irrigation is applied in excess of plant needs for establishment, and a large portion of the preplant fertilizer is still in the bed.

IRRIGATION SCHEDULE:

Scheduling drip irrigation consists of determining how much water to apply and when to start irrigation. Because of the low water holding capacity of Florida soils (<10%, v:v) and shallow root systems (12 to 14 inches), tomatoes and peppers are irrigated daily.

An irrigation schedule consists of **(see Table 5)**:

1. A target irrigation volume
2. A measurement of soil moisture to fine tune irrigation
3. A method to account for rainfall contribution to soil moisture
4. A rule for splitting irrigation
5. Record keeping

Seepage irrigation only allows for limited scheduling. Boards in a water-control structure located at the lowest point of the field control water height in the field **(Figure 9)**. However, drip irrigation allows for flexible irrigation schedules that can be adjusted based on crop water use.

IMPROVING EFFICIENCY:

Splitting daily irrigation into two or three short events is more efficient than a single, long irrigation. In practice, splitting irrigation has to be a compromise between two constraints. On one side, frequent and short irrigations are less likely to leach soluble nutrients below the root zone. On the other side, frequent and short irrigations waste water and reduce irrigation uniformity due to a large portion of the irrigation cycle used for system charge and flush.

Each irrigation cycle has to deliver enough water to completely wet the soil between two adjacent emitters to maintain crop uniformity, especially when the plants are small.

The injection of soluble dye and controlled irrigation events is a simple and practical tool to determine how fast water moves in the soil and when irrigation events need to be split **(Figures 10-12)**.

On sandy soils, the vertical movement of water is approximately 0.1 inch/gal/100ft in the absence of plants. In other words, a three hour irrigation event for a 24 gal/100ft/hr flow rate (medium flow rate) moves the water front by more than 7 inches. In commercial vegetable fields with drip irrigations ranging from 30 min to 3 hours, it was found that the water front was dropping 0.5 to 1.5 inches per day in the presence of a crop.

Figure 10.

Figure 11.

Figure 12.

Figures 10 - 12. Effect of short irrigations on the position of the waterfront. The position of the blue dye represents the movement of water. At 1-hour irrigation with a medium flow rate tape keeps the dye within 8 inches of the emitter **(Figure 10)**, but a leaching rainfall moved the dye into the row middle **(Figure 11)**. On a deep sandy soil, the dye may be below the root zone even with short irrigation times **(Figure 12)**. Photographs by: Eric Simonne.

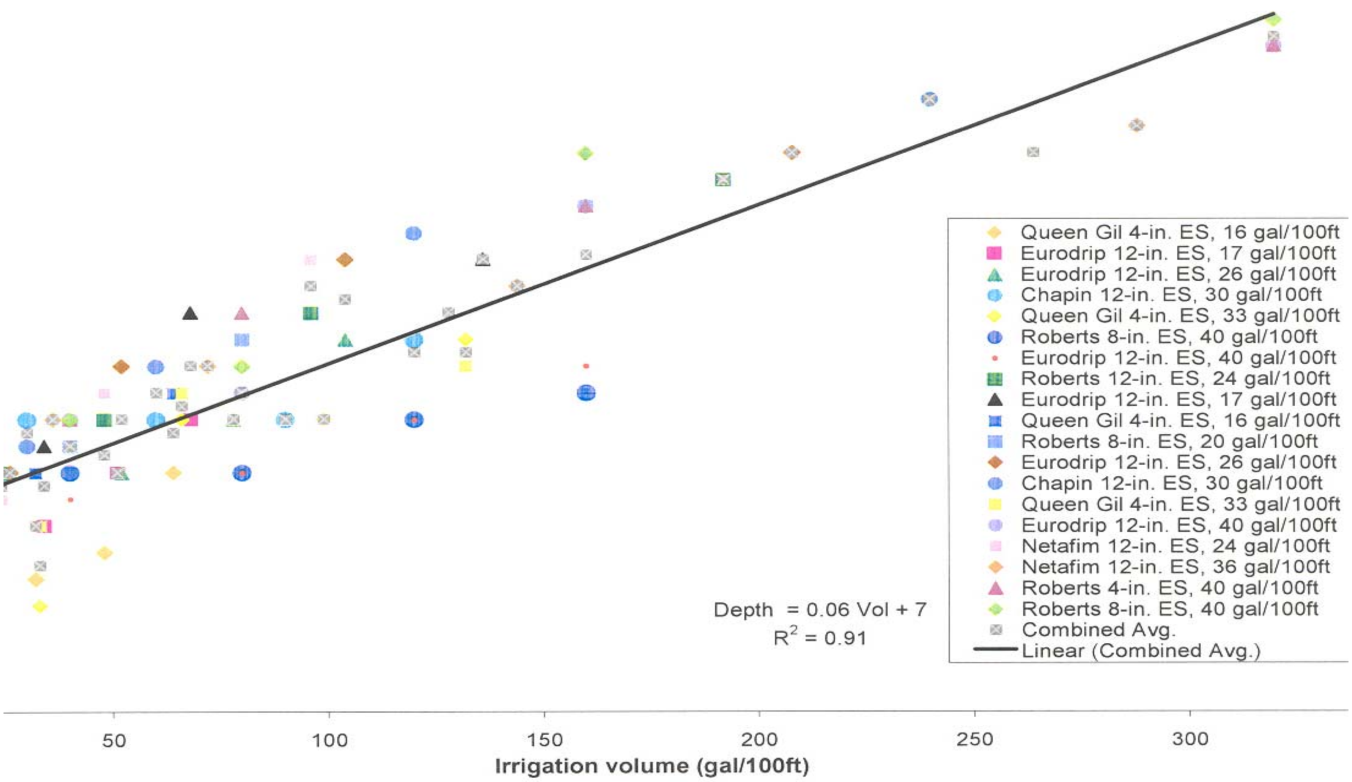

Figure 13. Depth of the water front response to irrigation rates using common drip irrigation tapes on a Lakeland fine sand. Note the slope is almost 1/10 inch for every gallon per 100ft of irrigation applied.

Table 5. Summary of guidelines for irrigation scheduling for tomato and pepper.

Irrigation scheduling component	Irrigation system[z]	
	Seepage[y]	Drip[x]
1- Target water application rate	Keep water table between 18 (for small plants)and 24 inch depth (for mature plants)	Historical weather data or crop evapotranspiration (ETc) calculated from reference ET or Class A pan evaporation
2- Fine tune application with soil moisture measurement	Monitor water table depth with observation wells	Maintain soil water tension in the root zone between 8 and 15 cbar
3- Determine the contribution of rainfall	Typically, 1 inch rainfall raises the water table by 1 foot	Poor lateral water movement on sandy and rocky soils limits the contribution of rainfall to crop water needs to (1) foliar absorption and cooling of foliage and (2) water funneled by the canopy through the plant hole
4- Rule for splitting irrigation	Not applicable. However, a water budget can be developed	Irrigations greater than 12 and 50 gal/100ft (or 30 min and 2 hrs for medium flow rate) when plants are small and fully grown, respectively are likely to push the water front below the root zone
5-Record keeping	Irrigation amount applied and total rainfall received[w] Days of system operation	Irrigation amount applied and total rainfall received[w] Daily irrigation schedule

[z] Efficient irrigation scheduling also requires a properly designed and maintained irrigation system
[y] Practical only when a spodic layer is present in the field
[x] On deep sandy soils
[w] Required by the BMPs

FLOODING:

Flooded conditions develop in Florida during heavy rains on soils that already have a shallow water table, and occasionally on sandy soils **(Figure 14)**. Typically, a 1-inch rain raises the water table by 1 foot. Flooding affects plants by creating anaerobic conditions (soil pores are saturated with water), reducing oxygen supply, creating reducing redox conditions, affecting soil microorganisms, creating conditions favorable for denitrification and leaching soluble nutrients when water recedes. Irreversible damage may be done to vegetable crops when flooding lasts for several days. However, additional fertilizer application and/or growth regulator may help vegetables recover from short floods.

Figure 14. Hurricanes can cause flooding damage like this caused by Hurricane Wilma. Photograph by: Monica Ozores-Hampton.

Prepared by: Dr. Eric Simonne

NUTRIENT NEEDS FOR TOMATO & PEPPER:

Fertilization and liming recommendations for tomato and pepper grown in Florida are based on soil testing, a bed spacing of 6 ft and 13-week-long growing seasons. This corresponds to 7,260 linear bed feet in one acre. Fertilization recommendations for tomato and pepper grown in Florida include a base recommendation and supplemental amount **(Tables 6a, b)**.

For subsurface irrigated crops, approximately 25% of the N and K_2O and all the P and micronutrients are broadcast incorporated in the bed ("cold mix") **(Figure 15).** The remaining N and K_2O are banded into one or two groves ("hot mix") placed on the bed shoulder. As water moves upwards by capillarity from the water table toward the top of the bed, it slowly dissolves fertilizer and releases nutrients. For drip irrigated crops, 20% to 40% and all the P and micronutrients are broadcast incorporated in the bed. The remaining N and K_2O may be injected daily or weekly at rates equivalent to 1.5 lbs/A/day when plants are small to 2.5 lbs/A/day for fully grown plants.

Figure 15. With seepage irrigation, the fertilizer is applied by combinations of preplant incorporated "cold mix" and one or two "hot" bands on the shoulder. Photograph by: Monica Ozores-Hampton.

SUPPLEMENTAL FERTILIZER APPLICATIONS:

Supplemental fertilizer applications may be used (1) after a leaching rain, (2) when "low" foliar nutrient concentrations have been diagnosed after sap testing **(Figure 16)** or leaf analysis, or (3) during extended harvest seasons. A leaching rain is defined as a rainfall amount of 3 inches in 3 days or 4 inches in 7 days. This definition is based on 3 and 4 consecutive days floating averages. Procedures and interpretations of sap testing and leaf analysis are described below. Extended harvest season may occur when a crop of tomato or pepper is harvested longer than a typical crop due to favorable market conditions.

Figure 16. Ion-specific meters are for measuring petiole sap nitrate and potassium concentrations. Photograph by: George Hochmuth.

Micronutrient applications should also be based on soil-test results. On sandy soils where a proven need exists, a general guide for fertilization is the addition of (in elemental lbs/A) 3 for manganese, 2 for copper, 5 for iron, 2 for zinc, 2 for boron and 0.02 for molybdenum. Micronutrients may be supplied from oxides, sulfates or chlorides. For most micronutrients, a very fine line exists between sufficiency and toxicity. Micronutrient deficiencies are often related to pH-induced reduced availability and not actual shortages. They usually occur on the high pH sandy soils of south Florida and the calcareous soils of Miami-Dade county. When pH is the cause of micronutrient deficiencies, additional soil applications of micronutrients are unlikely to correct the deficiency. In these cases, foliar applications are justified.

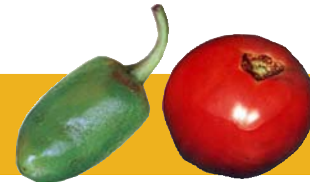

Table 6a. Fertilization recommendations for round, Roma, cherry and saladette tomato grown in Florida (from Olson et al., 2005a).

Production system	Nutrient	Recommended base fertilization[z]							Recommended supplemental fertilization[z]		
		Total (lbs/A)	Preplant[y] (lbs/A)	Injected[x] (lbs/A/day) Weeks after transplanting[w]					Leaching rain[r,s]	Measured >low= plant nutrient content[u,s]	Extended harvest season[s]
				1-2	3-4	5-11	12	13			
Drip irrigation, raised beds and polyethylene mulch	N	200	0-70	1.5	2.0	2.5	2.0	1.5	N/A	1.5-2 lbs/ A/day for 7days[t]	1.5-2 lbs/ A/day[p]
	K_2O	220	0-70	2.5	2.0	3.0	2.0	1.5	N/A	1.5-2 lbs/ A/day for 7days[t]	1.5-2 lbs/ A/day[p]
Seepage irrigation, raised beds and polyethylene mulch	N	200	200[v]	0	0	0	0	0	30 lbs/A[q]	30 lbs/A[t]	30 lbs/A[p]
	K_2O	220	220[v]	0	0	0	0	0	20 lbs/A[q]	20 lbs/A[t]	20 lbs/A[p]

[z] 1 A = 7,260 linear bed feet per acre (6-ft bed spacing); for soils testing very low in Mehlich 1 potassium (K_2O).

[y] 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.

[x] This fertigation schedule is applicable when no N and K_2O are applied preplant. Reduce schedule proportionally to the amount of N and K_2O 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.

[w] For a standard 13 week-long, transplanted crop grown in the Spring.

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

[u] 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.

[t] Plant nutritional status must be diagnosed every week to repeat supplemental application.

[s] Supplemental fertilizer applications are allowed when irrigation is scheduled following a recommended method. Supplemental fertilization is to be applied in addition to base fertilization when appropriate. Supplemental fertilization is not to be applied "in advance" with the preplant fertilizer.

[r] A leaching rain is defined as a rainfall amount of 3 inches in 3 days or 4 inches in 7 days.

[q] Supplemental amount for each leaching rain.

[p] Plant nutritional status must be diagnosed after each harvest before repeating supplemental fertilizer application.

Table 6b. Fertilization recommendations for pepper grown in Florida (from Olson et al., 2005b).

Production system	Nutrient	Recommended base fertilization[z]							Recommended supplemental fertilization[z]		
		Total (lbs/A)	Preplant[y] (lbs/A)	Injected[x] (lbs/A/day) Weeks after transplanting[w]					Leaching rain[r,s]	Measured >low= plant nutrient content[u,s]	Extended harvest season[s]
				1-2	3-4	5-11	12	13			
Drip irrigation, raised beds and polyethylene mulch	N	200	0-70	1.5	2.0	2.5	2.0	1.5	N/A	1.5-2 lbs/ A/day for 7days[t]	1.5-2 lbs/ A/day[p]
	K_2O	225	0-70	1.5	2.0	2.5	2.0	1.5	N/A	1.5-2 lbs/ A/day for 7days[t]	1.5-2 lbs/ A/day[p]
Seepage irrigation, raised beds and polyethylene mulch	N	200	200[v]	0	0	0	0	0	30 lbs/A[q]	30 lbs/A[t]	30 lbs/A[p]
	K_2O	225	220[v]	0	0	0	0	0	20 lbs/A[q]	20 lbs/A[t]	20 lbs/A[p]

[z] 1 A = 7,260 linear bed feet per acre (6-ft bed spacing); for soils testing very low in Mehlich 1 potassium (K_2O).

[y] 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.

[x] This fertigation schedule is applicable when no N and K_2O are applied preplant. Reduce schedule proportionally to the amount of N and K_2O 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.

[w] For a standard 13 week-long, transplanted crop grown in the Spring.

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

[u] 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.

[t] Plant nutritional status must be diagnosed every week to repeat supplemental application.

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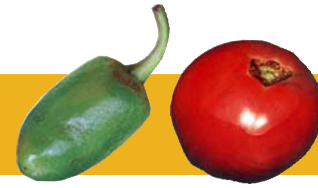
[r] A leaching rain is defined as a rainfall amount of 3 inches in 3 days or 4 inches in 7 days.

[q] Supplemental amount for each leaching rain.

[p] Plant nutritional status must be diagnosed after each harvest before repeating supplemental fertilizer application.



An estimated 200 acres of grape tomatoes are currently grown in Florida.

Figure 17. Because most cultivars used are indeterminate, grape tomato may need to be hedged to control growth. Photograph by: Eric Simonne.

PRELIMINARY N RATE RECOMMENDATION FOR GRAPE TOMATO:

Current recommendations for tomato production apply to the round, cherry, Roma and saladette types of tomato. Grape tomatoes have recently gained in popularity among consumers because they can be eaten without being cut, they are deep red in color and their flavor is intense.

Typically, grape tomatoes are grown with plasticulture (raised beds, polyethylene-mulched beds spaced 6-ft apart) using transplants and picked at the full-red stage to ensure high quality. Suitable red grape varieties include 'Santa', 'Tami G', and 'St. Nick'.

Because current grape tomato varieties are indeterminate, grape tomato may be grown for up to six months **(Figure 17).** Hence, grape tomatoes require taller stakes (8-ft tall), are tied 6 to 8 times and need hedging to control vigor. Preliminary fertigation research with drip-irrigated 'Tami G' grape tomatoes, have suggested that current N fertilization recommendations for round tomato need to be adapted for grape tomato.

The actual length of the growing season is determined by market conditions and not plant growth. Therefore, N fertilization programs for grape tomato should focus on establishing daily N rates at different periods of production rather than on the seasonal N rate: 40 lbs/A preplant incorporated and weekly injections of 0, 1.5, 2.0, 2.5, and 3.0 lbs/A/day for 1, 2, 3-4, 5-10, and 11-final harvest weeks after transplanting, respectively (Simonne et al., 2006). This proposed schedule needs to be validated under commercial conditions and under optimal irrigation practices.

NUTRIENT DEFICIENCIES:

General descriptions of symptoms of nutritional deficiencies exist. But overall, nutrient deficiencies in tomato and pepper crops grown in Florida are rare occurrences because these high-value crops are grown intensively. Nevertheless, micronutrient deficiencies, blossom-end rot **(Figure 18)**, and grey wall are the most common nutrient-related disorders of pepper and tomato in Florida **(See Disorders of Tomatoes in Chapter 5 starting on pg. 135)**.

Figure 18. Lack of calcium supply to the young growing fruits results in blossom-end rot when the fruit enlarges. Photograph by: Eric Simonne.

Prepared by: Dr. Eric Simonne

SAMPLING & DIAGNOSTIC TOOLS:

Soil sampling for soil testing: The only science-based method to determine how much nutrients need to be provided by a fertilization program and if, and how much lime is needed is to soil test. A producer soil test information sheet from the UF-IFAS ARL/ESTL can be found at http://edis.ifas.ufl.edu/pdffiles/SS/SS18600.pdf. **See Appendix 2**.

SOIL TESTING CONSISTS OF:

Sampling: Soil samples should be representative (at least 15 random spots), and random with an area of approx. 20 acres. Samples must be properly bagged, clearly identified and dated, and shipped within 24 hrs to an analytical laboratory **(Figure 19)**.

Analysis: While many soil testing methods are available, the UF-IFAS official methods for soil analysis are Mehlich 1 for acidic sandy soils with pH up to 7.3, AB-DTPA for alkaline (calcareous) soils with a pH of 7.4 or above, water for P extraction in all organic soils, and acetic acid for K, Mg, Ca, Si and Na in all organic soils.

Interpretation of soil test results and nutrient recommendation. These two steps are typically performed by the soil test laboratory using calibration data.

Figure 19. Soil samples should come from at least 15 random spots with an area of approximately 20 acres. Photograph by: UF/IFAS.

What constitutes a "credible research institution"?

A **"credible"** research institution (whether it is a private lab, private consultant, or fertilizer company) is one that conducts research by true scientific method involving hypotheses testing, etc., and solicits peer-review of research results and conclusions. It is the peer review and independent verification that makes the research credible. Obviously, research results and resulting recommendations from various land-grant universities in the Southeastern U.S. would qualify under this scenario.

HOW TO CHOOSE A SOIL TESTING LABORATORY IN THE BMP ERA:

Most tomato and pepper growers arrange for their soil tests to be collected, analyzed and interpreted through consultants or third-party service providers. The selection of a laboratory was mostly based on convenience of sample drop off, turn around time and price.

The "*Optimum fertilization management/application"* section of the BMP manual for vegetable crops (p. 93) clearly identifies that methods of soil extractions used should also be included in the selection of a laboratory (FDACS, 2005). On p. 93, it is recognized that growers "may use IFAS published fertilizer recommendations Soil and Nutrient Management: Sampling and Diagnostic Tools or use alternate recommendations supported by other credible research institutions only when regional, site-specific conditions and documented data support this approach".

Hence, fertilizer recommendations may not be consistent with the terms of the BMP program when they are based on the results of soil tests that are not based on "credible" research calibration.

WATER SAMPLING FOR DRIP IRRIGATION:

Determining water quality through water testing is an essential part of irrigation management. Water testing will help determine water chemical composition, pH, and hardness **(Table 7)**. These parameters have direct implications on chlorination, acidification and filtration needs for irrigation water. Analyses performed by the UF-IFAS ARL/ESTL are pH, electrical conductivity, Ca, Mg, Fe, Mn, Na, Cl, hardness, total carbonates and suspended solids. A sample water test information sheet may be found at http://edis.ifas.ufl.edu/pdffiles/SS/SS18400.pdf. Please note that these tests will not determine if the water is suitable for human consumption.

Table 7. Criteria for plugging potential of microirrigation water sources (adapted from Pitts et al., 2003).

Factor	Plugging hazard based on concentration		
	Slight	Moderate	Severe
pH	<7.0	7.0 to 7.5	>7.5
Dissolved solids (mg/L)	<500	500 to 2000	>2000
Manganese (mg/L)	<0.1	0.1 to 0.5	>0.5
Iron (mg/L)	<0.1	0.1 to 0.5	>0.5
Hydrogen sulfide (mg/L)	<0.5	0.5 to 2.0	>2.0
Hardness (mg/L $CaCO_3$)	<150	150 to 300	>300

Prepared by: Dr. Eric Simonne

PETIOLE SAP TESTING:

For sap testing, at least 25 petioles randomly collected from most-recently-matured leaves are needed. For best results, leaves with obvious defects or with diseases should be avoided. Sampling should always be done at the same time of the day (best between 10 AM and 2 PM). Then, petioles are promptly (within few minutes) separated from the leaf blades, cut into ¾ inch long sections, introduced into a garlic press and squeezed. Tomato petioles are longer and more succulent than pepper petioles and hence have a tendency to produce more sap under less pressure in the press. Two to three drops of sap are then placed on the sensor pads of calibrated ion-specific electrode meters (Cardy, Spectrum Technologies, Inc., Plainfield, IL) for determination of NO_3-N and K concentration **(Figure 20)**. Sodium (Na) electrodes are also available, but they are not routinely used for tomato and pepper nutrition diagnosis in Florida. Once stabilized, the concentration displayed on the reader is compared to sufficiency ranges **(Table 8)**. Sap test results are immediately available.

Figure 20. Petiole sap testing may be done in the field shortly after sampling. Photograph by: Eric Simonne.

Table 8. Sufficiency ranges for the diagnosis of tomato and pepper nutritional status based on petiole sap testing (from Olson et al., 2005a,b).

Crop stage of growth	Tomato		Pepper	
	NO_3-N (mg/L)	K (mg/L)	NO_3-N (mg/L)	K (mg/L)
First buds	1,000-1,200	3,500-4,000	1,400-1,600	3,200-3,500
First open flowers	600-800	3,500-4,000	1,400-1,600	3,000-3,200
Fruits one-inch diameter	400-600	3,000-3,500	N/A[z]	N/A[z]
Fruits half grown	400-600	3,000-3,500	1,200-1,400	3,000-3,200
First harvest	300-400	2,500-3,000	800-1,000	2,400-3,000
Second harvest	200-400	2,000-2,500	500-800	2,000-2,400

[z] N/A = Not available

WHOLE LEAF ANALYSIS:

A usable leaf sample should be made of at least 20, healthy, whole (blade + petiole) most recently matured leaves which for tomato and pepper corresponds to the 5th or 6th leaf from the top of each branch. Samples must be placed in a paper bag (not plastic bag), dried, ground to pass through a 20-mesh sieve and analyzed in a laboratory. Turn-around time is typically 2 to 3 days. Nutrient concentrations in the sample are then compared to sufficiency ranges **(Table 9)**. When available, customized sufficiency ranges may be used. When whole petiole sap or leaf analysis is used to diagnose a nutritional problem, separate samples should be taken of the symptomatic (problem) and healthy (normal) areas.

Table 9. Sufficiency ranges for the diagnosis of tomato and pepper nutritional status based on whole-leaf analysis (from Olson et al., 2005a,b).

Crop	Sufficiency range					
	Macronutrients (g/100DW[z] or %)					
	N	P	K	Ca	Mg	S
Tomato	2.0-3.0	0.2-0.4	1.5-2.5	1.0-2.0	0.25-0.50	0.3-0.6
Pepper	3.0-5.0	0.3-0.5	2.5-5.0	0.6-1.5	0.3-0.5	0.3-0.6
	Micronutrients (mg/kg DWor ppm)					
	B	Cu	Fe	Mn	Mo	Zn
Tomato	20-40	5-10	40-100	30-100	0.2-0.6	20-40
Pepper	20-50	5-10	30-150	30-100	0.2-0.8	25-80

[z] DW = dry weight

Prepared by: Dr. Eric Simonne

RECORD KEEPING:

Successful tomato and pepper production requires measurements and record keepings of fertilization, irrigation and plant nutritional status, together with those of pesticide applications. In the past record keeping requirements for irrigation were related to water permitting. Participation in the BMP program for vegetables also requires formalized record keeping of fertilization and irrigation practices **(Table 10)**.

Table 10. Fertilization and irrigation record keeping requirements for the BMP program.

Record keeping requirement	BMP title[z]	BMP number and page[z]
Fertilization		
Record or sketch where soil samples were taken within each area	Soil testing/soil pH	26
Record date, rate of application, materials used and method of application when liming	Soil testing/soil pH	26
Keep the soil testing lab report for each field and crops as well as information about the soil testing lab and the soil test method used (extractant)	Soil testing/soil pH	26
Fertilizer used and dates amounts applied	Optimum fertilization management/application	93
Irrigation		
Maintain records of well construction	Well head protection	6
Flow rate and pressure delivered by the injector and irrigation pumps(s), as well as the energy consumption of the power unit of the irrigation pump	Chemigation/fertigation	34
Record operating values of irrigation design and how they change throughout the crop (see table 4 for specifics)	Irrigation system maintenance and evaluation	39
Record the flow rate, pressure delivered by the pump, and energy consumption of the power unit frequently enough to gain an understanding	Irrigation system maintenance and evaluation	39
Keep records of irrigation amounts applied and total rainfall received. Please note when rainfall exceeds a leaching rainfall event by an asterisk	Irrigation scheduling	40
Keep permanent records of crop history	Seasonal or temporary farming operations	49
Keep records of flooded field duration, levels and water quality analyses	Seasonal or temporary farming operations	49

[z] in the BMP manual for vegetable crops, FDACS, 2005

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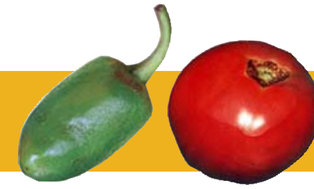

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Notes:

STEPS TO SUCCESS:

Decide if cover crops fit your production system and select the appropriate cover crops for your farm:

1. Do a cost-benefit analysis (fertility, soil quality, nutrient management, pest management vs. labor, expense, moisture loss).
2. Assess placement in the cropping sequence or rotation, method of establishment, legume or nonlegume, appropriate methods of terminating the cover crop.
3. Select the species and cultural measures that give the desired amount of biomass/ fertility/C:N/allelochemical just prior to establishment of the subsequent cash crop.
4. Choose a cover crop that has a strong root system. Cover crops that are allowed to decompose in the field increase soil stability and water retention.

BENEFITS OF COVER CROPS:

Improve health of agrosystem: Cover crops work to increase soil aeration, moderate soil temperature, improve soil structure by adding organic matter and increase water penetration. These improvements help to reduce soil loss due to erosion and tillage.

Reduce pests and pathogens: Certain cover crops can suppress insect, nematode and pathogen populations.

Reduce weed pressure: Cover crops fill an open niche and protect areas from weed invasion. These crops are called "smother crops" when grown in sequence with cash crops and "living mulches" when grown simultaneously with cash crop.

Cash crop production: Cover crops may provide an additional income source as many cover crops are utilized as forage and animal feed.

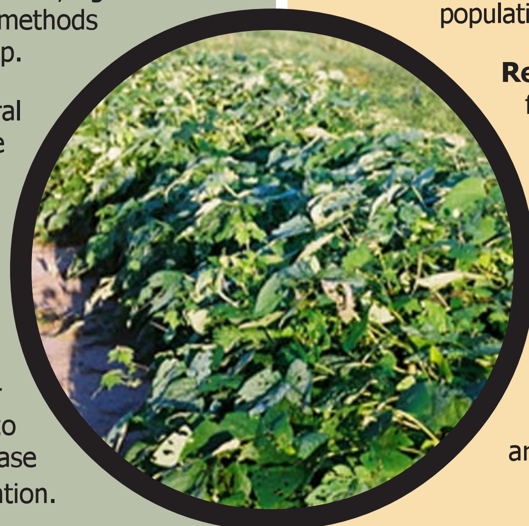

Figure 1. Velvetbean as a cover crop. Photograph by: Amanda Collins.

SELECTING A COVER CROP:

- Select a cover crop appropriate for the season of production.
  - Cool season cover crops for Florida include rye, black oat, hairy vetch and crimson clover.
  - Sorghum-sudan grass, cowpea, velvetbean or sunnhemp are appropriate for use as warm season cover crops.
- Use legumes to provide nitrogen.
- To prevent leaching, use non-legumes as catch crops to scavenge and cycle nitrogen especially in crops with high fertilizer requirement.
- Choose a problem to address when selecting a cover crop:
  - For nematode management, the specific cultivar of the cover crop is important, i.e. 'Iron Clay' cowpea.
  - For biofumigation select *Brassica* cover crops (i.e. white mustard and brown mustard) with high glucosinolate content and ensure maximum tissue disruption during incorporation.

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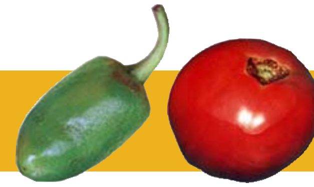

COVER CROP SELECTION CHECKLIST:

Seed cost and availability	• What is the seed cost and is the seed available in your area?
Growth Habit	• What kind of growth habit is needed? • When is the growth required, e.g., lots of vigorous late fall growth or rapid early spring growth?
Overwintering	• Does the cover crop need to survive over winter? • Would it suit the cropping schedule and soil type if the cover crop winter killed and dried out by spring?
Control Options	• Will the cover crop become a weed concern? • How is it controlled? • What options are there for control?
Sensitivity to Herbicides	• How sensitive is the cover crop to herbicide residues from other crops in the rotation?
Establishment	• What is the best way to plant the seed? • What equipment is needed? • How easy is it to establish? • Will it create a solid cover?
Nutrient Management	• Does the cover crop fix nitrogen or does it require nitrogen to grow well? • Does it scavenge nitrogen well?
Pest Management	• What crop family is the cover crop in? • Is it related to other crops in the rotation? • Are there pest concerns?

Adapted from: http://www.omafra.gov.on.ca/english/crops/pub811/2cover.htm#rye

Refer to the pg. 36 for the information on the different cover crops.

MATCHING PRODUCTION SYSTEM & CROPPING CYCLE:

- Use legumes as a green manure for organic production systems and to decrease the use of mineral fertilizers in sustainable conventional systems.
- Perennial cover crops and hard-seeded cover crops may be appropriate for perennial crops in vineyards, orchards and groves, so that growers do not have to replant annually.
- For organic systems, avoid cover crops that cannot be easily killed by rolling, undercutting or tillage and are otherwise prone to be weedy. Cover crops that are susceptible to pests, pathogens or nematodes that adversely affect the next cash crop in the cropping sequence should also be avoided.

Figure 2. Cover crop being used as a green manure. This crop, Sunn hemp, is being rototilled into the soil. Photograph by: UF/IFAS.

DEFINITIONS:

C:N Ratio: Carbon-to-Nitrogen ratio. The C:N ratio of the organic material added to the soil influences the rate of decomposition of organic matter and this results in the release or trapping of soil nitrogen.

Allelochemicals: Substances exuded by plants or produced during decomposition of their residues that inhibit the germination and growth of other plants.

Figure 3. 'Iron Clay' cowpea cover crop. Photograph by: Amanda Collins.

AVOIDING PROBLEMS:

- Cover crops may deplete soil moisture in dry climates – plant species that are adapted to dry climates and produce sufficient biomass to be used as mulch.
- Where allelopathic cover crops are used for weed control – avoid phytotoxicity to subsequent cash crops by direct-seeding only large seeded crops or by using transplants, which are usually less sensitive to allelochemicals than seed.
- Non-legume tend to have high **C:N ratios**, which depress available N. (Solve by turning under while still green = lower C:N ratio; plant in mixtures with a legume cover crop).
- Less predictable crop fertilizer requirements – estimate available nitrogen and supplement with a reduced rate of slow release fertilizer as necessary.
- Cover crops have low economic value and tie up land, therefore plant during fallow periods.
- Cover crop residues result in cooler soils and delayed development of subsequent crop:
  - Avoid use where earliness is desirable.
  - Use strip tillage to clear a narrow strip for cash crop establishment.
- Rapid decomposition of some legumes: N leaching – undercut or incorporate just prior to establishment of cash crop.
- Difficulty with residue incorporation with some covercrops – mow during season to ensure stems do not become woody.

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Table 1. Description of different cover crops.

Cover Crop	Type	Location-Season	Pro's	Con's
Sudan Grass (Sudax) *Sorghum bicolor* *S. sudanense*	grass	Florida – Warm	• Drought and heat tolerant • Decreases growth of weeds –smother crop (ragweed, redroot pigweed, purslane and foxtail) • Used as a forage crop • Cultivar SX-17 sorghum-sudangrass suppresses root-knot nematodes (*Meloidogyne* spp.) • Rapid growth builds up organic matter in soil • Some varieties resistant to downy mildew, anthracnose, maize dwarf mosaic virus, head smut and aphids	• Cold sensitive • Host to lesion nematodes (*Pratylenchus penetrans*) • Does not suppress other *Pratylenchus* nematodes • Hydrocyanide is released during frost or plant stress • Sudan grass grows 3-8 ft high and will re-grow after harvest until cool temperature or lack of moisture
Sunn Hemp *Crotalaria juncea*	legume	Florida – Warm	• Organic nitrogen source (green manure) • Suppresses weeds • Slows soil erosion • Reduces root-knot nematode populations • Enhances nematode natural enemies	• Difficult to obtain seed • High seed cost • Susceptible to frost kill • Nematodes can resurge on subsequent crops • *Pythium* host
Pearl Millet *Pennisetum glaucum*	grass	Florida – Warm	• Forage crop used for pasture and hay • Fast growing • Nematode resistant • Tolerant of drought, low fertility, low pH	• Some cultivars should not be grazed by horses
Hairy Vetch *Vicia villosa*	legume	North Florida – Cool	• Cold tolerant • High nitrogen fixing capability • Moderate shade and drought tolerance	
Cowpea *Vigna unguiculata*	legume	Florida – Warm	• Provides nitrogen • Moderate drought tolerance • Quick to establish • Grows well in hot weather • Nematode-suppressive cultivars – 'Iron Clay'	• Low cold and shade tolerance
Crimson clover *Trifolium incarnatum*	legume	North Florida Cool	• Cold tolerant • Has nitrogen fixation capability • Moderate drought tolerance • Shade tolerant	• Slow to establish
Velvetbean *Mucucna deeringiana*	legume	Florida – Warm	• Grows well in sandy and infertile soils • Vining and bush types • Fixes nitrogen • Suppresses root-knot nematode	• Large seed than can be damaged in seed drills • Expensive seed, difficult to obtain
Rye *Secale cereale*	grass	Florida – Cool	• Moderately cold tolerant • Shade tolerant • Drought tolerant • Forage crop for spring hay • Quick to establish	• Volunteers readily so may become a weed
Black oat *Avena strigosa*	grass	Florida – Cool	• Allelopathic to weeds • Resistant to root-knot nematode • Can be used as forage • Cycles N more effectively than rye	• Susceptible to *Helminthosporium avenae* • Only 1 cultivar available in the US 'Soilsaver'

Compost may contain enough micronutrients (trace elements) to meet the crop's annual requirements.

STEPS TO SUCCESS USING COMPOST:

- Compost must pass applicable federal and state law such as EPA regulation 40 CFR Part 503 for windrow composting of biosolids: temperatures of 55◦C for 15 days and turned 5 times will eliminate pathogen and kill weed seeds.
- Meet "horticultural specification" based in crop requirement **(Table 1)**.
- Compost should be stable and mature, to avoid nitrogen "rob" and phytotoxic reactions to chemicals (acetic, propionic and butyric acids).
- Compost is not considered a fertilizer; however, significant quantities of nutrients (particularly N, P, K and micronutrients) become bio-available with time as compost decomposes in the soil. Amending soil with compost provides a slow-release source of nutrients, whereas mineral fertilizer is usually water-soluble and is immediately available to plants.
- Compost usually contains large quantities of plant-available micronutrients. Therefore is important to determine the nutrient content by a compost certified laboratory. Total N, P and K apply by the compost or manure should be deducted from the total fertilizer N, P and K annual application rate.

BENEFITS OF COMPOST AND MANURES:

Compost as a transplant medium: The transplant industry for the production of tomato and pepper plants relies on peat moss as a major ingredient in soilless media. Peat is an expensive, non-renewable resource. Seed emergence and seedling growth was similar to traditional peat:vermiculite media when peat was partially replaced with compost. Negative growth effects were reported when the medium was 100% compost, especially when immature, unstable compost was used **(Figure 1)**.

Figure 1. Compost as substitute for potting soil component. C1 = 18% compost; C2: 35% compost; C3= 52% compost; C4= 70% compost; and C5 = No compost. Photograph by: Monica Ozores-Hampton.

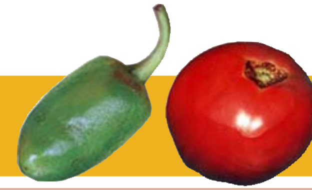
Compost as a soil amendment: Amending soils with composted materials has been reported to increase tomato and pepper yields. However, combining compost and inorganic fertilizer has generally been more effective in producing a positive plant response than separate application of either material alone **(Figures 2 & 3)**.

Figures 2 & 3. (Left) Reduction in fertilizer use and higher yields are a few of the benefits of long-term compost use. (Right) 0.8% organic matter in non-composted bed. Photographs by: Monica Ozores-Hampton.

After this 10 year study (to the right), the use of 3% organic matter from compost resulted in 50% less fertilizer.

Soilborne disease suppression: Compost can suppress plant diseases but not all composts and not all the time. The colonization of compost by beneficial microorganisms during the latter stages of composting appears to be responsible for inducing disease suppression, especially root-rot diseases and nematodes. Compost does not kill the pathogens that cause disease as fungicides do. Instead, compost controls the pathogens by keeping the beneficial microorganisms active and growing. Therefore, pathogenic agents will either not germinate or will remain inactive.

Prepared by: Dr. Monica Ozores-Hampton



More Benefits of compost:

Biological weed control: Weed growth suppression is an important attribute of surface-applied mulch. An organic mulch suppresses weeds by its physical presence as a surface cover, or by the action of phytotoxic compounds that it contains. Chemical effects of phytotoxic compounds (volatile fatty acids and/or ammonia) in compost can decrease weed seed germination. Inhibition of germination or subsequent weed growth may be attributed to both the physical effect of the mulch and the presence of phytotoxic compounds (fatty acids) in the immature compost **(Figure 4).**

Figure 4. Application of 3 inches or more immature compost in the row middle in vegetable beds suppressed weeds significantly. Photograph by: Monica Ozores-Hampton.

Figure 5. Application of Municipal Solid Waste compost as a polyethylene mulch replacement in a pepper field. Photograph by: Monica Ozores-Hampton.

Polyethylene mulch alternative: Removal and disposal of polyethylene mulch has been a major production cost to Florida growers. Polyethylene mulch regulates soil temperature and moisture, reduces weed seed germination and leaching of inorganic fertilizer, and is a barrier for soil fumigants. In general traditional raised beds were covered with polyethylene mulch or replaced by composted materials bell pepper yields were higher on compost mulch plots than on un-mulched plots but lower than on polyethylene-mulched beds **(Figure 5)**.

Table 1. Horticultural Specifications for Composted Materials

Horticultural Parameter	Optimal Range	Effect
pH	5.5 – 7.0	In acidic soil, alkaline compost will raise pH
Moisture (%)	35 – 55	Higher moisture, increased handling and transportation costs
Bulk density (lb per yd^3)	800 – 1000	Higher moisture content means a greater bulk density
Inert and oversize matter (% dry wt)	<1	
Organic matter content	30-65 %	Higher organic matter lowers application rate
Water holding capacity (WHC) (%)	100 or above	Higher WHC leads to lower irrigation frequency
Particle size	1' or less	Increase soil porosity
Stability or maturity index	Stable to highly stable	Instability can cause "N-immobilization"
Maturity growth	Must pass maturity screening test	GI lower than 60 indicates phytotoxicity
Soluble salts	Less than 6 dS	Higher than 6.0 means potential toxicity
C:N ratio	<20:1	Higher C:N ratio causes "N-immobilization"
Nitrogen	1 % or above	
Weed free	None	Uncomposted materials disseminate weeds
Heavy metals	Must pass USEPA, 40 CFR 503	
Fecal coliform	Must pass USEPA, 40 CFR 503	
Salmonella spp.	Absent	
Other (color and smell)	Should have an "earthy" odor that is not unpleasant	

[z] FDACS, 1995
[y] G.I = (% seed germination x root length growth in % of control) /100 (Zucconi et al., 1981a)

Prepared by: Dr. Monica Ozores-Hampton

How to calculate compost application rates for tomatoes based on crop N requirements:

10 tons of compost x 60% dry weight = 6 tons compost dry weight

6 tons dry weight x 3 % N = 360 lb of N

360 lb of N x 10% mineralization rate

36 lb NO_3-N if the tomato requirements are 200 lb/acre we need to added 164 lb of N as a N fertilizer

NUTRIENT RELEASE:

It is important to know the mineralization (decomposition, or microbial break-down) rate of the compost before determining its application rate to tomatoes and peppers. The rate of nitrogen (N) release is especially important, since this nutrient moves readily through sandy soil.

Evaluations of N mineralization *in situ* can be used to improve N use efficiency. However, the direct, quantitative measurement of N mineralization *in situ* is very difficult due to the complex and dynamic nature of N transformations in the soil environment.

Compost mineralization rates will vary depending on compost characteristics, soil characteristics and environmental conditions. As general recommendations where N immobilization occurred, composts had initial C:N greater than 20:1 and N concentration less than 1.6%. Mineralization occurred where compost had C:N ratio lower than 20:1 and N concentration greater than 1.6%.

HOW AND WHEN TO INCORPORATE?

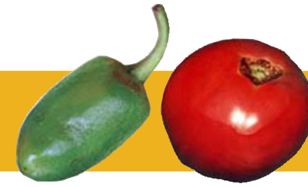
- Compost may be applied using a traditional manure spreader (flail/rear discharge or side discharge) or other specialized equipment.
- Compost is typically applied throughout an entire field, but may also be applied only in the rows. The product should be uniformly surface-applied, then incorporated to an approximate depth of 5 to 6 inches using a rototiller, disc, moldboard plow or other tillage equipment.
- Tomatoes have been cultivated using a wide range of compost application rates of 5 to 70 tons/acre. Lower rates of compost are typically being used as "maintenance applications." Appropriate compost application rates will be influenced by existing soil conditions, compost characteristics and the nutrient requirements of the crop.

Figure 6. Broadcast application using a manure spreader. Photograph by: Monica Ozores-Hampton.

Figure 7. Localized application of compost directly to bed. Photograph by: Monica Ozores-Hampton.

HOW TO CALIBRATE A COMPOST SPREADER:

- First load and weigh the contents of the spreader or weigh a 5-gallon bucket of manure and multiply the weight x 1.5 x length x width x height of the spreader. This will give you tons per load of compost or manure.
- Next determine the distance in feet that it takes to spread the entire load. Distance can be estimated or determined based on known field length or by counting fence posts along the length of the spread and multiplying by the average distance between posts.
- Then estimate the width of the spread in feet, allowing for a 10-20% pass overlap to ensure uniform coverage. Calculate the area covered and divide by 43,560 to convert to acres. Divide the weight or volume of manure in the spreader by the acres covered to determine the application rate for the given spreader setting (length x width of spread / acres covered = application rate in tons or gallons). Adjust the spreader settings and redo the calculations until the desired application rate is achieved.



AVOIDING PROBLEMS:

- Use of immature compost can cause detrimental effects on tomato and pepper growth **(Figure 8)**. Compost should be assayed for the presence of phytotoxic compounds using phytotoxicity test and seedling growth responses.

- Tomato and pepper crops are sensitive to high soluble salts, especially when they are direct-seeded. Measuring the soluble salts concentration of a saturation extract recommended. If the electrical conductivity (EC) is below 6.0 dS/m, no salt toxicity is expected. If EC is above 6.0 dS/m, the amended soil should be leached with water before planting seeds (only a few crops can tolerate this salt level).

- High C:N compost can result in N immobilization or "rob". Have the compost analyzed for C:N ratio. If it is above 20:1, some N fertilizer applied to the crop may be immobilized due to N immobilization, possibly causing plant N deficiency. When using compost with C:N ratios higher than 20:1, N fertilizer should be applied, or planting delayed for 6 to 10 weeks to allow the compost to stabilize in the soil.

- Lack of equipment to spread compost in vegetable fields is a concern. Composting facilities are encouraged to play an active role in developing spreading equipment.

Figure 8. Foreground: Pepper growth is stunted by phytotoxic chemicals in immature compost. In the background peppers with mature compost are thriving. Photograph by: Monica Ozores-Hampton.

SOURCES OF COMPOST AND MANURE:

Compost can be produced from a variety of feedstocks, including organic amendments from wastes produced by urban populations include municipal solid waste; yard trash/trimmings; food wastes from restaurants, grocery stores, and institutions; wood wastes from construction and/or demolition; wastewater (from water treatment plants); and biosolids (sewage sludge).

Agriculture produces other organic wastes that can be composted: poultry, dairy, horse, feedlot and swine manures; wastes from food processing plants; spoiled feeds, harvest wastes and mushroom media.

Figure 9. Interested in compost? Attend a compost field-day or training event to learn more about how compost can improve your production system. Photograph by: Monica Ozores-Hampton.

Visit www.Imok.ufl.edu/Compost for more information, research results and more.

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