

## Management of Soil and Water for Vegetable Production in Southwest Florida<sup>1</sup>

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### Introduction

This document integrates information that was presented at the Sand Land Workshop, 2003, dealing with vegetable production on mineral soils of southwest Florida. The intent of this document is to review those challenges facing vegetable growers dealing with soils, water management, and nutrients. Certain available strategies are evolving to efficiently produce vegetables in southwest Florida on variable mineral soils and are reviewed herein.

### Soil Genesis and Soil Characteristics Affecting Vegetable Production

The unique combination of climate, landscape, parent material, and living organisms in southwest Florida has greatly influenced the formation of soils in this area. With time, many of these soils have formed distinguishing characteristics, termed diagnostic horizons (See “Key to Soil Orders in Florida,” <http://edis.ifas.ufl.edu/SS113>). These horizons are identified by observing the soil with

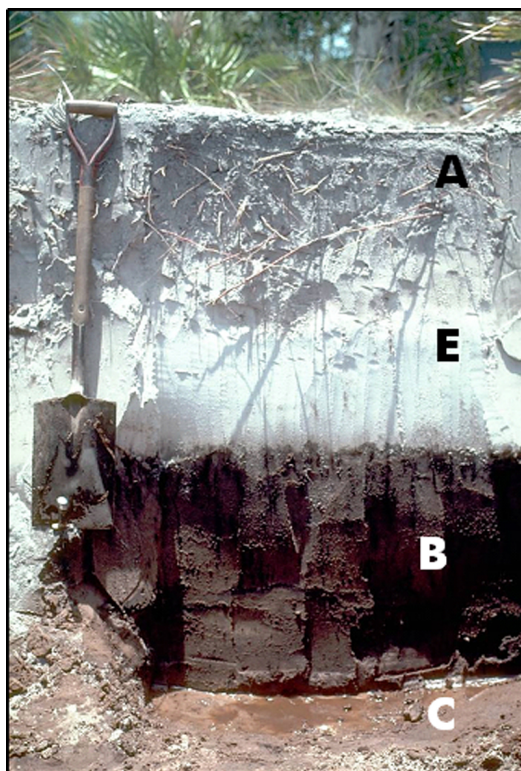
depth (Figure 1), such as the side of a pit or a road cut. In turn, these diagnostic horizons are useful for classifying soils and relating their characteristics to commercial crop production.

The surface horizon, designated by a capital A, usually appears gray to black and is almost always of sandy texture (Figure 1). Moving down the soil profile and just beneath the A horizon, a leached zone called the E horizon is often found. Nutrients and fine particles including organic matter are moved by water from this horizon. The E horizon is usually much lighter in color than the surface horizon, often gray to white.

Located beneath this leached zone, some soils have a distinct brown or black horizon, called the Bh or spodic horizon (Figure 1). This horizon is composed of organic matter that is leached down the profile and by both physical and chemical means has been deposited in the lower part of the soil profile. Often high in aluminum and iron and usually with a low pH, the Bh horizon is almost always sandy in

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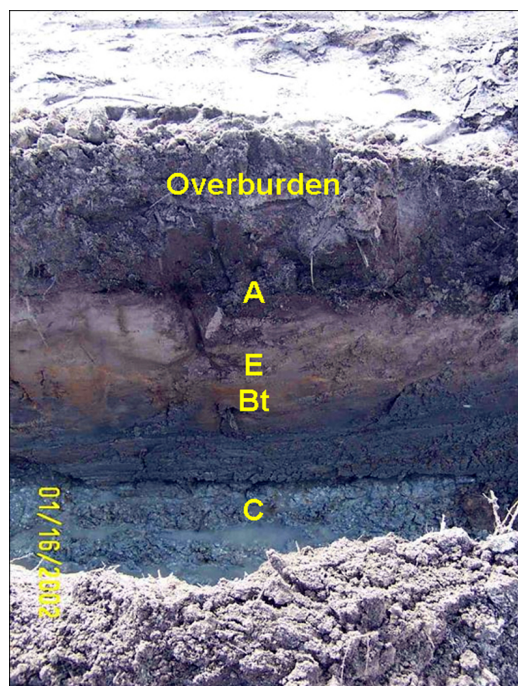
**Figure 1.** Immokalee soil series, showing the A, E, Bh, and C diagnostic horizons in the soil profile.

texture. This horizon impedes water flowing vertically through the soil and causes water to accumulate above this horizon. This water accumulation is referred to as a perched water table and is quite beneficial for maintaining a constant water table for row crop subsurface irrigation.

In some soils, the Bt is another diagnostic horizon that may be found below the leaching zone or occasionally with the Bh horizon. This horizon is created by the deposition of clay particles and is usually mottled gray in color and sandy or sandy loam in texture (Figure 2). Similar to the Bh horizon, the Bt horizon may also allow the formation of a perched water table.

Below these diagnostic horizons, substratum may be present. The C horizon denotes substratum that can be a variety of textures and colors but is usually unconsolidated materials (e.g., Figures 1 and 2). The R horizon denotes substratum that is limestone bedrock (not shown).

Using these diagnostic horizons, most of the mineral soils in southwest Florida can be classified. The USDA-NRCS (Natural Resource Conservation



**Figure 2.** Riviera soil series, showing the A, E, Bt, and C diagnostic horizons in the soil profile. Overburden was created when the soil was contoured (bedded for citrus production in this case).

Service) has prepared soil survey reports for each county in Florida. These documents are invaluable for understanding soils used for commercial vegetable operations and contain maps showing the spatial distribution of soils in the landscape (See a related publication: “Common Soils used for Citrus Production in Florida,” <http://edis.ifas.ufl.edu/SS403>).

While some soils may be better suited than others for vegetable production, soils often occur in associations and complexes, which describe a mixture of soils within the named mapping unit in the surveys. Thus, soil survey maps are considered accurate but not precise, meaning that the general management, as well as the chemical and physical characteristics within a mapping unit, is accurately described, but any one spot within the landscape may not be precisely described.

Further complicating precise characterization of any specific landscape point is the fact that some of the soil profile layers may be mixed during the construction of drainage ditches and beds. Depending upon the construction of field drainage and vegetable bedding operations, soil material used to create the



bed or excavated to form the drainage ditch may actually contain portions of the lower horizons (Table 1). Thus, vegetables may be planted (transplanted) in portions of the subsoil, rather than in the A horizon where most of the nutrients and organic matter of the original soil are located.

**Table 1.** Changes in organic matter in an undisturbed pasture soil (before bedding) and in the same soil after citrus bedding operations. Note that the organic matter originally in the soil (0-3 inches, pasture soil) is now found deeper in the bedded soil (6-12 inches, bedded grove). While soil-movement operations are usually not as dramatic for preparation of vegetable fields, when coupled with field leveling operations, similar conditions may exist in vegetable fields in southwest Florida.

Pasture soil		Bedded Grove	
Depth (inches)	Organic Matter (%)	Depth (inches)	Organic Matter (%)
0 – 3	2.30	0 – 3	0.99
3 – 6	1.43	3 – 6	1.15
6 – 12	1.00	6 – 12	1.85
12 – 18	0.48	12 – 18	1.25

Soils originally formed in sloughs and other low-lying areas, then graded through land-leveling and bedding techniques, may be quite difficult to manage for commercial vegetable production. Land leveling can create problems especially when large amounts of soil must be moved exposing sub soils. These areas may often take several seasons or longer to develop into productive soils for acceptable yields using traditional farming techniques.

Often, soils formed in low areas (sloughs) have been stripped of organic matter and clay that coat sand grains in other soils (Figure 3). These naturally formed uncoated sands are difficult to wet and difficult to drain. A common complaint of growers faced with cropping fields with uncoated sands is: “The places where I have problems with irrigation are the same places where I have problems with drainage.” Growers who have been farming for a while in southwest Florida note that so-called palmetto ridges are difficult to wet using seepage irrigation techniques. These soils are often associated with discontinuous or a lack of either a Bh or a Bt horizon. As rural land is converted into urban development, marginal lands such as sloughs and



**Figure 3.** Uncoated sands are difficult to manage for good crop production and may be the underlying cause of most poorly producing areas in vegetable fields of southwest Florida. Soils containing uncoated sands have poor water- and nutrient-holding capacities and are often found in the original landscape in low-lying areas.



**Figure 4.** Close-up of coated sand particles. The coating is often a combination of clay and organic matter (reddish-brown material on sand grains), which greatly improves crop production on soils that have coatings.

palmetto ridges are being brought into commercial vegetable production, often with poor results.

When uncoated sandy soils dominate a field, a grower should manage water and nutrients based upon crop response on soils containing uncoated sands. In the opposite case, where uncoated sands are only a small portion of the field, then nutrient and water decisions should be based upon vegetable responses growing in those soils containing coated sands (Figure 4). Depending upon the shape and location of the poorly producing areas, coupled with the soil forming processes originally present in the original landscape, these areas can be:

1. Amended to increase their productivity;
2. Kept in marginal production, but not amended;  
or
3. Treated as a greenbelt without direct crop production. In practice, a greenbelt can be difficult to incorporate into farming operations, as modern agriculture works best when tractors drive in straight lines and drip tapes and ditches run straight. Option 2 above may be the best choice for vegetable growers, working across small problem areas especially on soils that are highly variable.

### Water Management Considerations for High Yield and Quality Vegetables

The statement that vegetables are nothing but nicely packaged water is quite profound, and points to the fact that high quality and yield are directly associated with proper water management (Table 2 and Table 3). Given the information provided above concerning the genesis and variability of sandy soils in Southwest Florida, appropriate and timely water management decisions become all that more critical for commercial vegetable production.

Good water management must start with system design. The design should be such that transmission losses are minimized. Additionally, the system must be capable of addressing soils in southwest Florida that may present irrigation problems. If designed correctly, the system will allow the manager to avoid

water stress or an excess of nutrient leaching during the growing season.

**Table 2.** Typical moisture content in selected vegetable tissue.

Vegetable plant part	Moisture Content
Dry seeds	8 - 15%
Maturing seeds	6-70%
Roots & tubers	73-95%
Shoot parts	77-96%
Fruits	90-96%

Because irrigation management is so critical to commercial crop production throughout the United States, several philosophies or approaches to irrigation have evolved. One such approach is termed the Critical Moisture Period. This concept assumes that the crop can tolerate short periods of drought and that the Critical Moisture Period is often defined by the development of the harvestable plant part. This irrigation approach works well with agronomic crops with a long growing season and on finer texture soils. However with vegetable production in southern Florida, often with short growing seasons and variable rainfall, this approach does not result in the uniform watering regime needed to obtain proper fruit size and maintain vegetable quality. Short drought periods often result in malformations of fruit, fruit cracking once irrigation is provided, and smaller sized fruit with resulting loss of revenue.

**Table 3.** Amount of water contained in selected crops at indicated yields.

Crop	Water content	Average Yield	Water sold (1gal = 8lbs)
Cabbage	93%	300 cwt	27,900 lbs (3,500 gal)
Tomato	93%	1,600 box	37,200 lbs (4,650 gal)
Watermelon	93%	350 cwt	32,550 lbs (4,100 gal)
Potato	79%	300 sacks	23,700 lbs (3,000 gal)

Commercial vegetable production in Florida is best served by growers selecting an efficient irrigation system and *scheduling irrigation according to crop needs*. The most common systems are overhead (sprinkler or big gun), seepage (subsurface), and micro-irrigation (drip).

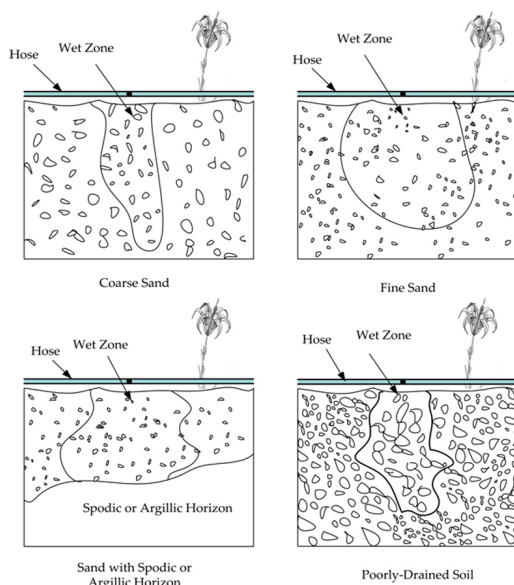
An overhead sprinkler irrigation system can take many forms that are not discussed herein. However in southwest Florida, the system is used less frequently than either seepage or drip systems. Sprinkler irrigation can be used to guard against possible frost or freeze damage, assist with the germination of direct seeded crops, wetting the field for soil operations such as bed formation, and sealing the soil surface after the application of fumigants.

Sprinkler systems are often expensive to purchase and install. Since water is applied through the atmosphere in small droplets, water loss due to evaporation is usually quite high compared with the other systems. With higher evaporative losses, pumping costs must also increase to supply the crop water demand.

The seepage system works best when the Bh or Bt horizons are present and continuous throughout the field. As stated above, these soil horizons allow for a perched water table, which is critical to the proper functioning of a seepage system. In fields where one or the other horizon is discontinuous, the seepage system will be more difficult to manage efficiently, often with one part of the field wetter or dryer than the other.

A properly designed drip irrigation system has the capability of being quite efficient at delivering irrigation water to the crop. Drip irrigation is most efficient for both crop production and water-use efficiency when sufficient water is added to wet only the root zone with minimum leaching below that zone (Figure 5). In fact 50 to 60% of vegetable growers in southwest Florida use drip systems. However, drip systems can be managed in several different, less water-efficient ways. A grower could use the drip system to distribute water throughout the field, but at volumes sufficient to create a perched water table. In this way, a more uniform application of water is

delivered to the crop, but with a water use efficiency comparable to a seepage system. The system could be run to reduce surface dust (wind erosion) to protect tender plants and soil loss, or to wet the soil for easier vehicular access during harvesting, for example. A drip system could be used to supply water during the dry season to maintain or preclude the loss of a perched water table.



**Figure 5.** Wetting patterns with depth produced in the soil from a single drip irrigation system emitter. To gain the Irrigation System Efficiency capable with the drip irrigation system, the wetting pattern should only supply water to the rooting zone. Note that there is no water table shown in these diagrams.

Still another alternative is to use the drip system to distribute soluble fertilizer and other appropriate chemicals, but use a seepage system for irrigation purposes. The grower is taking advantage of the uniformity of the drip system for nutrient and chemical delivery, avoiding the need for more conventional, tractor-based delivery systems. The irrigation system efficiency is, however, that of the seepage system.

While these alternative uses of the drip system are valid uses of water for agricultural purposes, each reduces the irrigation system efficiency compared to a drip system specifically operated to supply irrigation water for plant production.

The efficiency of the irrigation system can be measured by the following ratio, expressed as a percentage:

Irrigation system efficiency = amount of plant-available water/ total pumped water.

For a properly managed drip irrigation system, 85% of the water that is pumped is available for crop consumption (Table 4). Both overhead and seepage systems have lower potential efficiencies.

**Table 4.** Potential system irrigation efficiencies by irrigation system type.

Irrigation system type	Average irrigation system efficiency
Drip	85%
Overhead	70%
Seepage	50%

Smajstrla, A.G., B.J. Boman, G.A. Clark, D.Z. Haman, D.S. Harrison, F.T. Izuno, D.J. Pitts and F.S. Zazueta 2002. Efficiencies of Florida Agricultural Irrigation Systems. Florida Cooperative Extension Service, UF/IFAS, University of Florida, Gainesville. Available at <http://edis.ifas.ufl.edu/AE110> (link verified 19Sep05).

The advantages of striving for the potential savings with a properly managed drip irrigation system can be quickly demonstrated by the following example.

**A grower wishes to add 0.20 inches of water per day to match the anticipated evapotranspiration rate during the cropping season, which we shall assume to be 100 days.**

Admittedly, this scenario is a worst-case situation since the need for 0.2 inches of water per day throughout the 100-day growing season is rare and often less than that for Florida conditions.

Knowing that 1 acre-inch is equal to 27,150 gallons:

0.2 inches x 27,150 gallons/acre-inch = **5,430 gallons per acre.**

Since this amount will be needed each day of the growing season (assuming no rain), then the number of gallons needed for the growing season is:

5,430 gallons per acre x 100 days = **543,000 gallons.**

However, we must account for the irrigation system efficiencies. We shall assume that the efficiencies in Table 4 are obtained by this grower. The answers for each irrigation system are provided in the last column of Table 5.

**Table 5.** Irrigation system efficiencies for selected irrigation systems and the quantity of water required to irrigate one acre of vegetables for a 100-day growing season (assumes no precipitation).

Irrigation system type	Average irrigation system efficiency	Required gallons for the crop
Drip	85%	638,824
Overhead	70%	775,714
Seepage	50%	1,086,000

Smajstrla, A.G., B.J. Boman, G.A. Clark, D.Z. Haman, D.S. Harrison, F.T. Izuno, D.J. Pitts and F.S. Zazueta 2002. Efficiencies of Florida Agricultural Irrigation Systems. Florida Cooperative Extension Service, UF/IFAS, University of Florida, Gainesville. Available at <http://edis.ifas.ufl.edu/AE110> (link verified 19Sep05).

**These calculations were based on only one acre of vegetables!** As southwest Florida experiences continued human population growth, and water costs continue to increase, efficient drip systems make good sense for vegetable production. In this example alone, the average seepage system results in the application of 1.7 times the water used by the drip system.

Implementation of a drip irrigation system for vegetable production can save a considerable quantity of water, as well as reduce pumping charges, and give the grower flexibility for injection of nutrients and other chemicals needed for high yield and quality.

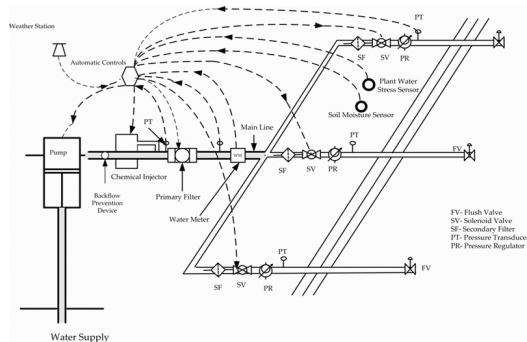
Water quality for use with the drip system is critical for proper functioning of the system. Drip systems will work best when the chemical parameters in Table 6 are in the *slight* range. When one or more of these parameters is in the *moderate* range, drip systems will also work but may require treatment of the water before entering the system. If one or more of these parameters is in the *severe* range, then the decision to use drip irrigation should be based on consultation with experts.

**Table 6.** Important chemical parameters to consider for proper drip irrigation system operations.

Chemical Factor	Slight	Moderate	Severe
pH	< 7.0	7.0 -- 8.0	> 8.0
Iron (ppm)	< 0.1	0.1 -- 1.5	> 1.5
Hydrogen sulfide (ppm)	<0.5	0.5 -- 2.0	> 2.0

Pitts, D. J., D. Z. Haman, and A. G. Smajstrla. 1990. Causes and prevention of emitter plugging in microirrigation systems. Bulletin 258, Fla. Coop. Ext. Serv., IFAS, Univ. of Florida (EDIS document no. AE032). (<http://edis.ifas.ufl.edu/AE032>)

Properly designed drip irrigation systems (Figure 6) can also be useful in addressing the soil variability problem discussed above. If the problem area is rather small, then using drip with either single, double, or triple tubes may provide sufficient water. Alternately, drip tubes with emitters closer together may work just as well. In either case, because of the increase in drip emitters per unit area, overall efficiency of the system will decrease from the optimum value of 85% Irrigation System Efficiency.

**Figure 6.** A schematic layout of a micro-irrigation (drip) system appropriate for use for vegetable production in southwest Florida.

In poorly producing spots within a field, composted organic materials may also be partially effective in improving water management, in addition to providing some nutrients and increased microbial activity. Composted materials appear to have the most value for vegetable production compared to un-composted organic sources for the reasons discussed below. High application rates of compost can lead to the mineralization and subsequent release of nitrogen in excess of that required to satisfy the crop nutrient requirements, and

may have environmental implications that should be avoided.

There are many other products on the market to address poorly producing vegetable areas such as humates, polymers, and selected biological admixtures. Many of these products have not been well evaluated relying dominantly on testimonial statements. Discussion of these products is beyond the scope of this document. In general, however, relatively high cost for most of these products favors the use of composts.

Another strategy to avoid poorly producing field sites is to design a bedding pattern that avoids problematic areas. In some cases where larger areas of the field are affected adversely, redesigning of the field boundaries may be possible. In either case, the problem area has been removed from vegetable production.

## Use of Compost in Vegetable Production

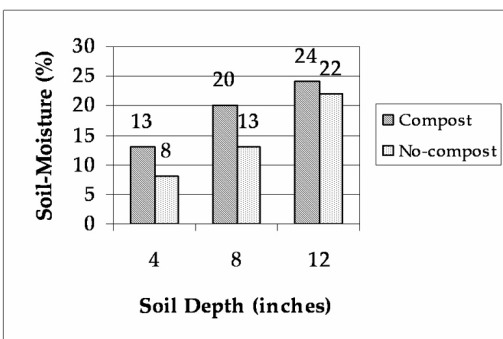
The benefits of adding organic amendments to sandy soils have been well documented (see <http://edis.ifas.ufl.edu/> for related EDIS documents) throughout Florida. Some of these documented benefits include:

- Increased water holding capacity;
- Increased cation-exchange capacity;
- Decreased erosion potential;
- Increased soil microbial activity;
- Improved soil tilth.

While these benefits can contribute to productivity in any sandy soil, in poorly drained soils the effect of compost is mixed. The organic matter will contribute to a higher water holding capacity within the soil profile. Improved water holding capacity can achieve higher rainfall retention within the soil profile compared to non-amended soils and reduce irrigation needs. Use of compost can also result in increased upward flux (water moving upward in the soil profile due to capillary rise) due to introduction of finer particles (Figure 7). Research is



underway at SWFREC to better understand the effect of compost on water holding capacity, drainage, and up flux from the water table to the root zone in sandy soils of southwest Florida.



**Figure 7.** Improvement in moisture holding capacity of a southwest Florida sandy soil due to compost addition. Values represent the mean of biweekly sampling for 1 year after the addition of 50 tons compost per acre to a southwest Florida vegetable field. The compost was incorporated into the soil to a depth of 8 inches.

Use of compost may or may not improve drainage. Often, drainage is a function of soil horizons or substratum well below the surface-applied organic matter. In fine sands or loamy sands, the addition of organic matter may actually improve drainage by providing pathways for the water to move downward/laterally by preventing compaction. In sands or coarse sands, organic matter additions may have no effect on drainage and may actually move with the water deeper into the soil profile. This loss of organic matter from the surface horizon will decrease the other benefits of organic matter for crop production.

Sources of organic materials in sufficient quantities for commercial vegetable production are yard trimmings (YT, Figure 8), animal manures, household garbage (often called municipal solid waste or MSW), biosolids (sewage sludge or BS), wood-waste byproducts, or food waste. In 1999, 26.2 million tons of solid waste were produced in Florida, averaging approximately 9.5 lb daily per person. If composted, this solid waste would yield:

15.7 million tons of compost per year of MSW;

3 million tons of YT;

230,000 tons of dry BS; and

490,000 tons of animal manure.



**Figure 8.** Yard trash from urban areas is problematic for municipalities due to disposal costs, but can be the feedstock for compost, a desirable product for commercial growers in southwest Florida.

Agricultural productivity is greatly enhanced by putting these materials through a composting process (Figure 9). The resulting mature compost is much more predictable in its effects on crop production. Composting operations also greatly decrease the volume of the original material by as much as 60%. Thus, transport and field spreading costs are reduced, and the composting operation also adds value to the product. UF/IFAS recommends that growers add only mature compost to commercial fields. Mature compost will contribute to nutrient supply rather than create nutrient deficiencies. If a partially decomposed (so-called immature compost) high carbon organic source, such as YT, is applied to fields, then growers may see reduced crop vigor from nutrient deficiencies induced by the addition of immature compost. UF/IFAS research has also demonstrated the possibility of phytotoxicity when immature compost is applied to sensitive crops.

Production managers should consider the original soil series, problem spots of which they are aware within their field, and other limiting factors, such as compost transportation and spreading costs. It is likely that the carbon source from the compost will help with crop productivity, and the magnitude of the effect will be a function of the compost application rate. Therefore, application rate should be viewed as





**Figure 9.** Yard trash materials are the feed stock for this commercial composting operation in southwest Florida. The resulting compost will be added to soils for crop production enhancement.

a realistic return on investment from the treated area of the field. For vegetable production, annual application rates of 3 to 6 tons of compost per acre (usually containing 50% moisture) are typical in southwest Florida vegetable production. However, if higher application rates can be afforded, then the effects of the organic addition on crop response will be seen sooner than at the typical rates mentioned above. Rates may range from 5 to 35 tons of compost per acre for vegetable field in southwest Florida. At rates in the upper end of this range, nitrogen and other nutrients may become available during the growing season at rates that exceed the crop nutrient requirements. Excess nutrients pose an environmental hazard, which growers could easily avoid by applying more moderate rates of compost, and basing compost rate selection on the amounts of nutrients that are plant-available from the compost.

Compost can be produced on the farm or purchased from commercial composting operations in the area. On-farm composting operations greatly reduce the cost of the compost, but require an added level of management, labor, and land allocation.

At the Southwest Florida Research and Education Center (SWFREC) in Immokalee, compost from selected sources has been used to produce vegetables for the last 10 years. Soil organic matter has increased from the original 0.8% at the beginning of the experiment to 3%. In addition to improving water holding capacity (Figure 7) and

crop yields, the need for inorganic fertilizer has been decreased by 50% (Figure 10). Increases of soil-test phosphorus, potassium, calcium, magnesium, micronutrients, and cation-exchange capacity within the treated soil has been due to regular additions of compost. When organic materials including composts are added to soils, a soil test that is calibrated to the vegetable crop is recommended to monitor the accumulation of plant-available nutrients. Excessive levels of nutrient buildup are somewhat offset by the ability of the added organic matter to retain nutrients. However, the possibility of loss of these nutrients to the environment, rather than to the intended vegetable crop, is of great concern in southwest Florida.



**Figure 10.** Results of 10 years of selected compost applications to a vegetable field at the UF/IFAS - SWFREC.

Composted soil amendments can have multiple positive financial impacts on a vegetable operation. Compost can reduce purchased fertilizer cost, lower fuel expenses from less irrigation, and perhaps increase overall crop yield. For composted amendments to be profitable in a vegetable operation, the combined benefits must be greater than the cost of compost, including its transport and application costs.

For growers who keep accurate accounting of their costs and production, the following formula can be used to assess whether added composted soil amendment would be profitable.

$$\text{Benefits} = [\text{saved fertilizer costs } (\$/\text{ac})] + [\text{saved fuel costs from less irrigation pumping } (\$/\text{ac})] + [\text{increase crop yield (carton/ac)} * \text{grower price } (\$/\text{carton})].$$

**Costs** = [compost material, including transport and application (\$/ton) \* application rate (ton/ac)].

So long as benefits are greater than costs, composted soil amendment should be part of the growers production plan.

As an example, consider the application of 6 tons per acre of compost to a tomato field. Including transportation and spreading costs, compost costs \$28 per ton, or an increase cost of \$168 per acre. A tomato grower estimates a reduction in purchased fertilizer of \$35 per acre and a \$10 per acre fuel cost savings from reduced irrigation pumping. If the growers price is \$9.50 per carton, an additional 13 cartons per acre of tomatoes must be grown and sold before the soil amendments contribute to the operational profitability. If compost amendments have an impact on vegetable fruit earliness and fruit quality, then these factors must be accounted for as well.

Overall, the effects of compost are more pronounced with regular annual additions. In the humid, hot conditions of southwest Florida, compost decomposes when added to the soil. While residual effects are small, they are cumulative. Therefore, it is important that the economic assessment of compost be evaluated on the basis of the long-term effect on improved crop production.

In mineral soils, the weight of an acre furrow slice (one acre of soil to a six-inch depth) is assumed to be 2,000,000 pounds per acre. If the organic matter content of the soil before compost addition is 1%, then the weight of the organic matter in an acre furrow slice is 20,000 pounds or 10 tons/acre.

For example, annual additions of 6 tons of wet compost per acre (moisture content is approximately 50%) will increase soil organic matter by 0.3% after 4 to 5 years. The remainder of the compost is lost due to decomposition. Tillage and bedding operations associated with one to three vegetable crops per year will likely further reduce the rate of organic matter buildup in the soil. These operations aerate the soil promoting accelerated decomposition of the compost (Figure 10). Building the level of organic matter in the surface soil is a slow process. First, the amount of residue and active organic matter will increase.

Gradually, the species and diversity of organisms in the soil will change, and amounts of stabilized organic matter will rise. It may take a decade or more for organic matter levels to significantly increase after a management change. Fortunately, the beneficial effects of the additions appear long before organic matter levels rise. From these estimates, it is obvious that repeated additions, such as on an annual basis, are required to improve vegetable production, especially on poorly producing areas of the field.

The use of precision agricultural techniques to apply compost in sufficient quantity to poorly producing areas within the field will likely prove to be the best solution in southwest Florida.