Compost Use in Commercial Citrus in Florida

Mike Litvany[1] and Monica Ozores-Hampton[2]

Additional index words. compost, municipal solid waste, garbage, biosolids, sewage sludge, yard trimming, sustainable agriculture

Summary. Commercial citrus (*Citrus* sp.) groves in Florida use an average of 150 lb/acre (168 kg·ha^{-1}) of elemental nitrogen (N) per year. There are about 853,000 acres (345,000 ha) of commercial citrus requiring about 63,975 tons (62,652 t) of N. At an average analysis of 12% N, about 533,125 tons (483,811 t) of blended nitrogenous fertilizers are applied to citrus annually. To meet this annual N demand from compost, it would be necessary to produce 3,198,750 tons (2,901,906 t) of 2% N compost. The market for high-quality compost products in Florida is far greater than the current or projected production capacity of the state. As long as the cost benefits of compost are clear to citrus growers, demand will always exceed supply. Not all composts are equal in their nutrient availability. The best composts for use as fertilizers are derived from sewage sludge or biosolids, municipal solid waste and sludge, food waste, and/or animal manure combined with a bulking agent such as sawdust or wood chips. Composts made from wood waste as their only feedstock contain large amounts of lignin and cellulose to break down within a reasonable period to directly offset chemical fertilizers. Ultimately, they will mineralize in the soil and provide all of the benefits described earlier, but their rates of availability are in years rather than months, like the other composts.

Before World War II, most commercial citrus groves in Florida received a majority of their N from a combination of animal manure and ammonium sulfate (Ruprecht, 1939). Following the war, with excess nitrate production capacity, the advent of chemical fertilizers coincided with the mechanization of citrus. For the past two generations, the university system has advocated the use of the highest possible analysis chemical fertilizers for use in Florida citrus. It has only been in the last 5 to 10 years that serious interest has returned to using organic materials in production agriculture (Downs, 1995). This interest has become even greater during the past 2 years as the fertilizer industry has been strongly influenced by demand for their products from India, China, Taiwan, Japan, Korea and other emerging agricultural economies with strong currencies. It appears that this is a long-term trend with annual increases of up to 10% per year for chemical fertilizer (Progressive Farmer, 1995).

Florida Agricultural Experiment Station journal series R-08570.

[1]Nutri-Source, Inc., P.O. Box 1696, Windermere, FL 34786-1696.

[2]University of Florida, Southwest Florida Research and Education Center, 2686 State Road 29 North, Immokalee, FL 34142-9515, to whom reprint request should be addressed.

Table 1. Annual recommended fertilizer rates for Florida citrus (Tucker et al., 1995).

Nutrient	Form	Annual rate (lb/acre)^z
Nitrogen	Elemental	200
Phosphorus	Phosphoric acid	40
Potassium	Potassium oxide	200
Magnesium	Elemental	25
Manganese	Elemental	8
Boron	Elemental	2
Iron	Elemental	1
Calcium	Elemental	21
Sulfur	Elemental	5

^z 1 lb/acre = 1.12 kg·ha^{-1}.

Table 2. Recommended nitrogen rates in Florida for orange (*Citrus sinensis*), grapefruit (*C. paradisi*), tangelo (*C. paradisi* x *C. reticulata*), murcott (*C. reticulata* x *C. sinensis*), and other citrus trees.

Years in grove	Annual N use				
	Oranges	Grapefruit	Tangelo	Murcott	Other
			(lb/tree)^z		
1	0.15–0.30	Same	Same	Same	Same
2	0.30–0.60	Same	Same	Same	Same
3	0.45–0.90	Same	Same	Same	Same
			(lb/acre)^y		
≥4	120–240	120–180	120–250	120–300	120–200

^z 1.00 lb = 0.454 kg.
^y 1 lb/acre = 1.12 kg·ha^{-1}.

Acceptable commercial citrus crops can be produced using a combination of compost and chemical fertilizers. This paper will examine several aspects of determining a successful compost fertilization program for the Florida citrus industry. First, in consideration of the new interim best management practices (BMP) for N coming from the Florida Department of Environmental Protection. Second, developing compost application rates, that will provide the highest yields commensurate with maximizing profit per acre. And lastly, review some current research experiences and suggest future research needs to further substantiate the viability/desirability of a combined compost/chemical fertility program. The comparative economics of a compost/chemical program versus a purely conventional chemical program will include both manufacturing and application costs of the compost.

Since citrus was first grown as a commercial crop in Florida, there have been countless investigations into crop nutrient requirements necessary to maximize crop production (Table 1). For the past 35 years, growers have relied on the University system's recommendation of 0.4 lb (0.18 kg) of N per box of oranges (*Citrus sinensis*) and 0.3 lb (0.14 kg) of N per box of grapefruit (*Citrus paradisi*) (Tucker et al., 1995). Accordingly, an orange grove producing 500 boxes [90 lb (40.8 kg) per box] of fruit per acre per year would require 200 lb/acre (224 kg·ha^{-1}) of N fertilizer annually, split into three applications.

The interim nitrogen BMP (Table 2) now under consideration coincides with this annual rate of N per acre. The BMP is interested only in how much N is applied annually and in what time frame. This particular grower is applying about 60 lb/acre (67 kg·ha^{-1}) per application. When organic materials are incorporated, their N content is counted at 50% the rate of water-soluble N chemical fertilizer. The assumption is that organic materials are more slowly available, more efficiently used by the trees and that water insoluble forms of N, do not pose a threat to drinking water aquifers below citrus groves.

Phosphorus (P) is recommended at 1/8 to 1/4 of the N rate depending on soil analyses and the specific variety of fruit being grown (Florida grows over 150 different and distinct varieties of citrus fruit).

Potassium (K) in the form of potash (K_2O) is recommended at the same rate as N for oranges and up to 1.3 times the N rate for grapefruit. These application rates assume water-soluble forms of chemical fertilizers.

Years of research have shown that under Florida growing conditions, efficiency of water-soluble N fertilizer is only about 50% of the applied rate. From 200 lb/acre of N applied in chemical form, typically only about 1/2 will be used by the citrus trees, with the balance being lost to leaching, runoff and volatilization (Lea-Cox et al., 1992). The assumption that organic forms of N are more slowly available is very important to this discussion. This is key to understanding why a compost-chemical program is more economical and environmentally beneficial than a straight chemical program.

When using compost as an N source, it is essential for the grower to understand that the N concentration of the compost is on an "as delivered" basis. Most laboratories will analyze nutrient content of composts on a dry weight basis. The compost should be produced using a technology that is repeatable so that the finished material will have a relatively consistent moisture and N content. The dealer or farmer can then calculate the actual N

Table 3. Average nutrient value and heavy metals content of compost.

Nutrient	Dry wt
	(%)
Nitrogen	3.87
Phosphorus	9.80
Potassium	0.63
Sulfur	0.47
Calcium	1.50
Magnesium	0.15
Boron	0.02
Copper	0.05
Iron	3.80
Manganese	0.22
Molybdenum	0.0
Zinc	0.03
	ppm (mg·kg^{-1})
Arsenic	18.4
Cadmium	4.20
Copper	508
Chromium	120
Lead	50.8
Mercury	0.44
Molybdenum	13.6
Nickel	9.42
Selenium	BDL^z
Zinc	272

^z BDL = below detectable limit.

Table 4. Cost basis for typical blended fertilizer formula for Florida citrus (12–2–12; 2Mg–1Mn–0.1B).

Nutrient source	Nutrient amount (lb)[z]	Cost ($)/ ton	Cost ($) in formulation
Ammonium nitrate	456	155.00	35.34
Ammonium sulfate	404	110.00	22.22
Triple super phospahte	87	140.00	6.09
Muriate of potash	267	130.00	17.36
Potassium mangesium-sulfate	364	165.75	30.17
Solubor[y]	4	1,330.00	2.66
Manganous oxide	31	320.00	4.96
Calcium carbonate filler	387	24.00	4.64
Cost/ton to blend			8.00
Taxes			1.25
Feight			5.00
Profit @ 5%			6.82
Net, deliver price/ton			144.51

[z]1 lb = 0.454 kg.
[y]U.S. Borax, Inc., Valencia, Calif.

being applied to the grove, while at the same time preserving the grower's waiver of liability for N pollution as provided in the BMP rules. Table 3 provides a chemical analysis of a typical compost product. An adjustment is made to compensate for the moisture content of the material as delivered to the grove.

It is assumed that compost, properly made, will provide fertilizer efficiency on an order of 85% versus the 50% of chemicals (Lea-Cox et al., 1992). If a grower is applying 200 lb/acre of conventional water-soluble N per year, the actual use rate is 100 lb/acre (112 $kg \cdot ha^{-1}$) of N. To achieve a similar level of N fertility from compost with a content of 2% N [40 lb/ton (18 $kg \cdot t^{-1}$)], from which the grove is to use 34 lb (15.4 kg) of usable N. At the 85% efficiency level, then 3 tons/acre (6.7 $t \cdot ha^{-1}$) of compost per year would be required.

A key question being addressed by current Florida research is determining the rate of mineralization of several nutrients in the compost. This research for the BMP program is being conducted under Florida conditions. Ten years experience growing commercial citrus using compost indicates that at 3 tons/acre, split applied in three applications, mineralization is just about complete in 90 d, presuming that the compost is mature with a carbon:nitrogen ratio of less than 25:1.

To compare a conventional chemical fertility system to a chemical-compost system; consider the fertilizer needs of a typical Florida citrus grove as described in Table 4. This table shows the formulation for 1 ton (0.9 t) of dry chemical fertilizer determined to meet the grove's established requirements.

This particular grove is producing at a level that requires 200 lb/acre of N annually. Annual applications are split applied evenly three times per year. The total cost for this conventional dry fertilizer (delivered blended) is about $144.51/acre ($357.08/ha) per year plus application costs of $7/acre ($17.30/ha) per application. Material costs of essential elements, such as copper (Cu), iron (Fe), manganese (Mn) and zinc (Zn), that are not included in the above fertilizer program, are estimated to be $25/acre ($61.77/ha) annually. Typically, these elements are included as a part of normal spraying programs, so their incremental application costs are negligible. This brings the estimated real total for a complete annual citrus nutrition program for this grove to about $190.51/acre ($470.55/ha) (Table 5).

Table 5 provides a cost comparison of the two programs. Because most locally produced composts are low in K, a separate application is required. A net saving of $40.81/acre ($100.80/ha) is indicated. While a direct cost savings of almost $41/acre ($101.27/ha) per year is compelling to most growers, the ancillary benefits of regular compost in the form of improved yields can also be assigned a cash value. When the improvements to fruit quality demonstrated by research are included, annual profitability increases of about $700/acre ($1729.68/ha)

Table 5. Cost comparison of chemical nutritional program versus compost-chemical nutritional program for Florida citrus.

Production cost	Total cost ($/acre)[z]
Compost at (3 tons/acre at $34/ton)[y]	102
Spreading compost at $7/ton	21
Potash from muriate of potash[x] at $130/ton	21.7
Spreading potash at $5/acre	5
Total cost of compost-chemical program	149.7
Total cost of chemical program	190.51

[z]$1.00/acre = $2.47/ha.
[y]1 ton/acre = 2.24 $t \cdot ha^{-1}$, $1.00/ton = $1.10/t.
[x]Muriate of potash (KCl) at 200 lb/acre (224 $kg \cdot ha^{-1}$) of potash (K_2O).

Table 6. Comparison of compost-fertilizer versus fertilizer programs on citrus productivity and profitability in Florida.

Yield and production costs	Fertilizer program	Compost-fertilizer program
Yield (90-lb boxes/acre)[z]	400	432
Soluble solids (lb/box)[y]	5.4	6.9
Total solids (lb/acre)[x]	2,160	2,981
Price of solids ($/lb)[w]	0.85	0.85
Gross revenues ($/acre)[v]	1,836	2,534
Cost of harvesting ($/box)[u]	2	2
Cost of harvesting ($/acre)	800	864
Net pre-tax income ($/acre)	1,036	1,670
Profitability increase ($)		591

[z]90 lb = 40.8 kg, 1 box/acre = 100.9 $kg \cdot ha^{-1}$.
[y]1 lb/box = 1.1%.
[x]1 lb/acre = 1.12 $kg \cdot ha^{-1}$.
[w]$1.00/lb = $2.20/kg.
[v]$1.00/acre = $2.47/ha.
[u]$1.00/box = $0.025/kg.

Table 7. Effect of compost program on total revenues for citrus in Florida.

Gross income or savings	Amount ($/acre)
Increased gross income[z]	591.00
Fertilizer program savings	40.81
Fungicide savings	24.00
Herbicide savings	33.34
Liming savings	12.00
Increased revenue[y]	701.15

[z]Details presented in Table 6.
[y]$1.00/acre = $2.47/ha.

can be demonstrated after several years of regular compost use.

Using compost regularly has been shown to reduce the cost for fungicides used to control greasy spot disease, caused by the fungus *Mycosphaerella citri*. This disease causes premature leaf drop. The life cycle is as follows: infected leaves fall from the tree and become leaf litter under the canopy of the trees. When temperatures reach 70 °F (21.1 °C) in the presence of rainfall, the fungus spores on the fallen leaves eject new spores, that reinfect leaves on the tree above (Russo and Bistline, 1992). Due to the biological activity of the microbes in compost, leaf litter will tend to decompose more quickly, minimizing the opportunity for sporulation. Conventional fungicides cost growers about $24/acre ($59.30/ha).

The greatest benefit of compost use is the large amount of organic matter content. Although application rates suggested here are low in relation to the amount of soil to be influenced, regular, consistent use of compost has been shown to increase soil organic matter over time. This organic matter improves the water holding capacity and the cation exchange capacity of Florida's sandy soils, thereby slowing the leaching effects of heavy summer rains. In some cases herbicide applications may also be reduced from three to only two per year, realizing dollar cost savings of about $33.34/acre ($82.38/ha) per year. This is because long term use of compost may attenuate the degradation of residual herbicides.

Most compost produced in Florida tends to be slightly alkaline. This attribute, in combination with increases in cation exchange capacity, minimizes rapid leaching of calcium (Ca), magnesium (Mg) and K from the root zone that would normally decrease soil pH. Normal practice is to apply 1 ton/acre ($2.24\ t\cdot ha^{-1}$) of liming material per year at a cost of $24/acre. Long term use of compost can enable growers to apply lime every other year, thereby saving another $12/acre ($29.65/ha). These compost related benefits can further reduce costs another $69.34/acre ($171.34/ha) per year.

Most of the research regarding agricultural use of compost has been performed on crops other than Florida citrus. However, citrus composting will be addressed more aggressively in the near future with funds derived from the BMP tax on nitrogenous fertilizers to be administered by Institute of Food and Agricultural Sciences (IFAS).

We know this much from the previous research regarding compost use on agricultural soils—it increases soil organic matter, improves cation exchange capacity and tends to neutralize soil acidity.

Table 6 shows the direct monetary returns to Florida citrus growers. Research has shown an 8% increase in production combined with a 25% increase in soluble solids. This increase in productivity in combination with the direct production program cost savings is reflected in Table 7.

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