ciality markets ranging from 20 to 30% higher than conventionally grown citrus. Aggregate organic farm income per acre could be higher than conventional farm income because the percentage increase in the price of organic produce could offset any potential decrease in organic production. Marketing research comparing organic and conventional production practices, costs and returns should also be conducted for the benefit of both certified organic farmers and the larger number of conventional growers interested in sustainable and organic production practices. Although only a small percentage of Florida's total citrus acreage is committed to organic production, the concepts and production practices used in organic farming may assume greater importance to conventional growers because of increasing concern about agrichemical regulation and use; food safety issues; depressed prices for farmland; competitive pressure to reduce production costs; and the pursuit of more profitable market niches, especially with an 8% acreage increase from 1992 to 1994 for a 20-year high of 853,742 acres (Fla. Dept. Agriculture, 1994).

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GROWTH AND YIELD OF BEARING AND NON-BEARING CITRUS TREES FERTILIZED WITH FRESH AND PROCESSED CHICKEN MANURE

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Abstract. **Both fresh and processed chicken manure were applied to bearing and non-bearing citrus trees at sites in central and southern Florida. Fresh cage layer manure applied to 3-year old 'Ambersweet' (*Citrus reticulata* Blanco x [*C. paradisi* Macf. x *C. reticulata*] x midseason orange *C. sinensis* (L.) Osb.) on Swingle citrumelo rootstock [*C. paradisi* Macf. x *Poncirus trifoliata* (L.) Raf.] trees at 10 tons/acre/year (280-330 lbs N/acre) and 20 tons/acre/year (560-660 lbs N/acre) stimulated comparable growth and yield in both treatments. Standard, granular fertilizer and processed chicken manure applied at recommended N rates (0.48 lbs N/tree/year) to 1-year old 'Hamlin' orange [*C. sinensis* (L.) Osb.] trees on Swingle citrumelo rootstock stimulated similar growth increases in stem caliper and plant height. A similar growth response was also obtained when 2-year old grapefruit (*C. paradisi* Macf.) trees on 'Swingle' citrumelo rootstock were fertilized at recommended rates (0.60 lbs N/tree/year) with water soluble and controlled release fertilizers and processed chicken manure plus an additional 0.23 lbs N/tree/year applied via fertigation in all treatments.**

Although the certified organic citrus acreage in Florida, for which chicken manure is the primary fertilizer, accounts for less than 1% of the total citrus acreage, livestock or poultry manure was applied to 14,001 acres in 1992 (Ferguson and Taylor, 1993) a larger acreage than is certified organic or entered into the required 3-year organic certification process.

However, best management practices for citrus fertilization programs based primarily on chicken manure are more difficult to define than programs based on synthetic fertilizers with more clearly defined nutrient contents. Macronutrient and micronutrient content per ton of chicken manure varies considerably, depending on moisture content, source and storage time (Tables 1, 2). Furthermore, in the field the availability of nutrients from chicken manure is affected by N loss through ammonia volatilization, application method, and weather, with general estimates that 50%, 12% and 5% of applied manure-N is available under optimum conditions in years 1, 2 and 3 after application (Mitchell et al, 1981). Given the difficulty of estimating available N in unprocessed chicken manure, this research was conducted to monitor growth and yield of bearing trees fertilized with fresh cage layer manure within an organic production program. Research at other sites focused on growth of nonbearing trees fertilized with processed chicken manure, controlled release fertilizers and standard, water soluble materials.

Table 1. Macronutrient analysis of samples of Florida chicken manure

Manure sample	pH	Moisture (%)	Nutrients (lbs/T)					
			N	P	K	Ca	Mg	S
Fresh cage layer	7.4	75.0	33.0	16.0	8.0	—	—	—
Fresh cage layer	7.4	72.0	28.0	12.0	14.0	—	—	—
Stacked cage layer	7.0	16.0	47.0	41.0	59.0	—	—	—
Stacked cage layer	8.1	18.0	33.0	45.0	71.0	—	—	—
Stacked cage layer	7.9	29.0	54.0	33.0	36.0	—	—	—
Broiler litter	—	46.0	9.0	33.0	14.0	45.0	6.9	4.8
Broiler litter	—	16.0	61.0	27.2	47.3	141.0	11.0	12.0

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Table 2. Micronutrient analysis of samples of Florida chicken manure

Manure sample	pH	Moisture (%)	Nutrients (lbs/T)				
			Mn	Cu	Zn	Fe	Al
Broiler litter	—	46.0	0.49	0.08	0.52	11.5	1.77
Broiler litter	—	16.0	0.20	<0.20	0.20	12.4	5.20

Materials and Methods

Fresh cage layer manure experiments. Chicken manure was obtained from commercial cage layer and broiler operations and from the Poultry Science Department, University of Florida, Gainesville. Manure samples were analyzed at commercial agricultural laboratories, the IFAS Livestock Waste Testing Laboratory at Live Oak and in the Agricultural Engineering Department, University of Florida, Gainesville. Complete nutrient analysis was often not available, as is reflected in Tables 1 and 2. Cage layer manure contained 28 to 33 lbs N per ton, 12-16 lbs P per ton and 8 to 14 lbs K per ton. Although analysis was not conducted for other macro and micronutrients, cage layer manure would typically contain the full range of nutrients listed for broiler litter in tables 1 and 2.

Cage layer manure was applied at 10 and 20 tons per acre per year to 30 paired trees per treatment of young 'Ambersweet'/'Swingle' citrumelo planted in 1991 on a Tavares fine sand near Clermont, Florida. These manure rates are higher than those recommended for other tree crops in other states (Shipp et al., 1985) but were applied by the grower in an attempt to increase soil organic matter on a sandy soil as well as to provide all N required. Manure was broadcast with a manure spreader and incorporated the same day with a shallow grove disk. Manure was applied in three equal applications in February, April and June of year 1 and in one application in March of year 2. Trunk caliper and plant height were measured in February and October of 1993 and 1994 and yield data were collected in November of each year. Soil and leaf analyses were also conducted in the fall of 1993 and 1994. Manure was also applied as above at the 10 and 20 ton per acre per year rate to 15 paired trees per treatment of mature navel orange/sour orange trees planted in 1979 on an Astatula fine sand near Clermont. Samples for leaf and soil analysis were taken in the fall of 1993 and 1994 and yield data was collected in November of each year.

Processed chicken manure experiments. Granular water soluble fertilizer, controlled release fertilizer, processed chicken manure and liquid fertilizer were applied in February, 1993 to young grapefruit/'Swingle' citrumelo trees planted in 1992 on an Oldsmar fine sand near La Belle. The processed chicken manure treatments included two different products: Plant Right® 3-4-3, a pelleted chicken manure and Plant Right® 8-8-8, 50% granular fertilizer and 50% processed chicken manure granules. In addition, all trees received 0.23 lbs N per tree per year via fertigation according to the grower's fertilization program. Fertilizer analysis, application frequency and total N applied per tree are listed in Table 3. Treatments were arranged in a randomized complete block design with five 3-tree replications per treatment. Trunk caliper and plant height were measured in February and November, 1993 and samples for soil and leaf analysis were also taken.

Granular water soluble fertilizer, controlled release fertilizer, processed chicken manure and unprocessed chicken manure were also applied to newly planted Hamlin/sour orange trees planted in March, 1993 on an Arrendondo fine sand in Gainesville. Fertilizer analysis, application frequency and total N applied per tree per tree are listed in Table 4. Treatments were arranged in a randomized complete block design with five 3-tree replications per treatment. Trunk caliper and plant height were measured in February and November, 1993 and soil and leaf samples were also analyzed.

Table 3. Fertilizer application rates for 2-year old grapefruit/'Swingle' citrumelo trees on a Flatwoods site

Fertilizer	Applications/ yr	N/tree/yr (lbs)	N/tree/yr fertigation (lbs)	Total N/tree/yr (lbs)
Granular (8-8-8)	6	0.60	0.23	0.83
IBDU (10-3-7)	2	0.30	0.23	0.53
IBDU (19-6-12)	1	0.14	0.23	0.37
Plant Right[z] (3-4-3)	3	0.30	0.23	0.53
Plant Right (3-4-3)	3	0.60	0.23	0.83
Plant Right (8-8-8)	3	0.30	0.23	0.53
Plant Right (8-8-8)	3	0.60	0.23	0.83

[z]Plant Right® Produced by Agri-Cycle, Inc. Victor, N. Y.

Results and Discussion

Fresh cage layer manure experiments. 'Ambersweet'/'Swingle' citrumelo trees increased approximately 1 inch in trunk caliper and 3 feet in tree height over the 2-year experiment but there were no significant differences in caliper and height for the 10 and 20 ton per acre rates (Tables 5, 6). Yields ranged from an average 0.19 to 0. 26 90-lb boxes per tree for 30

Table 4. Fertilizer application rates for 1-year old Hamlin/sour orange trees on a Ridge site

Fertilizer	Applications/yr	Total N/tree/yr (lbs)
Granular (8-8-8)	6	0.60
Osmocote® (17-6-9)	2	0.30
Plant Right[z] (3-4-3)	3	0.15
Plant Right (3-4-3)	3	0.30
Plant Right (3-4-3)	3	0.45
Plant Right (3-4-3)	3	0.60
Plant Right (8-8-8)	3	0.15
Plant Right (8-8-8)	3	0.30
Plant Right (8-8-8)	3	0.45
Plant Right (8-8-8)	3	0.60
Chicken manure	6	0.60

[z]Plant Right® Produced by Agri-Cycle, Inc., Victor, N. Y.

Table 5. Trunk caliper of young 'Ambersweet'/'Swingle' citrumelo trees fertilized with chicken manure[z]

	Trunk Caliper[y] (inch)	
	Manure Application Rate (T/acre/yr)	
	10	20
Feb., 1993	1.7 ± 0.1	1.7 ± 0.1
Oct., 1993	2.2 ± 0.2	2.2 ± 0.1
Feb., 1994	2.3 ± 0.1	2.3 ± 0.1
Oct., 1994	2.8 ± 0.2	2.7 ± 0.2

[z]Planted 1/91.
[y]Mean of 30 paired trees per treatment ± standard deviation.
No significant differences according to the paired t test at the 5% level.

Table 6. Plant height of young 'Ambersweet'/'Swingle' citrumelo trees fertilized with chicken manure[z]

Application date	Plant Height[y] (ft) Manure application rate (T/acre/yr) 10	20
Feb., 1993	4.9 ± 0.6	5.4 ± 0.6
Oct., 1993	6.3 ± 0.6	6.3 ± 0.4
Feb., 1994	6.9 ± 0.5	6.9 ± 0.5
Oct., 1994	8.1 ± 0.6	8.0 ± 0.4

[z]Planted 1/91.
[y]Mean of 30 paired trees per treatment ± standard deviation.
No significant differences according to the paired t test at the 5% level.

paired trees per treatment in 1993 (year 3) and 0.49 boxes per tree in 1994 (year 4) without significant differences between treatments in either year. Although fruit production on young trees is highly variable, state averages for 3 and 4-year old trees are 0.5+ and 1.5 boxes per tree (Ferguson and Taylor, 1993), higher than yields obtained in this experiment. Yield of mature navel orange trees ranged from 1.64 to 2.23 boxes 90-lb boxes in 1993 and from 2.62 to 2.71 boxes in 1994 for the 10 and 20 ton per acre treatments, respectively, without significant differences between treatments in either year.

Leaf N levels in 'Ambersweet' trees were low to deficient only at the 10 ton per acre rate in 1993 but Mn and Zn were low to deficient in both treatments in both years, as was Fe at the 10 ton per acre rate in both 1993 and 1994 (Table 7). Leaf K levels were high to excessive in both treatments in 1993 and in the 20 ton per acre treatment in 1994. Leaf N levels in mature navel orange trees followed similar trends, with low to deficient Mn in both treatments in 1994 and low to deficient Zn levels in both treatments in both years. However, few nutrient deficiency symptoms were observed. Continued application of high rates of chicken manure would warrant careful monitoring of excessive and deficient levels of the above nutrients in leaf tissue. Soil analysis in the 'Ambersweet' grove indicated a decrease in pH from 7.4 to 6.4 and 7.2 to 6.5 in the 10 and 20 ton per acre treatments, respectively (Table 8). Percent soil organic matter increased 0.1 - 0.3% over that of uncultivated soil. High levels of P occurred in the 20 ton per acre rate in both years; high levels of Mg and low levels of K were also observed at both rates in 1993 and 1994. Soil analysis in the navel grove followed similar trends with 0.2 - 0.3% increases in soil organic matter, high levels of P and Mg and low levels of K.

Table 7. Leaf analysis of young 'Ambersweet'/'Swingle' citrumelo trees fertilized with chicken manure[zy]

Element	Manure Application Rate 10 T/acre/yr 1993	1994	20 T/acre/yr 1993	1994
	%			
N	2.33[x]	2.61	2.57	2.77
P	0.16	0.17	0.17	0.18
K	2.07[w]	2.15[w]	1.77	2.23[w]
Ca	3.28	4.01	4.11	3.66
Mg	0.34	0.36	0.35	0.37
	ppm			
Mn	14.0[x]	14.0[x]	20.0[x]	15.0[x]
Zn	14.0[x]	13.0[x]	16.0[x]	15.0[x]
Cu	5.0	8.0	7.0	8.0
Fe	53.0[x]	64.0	55.0[x]	59.0
B	46.0	56.0	44.0	59.0

[z]Planted 1/91.
[y]Mean of 4 samples consisting of 100 4- to 6-month old spring flush leaves taken from 30 trees/treatment.
[x]Low to deficient.
[w]High to excess.

No symptoms of leaf burn or fruit damage was observed when fresh cage layer manure was applied at high rates to 'Ambersweet' or navel orange trees. In other field experiments with young trees, up to 20 lbs of fresh cage layer manure were broadcast and incorporated into the root zone of 2-year old trees to equal the amount N applied in synthetic fertilizers, without any observable damage from ammonia volatilization or leaf burn.

Processed chicken manure experiments. Young grapefruit/'Swingle' citrumelo trees at La Belle increased 0.34 - 0.57 inch in trunk caliper and 1.15 - 2.02 feet in tree height over the 1-year experiment but there were no significant differences in caliper and height among fertilizer treatments. Similar increases in trunk caliper (0.22 - 0.34 inch) and plant height (1.32 - 1.64 ft) occurred at Gainesville during this 1-year experiment but again there were no significant differences in caliper and height among fertilizer treatments, even at low N rates, suggesting that young trees grown in the nursery under high nutrient fertilization programs may need little fertilization during the first year. Although originally planned as 4-year trials, both the fresh and processed chicken manure experiments were terminated after 2 years and 1 year, respectively, because of a change from organic to conventional production practices and a shortfall in funding. Experiments involving high rates of fresh cage layer manure were not planned as such but provided an opportunity to monitor grove and soil conditions on soils where manure had not been previously applied. Longer term experiments using a range of manure rates under controlled conditions are necessary to obtain more definitive data on growth, yield, nutrition, nutrient leaching and soil conditions. The Soil Conservation Service has established maximum application rates of animal

Table 8. Soil mineral content of a young 'Ambersweet'/'Swingle' citrumelo grove fertilized with chicken manure[zy]

	Noncultivated soil	Manure Application Rate 10T/acre/yr 1993	1994	20 T/acre/yr 1993	1994
pH	4.6	7.4	6.4	7.2	6.5
OM (%)	0.9	0.9	1.0	0.8	1.2
		ppm			
P	3.2	57.4	125.0	73.0	108.0
K	8.1	12.8	26.0	22.6	15.3
Ca	167.0	851.0	1458.0	967.0	279.0
Mg	22.5	129.4	170.0	113.0	154.0
Mn	1.65	9.0	9.7	8.7	8.6
Cu	0.20	4.5	3.5	4.4	3.5
Zn	1.71	13.8	15.9	15.4	15.3
Fe	6.4	10.5	7.7	7.4	7.5
Al	28.8	39.2	45.2	40.8	28.9

[z]Planted 1/91.
[y]Mean of 4 soil samples from 30 trees per treatment.

manures on agricultural lands to allow farmers to obtain an economic return from a specific crop at specific fertilization rates. As fertilization practices and nutrient leaching come under closer examination, use of animal manures will be monitored more closely, especially in terms of nutrient leaching on highly permeable soils.

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EFFECTS OF NITROGEN RATES ON GRAPEFRUIT PRODUCTION IN SOUTHWEST FLORIDA

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Additional index words. N rates, Leaf N concentration, Reclaimed water, Suspension fertilizer

Abstract. **Fertilizer requirements for orange and grapefruit trees in Florida are under reevaluation due to the recent changes in fertilizer formulations, application technology, irrigation practices, and some evidence of nitrate contamination of groundwater in some parts of Florida. A 3-yr field experiment was conducted near Bradenton on 30-yr old Marsh grapefruit trees on sour orange rootstock (20 x 30 ft, 72 trees/acre). Three N rates, i.e., 150, 200, and 250 lb N/acre/yr, were applied in 3 split doses. A suspension containing 14-0.87-11.6 (N-P-K) was applied using herbicide boom, with a band width of 7 ft, twice/yr with a third application of 16-0.87-13.3 dry blend broadcast over the growing season. The concentration of N in mature spring flush foliage over the 3-yr period varied between 2.2 to 2.4%. However, there were no significant effects of N rates either on leaf N concentration or on fruit yield and juice quality. Fruit yield averaged 13.2, 10.3, and 11.3 box/tree for the 3 consecutive years of this study. This study demonstrated that with localized application of fertilizer (approximately 2/3 of the annual N rate) by using suspension material through a herbicide boom, N rate can be reduced from rates as high as 250 lb/acre to 150 lb/acre in a high production grove condition without any adverse effects on fruit yield and/or quality. The study will be continued, with further reduced rates of N, to determine the optimum N rates for this method of fertilizer delivery.**

Nitrogen (N) recommendation for grapefruit was based on potential fruit production target at the rate of 0.3 lb N per box fruit with minimum and maximum N rates set at 90 and 240 lb per acre, respectively (Koo et al., 1984). This recommendation was based on the study of Sites et al. (1961) who conducted a study using seedy grapefruit trees on rough lemon rootstock. They used N rates of 0.1, 0.2, 0.3, 0.45, 0.6, 0.75 and 1.0 lb N per box of expected fruit production. Nitrogen was applied in various combinations of timing of application and split doses. The above N rates were equivalent to 57.5 to 575 lb N per acre per yr. Three years (1953-1956) average fruit yield was regressed against N rates. Based upon the regression analysis, fruit production decreased with an increase in rate of N application; however, evaluation of the individual data points showed that fruit yield was greater by 0.15 box per tree when N was applied on the basis of 0.3 lb N per box of fruit as compared to 0.1 lb N rate.

Smith et al. (1969) studied the effects of N rates at 50, 75, 100, 150, and 200 lb N per acre per yr on Marsh grapefruit trees. Significant fruit yield response was obtained when N rate was increased up to 150 lb per acre per yr, but not at the highest N rate. Timing of N application had minimal effects on fruit production, especially at the higher N rates.

Smith and Rasmussen (1961) reported no significant difference in fruit yield of Marsh grapefruit trees on rough lemon rootstock over 8 yr at N rates of 120, 240, and 540 lb per acre per yr. The mean fruit yield varied from 504 to 511 box per acre despite this wide range in N rates.

Some drinking water from private shallow wells in some parts of the state have been found to have elevated nitrate levels, probably originating from use of nitrogen fertilizers. Therefore, there is a need to reexamine fertilizer recommendations for major crops including citrus in an effort to minimize any further loading of nitrates to groundwater.

A recent study (Boman, 1993) on Marsh grapefruit has shown potential for reduction in N rates without any noticeable decrease in fruit production. Furthermore, Boman (1994) also demonstrated potential advantage of improved N application practice by application of part of the N rate as fertigation under the canopy. These recent studies strongly suggest the need to further evaluate the N management practice for grapefruit to increase N use efficiency.

The objective of this study was to evaluate the effects of various rates of N application on the leaf N concentration, fruit quality, and fruit yield over a 3-yr period.

Materials and Methods

This study was conducted in a grove located east of Bradenton in Manatee County using 30-yr-old Marsh grapefruit trees on sour orange rootstock in a commercial grove planted at 20 x 30 ft (72 trees per acre). The soil in the experimental area was Eau Gallie fine sand. Prior to the beginning of the study, this grove received 250 lb N/acre/yr. The experimental area included two 10-acre blocks. The trees were planted on slightly elevated single row beds. The grove was irrigated by low volume microsprinklers with one emitter (10

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