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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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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gal per hr) per tree. Reclaimed water was used for irrigation with an average total N concentration of 5.74 ppm. The contribution of N from irrigation water was 4.3 lb N per acre per yr.

Each treatment was applied to 50-tree plots with a buffer row between each plot. A randomized block design was employed with 4 replications.

Prior to the beginning of the study, the grove yielded an average of 800 boxes per acre in 1988-89 season, 631 in 1989-90 and 670 in 1990-91. The study began in March of 1991. The treatments included 3 N rates of 150, 200, and 250 lb N per acre per yr applied in 3 doses. Applications were made in March, June and October and represent 40, 30 and 30% of the annual fertilizer rate, respectively. The first 2 applications each yr were made using a suspension fertilizer applied via a 7 ft herbicide boom of a mix containing 14-2-14 (N-P_2O_5-K_2O). A dry blend (16-2-16) was used for the final application in the fall of year. A broadcast spreader was used to apply the dry fertilizer over the entire grove area including the row middle.

Soil and leaf analyses. During spring of 1991, before starting the treatments, soil samples were taken from 0-6 inch depth from all the plots. These soil samples were air-dried, sieved through a 2mm screen. The mean concentration of total N (Kjeldahl N) was 0.08%. The concentrations of P, Ca, Mg, and K in Mehlich 1 extractant (Mehlich, 1953) were 56, 657, 79, and 13 mg/kg, respectively.

Six-month-old spring flush leaf samples were taken from 4 clusters of 4 trees each within each plot. Since the experiment was conducted using large plots of 50 trees each, multiple samples were taken from each replicate plot. The leaves were washed in detergent solution using a cheesecloth to scrub both sides of the leaves, rinsed in distilled water, soaked in 5% HCl for 20 sec, followed by 3 to 4 rinses in distilled water, and dried at 70°C for 48 hr. The dried leaves were ground and concentration of N was determined by the Kjeldahl method. The ground leaf sample (0.5 g) was ashed in a muffle furnace at 500°C for 5 hr. The ash was dissolved in 20 mL 1.0 M HCl. The concentrations of P, K, Ca, Mg, Na, Fe, Mn, Zn, and Cu were measured using inductively coupled plasma emission spectroscopy (ICPES).

Yield and fruit quality. When the fruit attained the legal maturity standards, 4 subsamples of 30 fruit each was taken from each plot in early December of each year. Fruit weight per sample was determined to calculate the weight of the fruit on a per fruit basis. These fruit samples were used to analyze pound solids per box, percent juice, percent acid, percent brix, and brix/acid ratio. Fruit was harvested by late March each year from 4 trees per plot to measure the fruit yield and expressed as fruit yield per tree.

Results and Discussion

During the course of the 3-yr period, fruit yield was not significantly influenced by the N rates (Figure 1). Therefore, under the current experimental conditions there was no evidence of benefits of N rates above 150 lb/acre/yr. Fruit yield varied from 943 to 965, 655 to 835, and 799 to 835 boxes/acre during the 3 yr of this study. Based on the recommendation of 0.3 lb N per box in IFAS Bulletin 536D (Koo et al., 1984) it would appear reasonable to apply N rate as high as 240 lb N/acre/yr (800 boxes x 0.3 lb N/box), which was the maximum quantity recommended. However, this study clearly demonstrates that the production was not decreased despite the re-

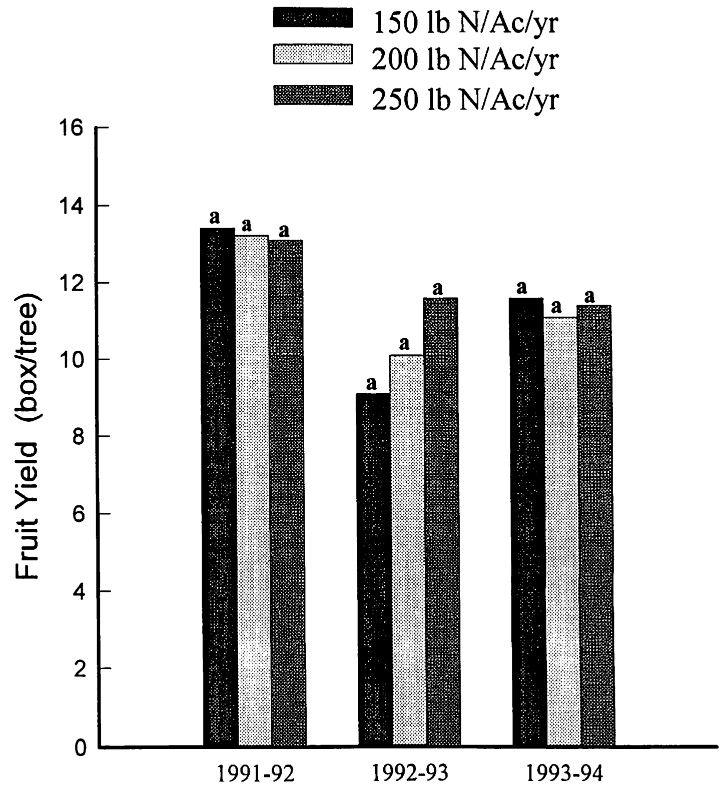

Figure 1. Fruit yield of White Marsh grapefruit trees on sour orange rootstock as influenced by 3 rates of N application over a 3-year period. Means followed by same letters within each year are not significantly different according to Duncan's Multiple Range Test at P = 0.05.

duction in N rate down to 150 lb/acre/yr. This 150 lb/acre/yr rate is near the proposed maximum being recommended in the revised IFAS bulletin (Tucker et al., 1994).

The yield varied from year to year with the lowest yields obtained in 1992-93. Yields in 1992-93 may have been reduced due to the severe weather in March 1993 which resulted in fruit drop and severe defoliation of the trees which was caused by the no-name storm of March 1993.

Nitrogen concentrations in 6-month-old leaves remained in the low range which is 2.2% to 2.4% for all treatments each year (Table 1). While the nutritional levels are given for citrus, differences may occur between oranges and grapefruit. Additional studies need to be conducted to see if optimum leaf levels are in fact the same for all cultivars.

In 1992-93, the leaf N concentration was highest (2.3%) in the trees which received 200 lb/N/yr while lowest (2.14%) in the trees which received 150 lb/N/yr. In 1993-94, leaf N concentration was the highest (2.48%) in the trees which received 250 lb/N/yr.

The concentrations of K in the leaves were within the optimum range of 1.2% to 1.7% for all treatments. Although the differences were not significant, the leaf K concentrations tended to decrease with an increase in N rate. In 1993-94, leaf K concentration was significantly greater in the trees which received 150 lb/N/yr compared to those which received 250 lb/N/yr.

Table 1 shows concentrations of mineral elements in 6-month-old spring flush. In 1992-93, there was no significant difference in concentrations of P, Mg, and Na between the

Table 1. Concentrations of mineral elements in 6-mo-old spring flush leaves of White Marsh grapefruit trees on sour orange rootstock grown under various N rates.

Treatments (lb N/ac/yr)	N	P		Ca	Mg	Na	Fe	Mn	Zn	Cu
	Concentrations in 6-mo-old spring flush leaves									
		% on dry wt basis					mg/kg			
					1991-92					
150	2.23a	0.11a[y]	1.19a	3.52b	0.31a	ND	47a	30a	43a	165a
200	2.28a	0.12a	1.43a	3.58ab	0.29a	ND	49a	30a	30b	183a
250	2.31a	0.11a	1.39a	3.68a	0.30a	ND	51a	28a	30b	182a
					1992-93					
150	2.14a	0.11a	1.27a	3.27b	0.31a	0.06a	51a	13a	18a	86ab
200	2.30a	0.11a	1.20a	3.39b	0.28a	0.05a	51a	12a	17b	72b
250	2.23a	0.11a	1.18a	3.77a	0.30a	0.05a	57a	13a	20a	103a
					1993-94					
150	2.34b	0.11a	1.55a	3.29b	0.32a	0.05a	ND[z]	Nd	ND	ND
200	2.43ab	0.11a	1.50ab	3.35ab	0.29b	0.05a	ND	ND	ND	ND
250	2.48a	0.11a	1.40b	3.57a	0.29b	0.06a	ND	ND	ND	ND

ND[z] = No data available.
[y]Mean followed by the same letters within each column for each year are not significantly different according to Duncan's Multiple Range Test at P = 0.05.

treatments. In 1993-94, the concentrations of P and Na were not influenced by the N treatments.

Table 2 shows juice quality factors and fruit weight are shown. There was no significant influence of N rates on any of the above parameters. Fruit weights were heaviest in the second year of the study in which box/tree were lower as compared to the first and third years.

In summary, the study clearly demonstrates no beneficial effects of rates of N application over 150 lb/acre/yr in this grapefruit grove with production levels over 800 boxes/acre.

Table 2. Juice quality of White Marsh grapefruit (on sour orange rootstock) as influenced by various N rates.

Treatment (lb N/ac/yr)	Fruit wt (g/fruit)	Juice %	Acid %	Brix %	Ratio	Pound solids per box
			1991-92			
150	440a[z]	56.00a	1.32a	8.83a	6.72a	4.95a
200	459a	55.99a	1.31a	8.86a	6.74a	4.96a
250	426a	58.06a	1.32a	8.89a	6.75a	5.16a
			1992-93			
150	542a	53.80b	1.34a	9.35a	7.00a	5.03a
200	515a	56.63a	1.31a	9.41a	7.20a	5.33a
250	520a	54.71ab	1.34a	9.40a	7.03a	5.14a
			1993-94			
150	422a	56.96a	1.49a	9.68a	6.52a	5.52a
200	447a	56.38a	1.43b	9.61a	6.73a	5.42a
250	439a	57.95a	1.46ab	9.71a	6.67a	5.63a

[z]Means followed by the same letters within each column for each year are not significantly different according to Duncan's Multiple Range Test at P= 0.05.

Therefore, N application to grapefruit on the basis of 0.3 lb N/box fruit may lead to over-application of N resulting in low N use by the crop, possible groundwater contamination and low return per unit investment on fertilizer.

This study will be continued for several additional years with N application rates reduced from the current levels to 100, 130, and 160 lb N/acre/yr.

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