Bromacil was found more frequently than atrazine in this survey. After them terbumetone showed more than terbuthylazine and simazine. Terbutryn is less leachable and persistent (Gómez de Barreda et al., 1995), therefore it has been almost impossible to find it.

In summary, some of the wells selected, that belong to high risk situations of contamination by residual herbicides, during some dates of the year, contain insignificant concentrations, parent compounds or even in some cases, degradation chemicals, above the EC limits for drinking purposes. The concentration found, is in the levels of few µg/l. The main danger in using this water for drinking is more due to the high nitrate levels than to the concentration of the citrus selective residual herbicides studied.

Acknowledgments

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VARIATION IN GROUNDWATER NITRATE UNDER AN EAST CENTRAL FLORIDA CITRUS GROVE

H. K. Wutscher
USDA/ARS Horticultural Research Laboratory
2120 Camden Road
Orlando, FL 32803

Additional index words. Fertilization, environment.

Abstract. **Groundwater nitrate levels under a 'Valencia' (*Citrus sinensis* L. Osbeck) on rough lemon (*C. limon* L. Burm.f) grove planted in 1984 near St. Cloud, Florida, were monitored every 30 days from November 1994 to September 1996. The samples were taken from four 5 cm (2.0 in) diameter wells, 3.7 m (12 ft) deep, spaced 87 m (264 ft) apart in the center of the 600 m (1312 ft) × 70 m (230 ft) grove. The wells were jetted in with water and had 1.5 m (5 ft) of finely slotted (0.5 mm [0.02 in]) filter pipe on the lower end. Eight 30 cm (1 ft) deep shallow wells were designed to intercept seepage into drainage ditches on three sides of the grove. To the north side, the land is bordered by swampy woodland from which groundwater drained into the grove. Water in the drainage ditches was also monitored. The water table in the center of the grove was at 1.7 to 2.0 m (5.6 to 6.8 ft), with little fluctuation. The grove was irrigated with microsprinklers, but fertilization was with dry fertilizer only. The grove was fertilized uniformly until April 1995. After that, Plots 1 and 3 received approximately half the amount of N applied to Plots 2 and 4. The high N plots received 244 kg N/ha (217 lb N/acre) in four applications, and the low N plots received 169 kg N/ha (150 lb N/acre) in three applications in 1995. In 1996, N was applied four times between January and September, 106 kg N/ha (95 lb N/acre) to the high N plots in four applications, and 70 kg N/ha (62 lb n/acre) in two applications to the low N plots. Water in the well in Plot 3 and the seepage well on its east side had between 8 and 28 mg/l nitrate N in 1995, while Well No. 2 never exceeded 12 mg/l. Water from Wells 1 and 4 was intermediate and never exceeded 10 mg/l NO_3-N. All four wells were essentially nitrate-free in December 1995. In the first 8 months of 1996, none of the wells had NO_3-N higher than 8 mg/l, with the highest levels in Well No. 2.**

For decades, there has been concern about chemicals applied to agricultural land entering the groundwater (Canter, 1996). The problem can be acute in temperate zone areas where, because of shallow soil and low soil temperatures, high concentrations of pollutants accumulate (Baier and Rykbost, 1976). In the often deep soils of Florida, where higher soil and water temperatures favor faster breakdown of substances and root absorption of nutrient elements, phosphorus has long been blamed for eutrophication of lakes and ponds, but nitrates have received increased attention recently (McNeal et al., 1994). Provisional regulations imposing a 10 ppm NO_3-N limit on all groundwater, even under agricultural land, have been passed (Westly and Kuhl, 1995). A favorable site near Alligator Lake, between St. Cloud and Holopaw, for studying groundwater nitrate in an upper flatwoods setting, was offered by a grower. This report describes the groundwater nitrate pattern there, as it was found after uniform and differential fertilization to parts of the grove.

Materials and Methods

A grove of 'Valencia' (*Citrus sinensis* L. Osbeck) on rough lemon (*C. limon* L. Burm.f.) rootstock, planted in 1984 with 6.7 × 4.3 m (22 × 14 ft) spacing, consisting of 52 rows of 17 trees each, was divided into four plots (Fig. 1). In the center of each plot, a 5 cm (2 in.) diameter well was jetted in. The wells were 3.5 m (11.5 ft.) deep and the bottom of each well pipe consisted of 1.5 m (5 ft) of finely slotted (0.5 mm [0.02 in]) capped sand filter pipe. The groundwater level varied between 170 and 200 cm (5.6 and 6.8 ft), with little fluctuation because it is controlled by a nearby lake. On both sides of each plot, in line with the deep well in the center, 60 cm (2 ft) of the same sand filter pipe was inserted into the water-saturated ditch bank soil above the level of the drainage ditch water to intercept the seepage out of the grove. The land was originally Pomello (sandy, siliceous, hyperthermic Arenic Haplohumods) soil, extensively modified by 4 m (12 ft) deep drainage ditches on three sides. On the north end, the block was connected to swampy forest land from which the groundwater drained into the grove. The spoil from digging the drainage ditches was used to raise the grove surface above the surrounding land.

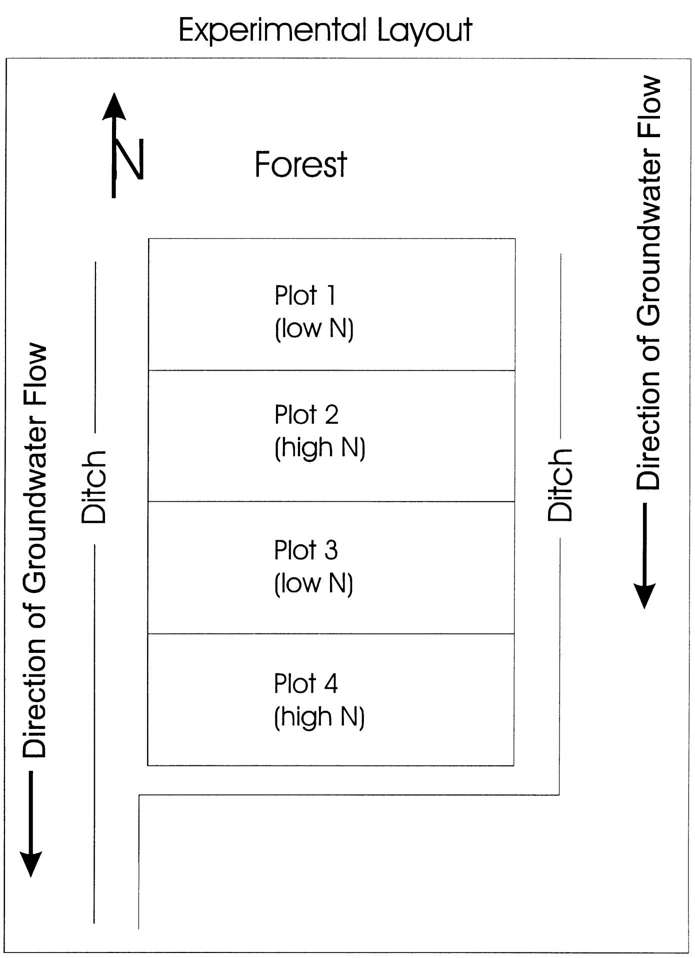

Figure 1. Experimental Layout.

The deep wells were sampled every 30 days between November 1994 and September 1996, by pumping 55 L (15 gal) out of each well with a centrifugal pump and then collecting a 300 ml sample. The seepage wells were sampled with a siphon. A weighted sample bottle was used for the east and west drainage ditches and a canal draining the whole area. Water entering the grove from the adjacent woodland was sampled twice. The water samples were transported in ice to the laboratory and analyzed for pH with a pH meter, for electrical conductivity with a Wheatstone bridge, for NO_3-N (Rump and Krist, 1988) and P (Gomori, 1942) colorimetrically, for K and Na by flame emission, and for Cl by electrometric titration.

The grove was irrigated with microsprinklers, but all fertilizer was applied in dry form, four times each year. The fertilization rate before the start of the experiment was 224 kg N/ha (200 lb N/acre) uniformly applied to the whole block. After April 1995, Plots 1 and 3 received approximately half the nitrogen applied to Plots 2 and 4. Fertilizer applications during the period 11/94 to 9/96 are listed in Table 1. Yield records for the whole block for crop year 1994/95 and for individual plots in 1995/96 were kept, and per tree yields for 1995/96 were calculated for the high and low N plots. Hundred-leaf samples from each plot were collected in July 1995 and 1996, and analyzed for 14 elements by standard methods (Wutscher and Hardesty, 1979). Soil samples (0-30 cm depth) collected in January 1995 were analyzed for pH, and 8 elements were determined in the Mehlich I (double acid) extract. Saturation extracts from soil at 30 cm (1 ft) and 60 cm (2 ft) were analyzed for electrical conductivity, NO_3-N, P, K, Ca, Mg, Na, and Cl. Organic matter (Walkley and Black, 1934) and soil color (Wutscher and McCollum, 1993) were determined in 30 cm (1 ft) increments to 180 cm (6 ft) depth. Monitoring continues because effects of changes in fertilization cannot be determined in short term experiments.

Results and Discussion

The response of groundwater nitrate levels to different levels of fertilization (Table 1) was slow, and varied greatly from plot to plot, even with uniform, high level fertilization at the beginning of the experiment (Fig. 2). The well water from Plot 3 contained more than twice as much NO_3-N as water from Plots 1 and 4, while water

Table 1. Fertilizer application to high and low nitrogen plots between November 1994 and September 1996.

	Fertilizer	High N (Plots 2 & 4)		Low N (Plots 1 & 3)	
	$N-P_2O_5-K_2O$	kg N/ha	lb N/acre	kg N/ha	lb N/acre
December 94	11-11-11	62	55	62	55
January 95	16-0-16	36	32	36	32
April 95	16-0-16	68	61	0	0
July 95	15-0-15	67	60	34	30
December 95	13-0-13	73	65	37	33
January 96	16-0-0	56	50	0	0
March 96	16-0-16	27	24	27	24
April 96	15-0-15	43	38	0	0
June 96	15-0-15	43	38	43	38
1995 Total		244	218	107	95
January to September 1996 Total		169	150	70	62

from Well 2 was almost without nitrate. Only in November 1995,

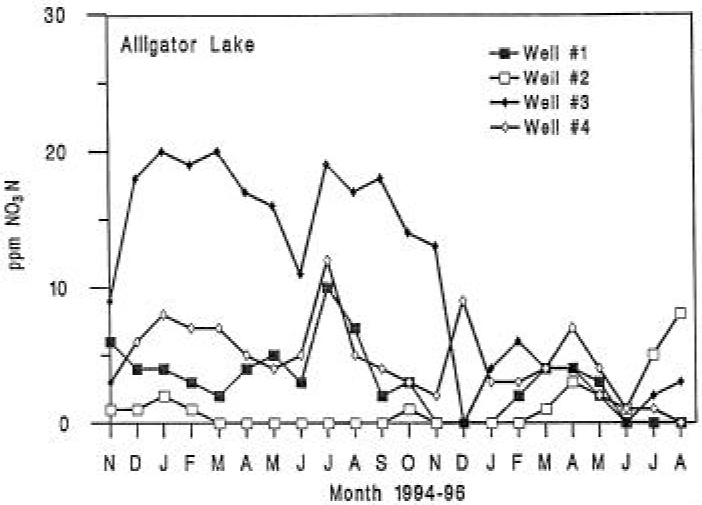

Figure 2. NO_3-N levels in groundwater collected from four wells in the experimental grove between November 1994 and August 1996.

10 months after the last high-rate nitrogen application, did the NO_3-N level in Well 3 drop to that in the other wells. The high NO_3-N levels were apparently confined to the center and the east side of Plot 3, because only the seepage water there had elevated nitrate levels (Fig. 3) in 1995, levels that declined towards the end of the year after N application was reduced. Short-lived increases in NO_3-N levels in the seepage water were found on the west side of Plot 2 late in 1995 and three times on the east side of Plot 3 in 1996 (Fig. 2). All plots had lower NO_3-N levels in the water in 1996 than in 1995 in response to lower N application to both the high N and low N plots (Table 1). Well 2, almost without nitrate in 1995, had 7 mg/l NO_3-N, the highest nitrate levels in August 1996. Plots 3 and 4 both had levels in that range earlier in the year. Although 57% more N was applied to Plots 2 and 4 in the 20 months between January 1995 and September 1996 than to Plots 1 and 3, their groundwater NO_3-N levels were well below 10 mg/l after January 1996. The lowest NO_3-N levels were found in Plot 1, a high-nitrogen plot, and Plot 4, a low nitrogen plot (Fig. 1). The amount of N applied to the high N plots between January and September 1995 (171 kg/ha [152 lb/acre]) was almost the same as during the same period in 1996 (169 kg/ha [150 lb/acre]). NO_3-N in the groundwater was much lower and about the same as in the low N plots (70 kg/ha [62 lb/acre]) in 1995 and 1996. Factors other than the amount of N applied apparently governed the groundwater nitrate level. The same effect has been observed in other locations (unpublished data). The soil in the four plots shows little variation despite the dredge-and-fill work before planting. Table 2 shows soil pH varying from 5.1 to 5.7. There was more variation in the seven elements extracted with Mehlich I solution. The NO_3-N and other element levels in the saturation extract of soil to 60 cm (2 ft) depth are commonly found in the area. The soil on the east side of Plot 3, where groundwater nitrate was high, contained no more nitrate than other sites in the block (Table 3). Organic matter analysis and soil color measurement of 30 cm (1 ft) increments to a depth of 180 cm (6 ft) (Table 4) contain a feature that coincides with high groundwater nitrate in Plot 3: a dark-colored buried organic horizon at 90 to 120 cm (3 to 4 ft). It is not clear if this layer is responsible for the NO_3-N levels at this site. Normally, high organic

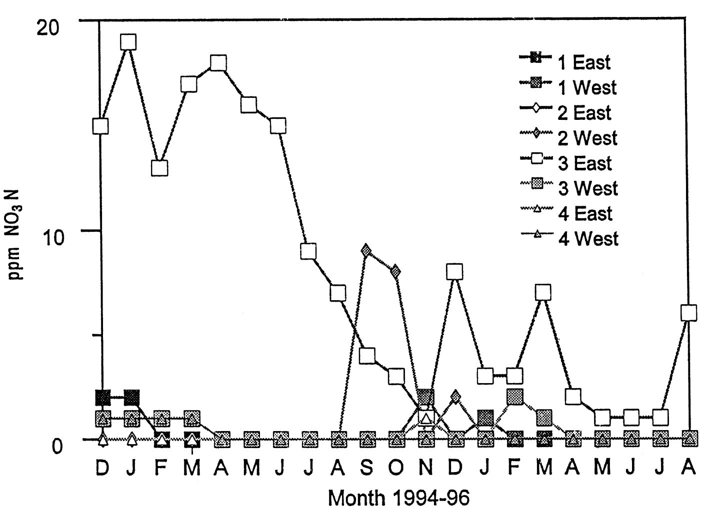

Figure 3. NO_3-N levels in water collected from seepage wells on both sides of the experimental grove between December 1994 and August 1996.

Table 2. Soil analysis of the high and low nitrogen plots in the experimental grove before changes in fertilization rates.

			Mehlich I extractable elements Parts per million							
Low N	Depth (cm)	pH	P	K	Ca	Mg	Na	Fe	Mn	Cu
East 1	0 - 30	5.1	23	32	320	64	6	3	2	2
East 3	0 - 30	5.7	62	32	350	47	5	3	3	3
West 1	0 - 30	5.4	24	30	240	41	4	3	3	2
West 3	0 - 30	5.6	57	28	373	69	7	3	5	3
High N										
East 2	0 - 30	5.4	93	73	500	52	7	3	5	3
East 4	0 - 30	5.7	55	32	275	35	4	6	3	3
West 2	0 - 30	5.2	62	40	80	32	7	4	9	2
West 4	0 - 30	5.5	85	37	367	58	6	7	7	2

Table 3. Electrical conductivity, ppm NO_3-N, P, K, Ca, Mg, Na, and Cl in the saturation extract of soil at 30 cm (1 ft) and 60 cm (2 ft) depth.

			Parts per million						
	Depth (cm)	E.C.[z] (dS/m)	NO_3-N	P	K	Ca	Mg	Na	Cl
Low N									
East 1	30	.22	20	19	15	33	7	3	2
	60	.13	9	18	9	10	2	4	4
West 1	30	.21	6	12	19	29	5	3	5
	60	.26	8	18	12	19	8	4	7
East 3	30	.25	9	11	20	22	7	3	5
	60	.26	11	10	29	16	6	5	5
West 3	30	.17	7	15	15	12	4	4	7
	60	.17	9	10	14	13	4	3	4
High N									
East 2	30	.22	13	23	19	17	6	6	6
	60	.18	10	17	14	13	5	5	5
West 2	30	.43	10	15	53	16	6	19	19
	60	.20	5	11	17	27	6	7	7
East 4	30	.24	10	9	23	17	5	4	5
	60	.24	10	9	15	19	6	4	6
West 4	30	.27	16	15	14	20	6	3	4
	60	.27	13	9	11	20	9	4	5

[z]E.C. = Electrical Conductivity.

Table 4. Percent organic matter (O.M.) and soil color in 30 cm (1 ft) increments, 180 cm (6 ft) depth.

Depth (cm)	% O.M.	Soil color	% O.M.	Soil color	% O.M.	Soil color	% O.M.	Soil color
				Low N				
	Plot 1				Plot 3			
	East		West		East		West	
0 - 30	1.26	6.9YR 2.6/0.7[z]	1.03	7.4YR 3.3/0.8	1.33	4.9YR 1.3/0.5	1.03	7.9YR 3.1/1.0
31 - 60	0.46	7.7YR 4.4/0.9	1.37	8.1YR 3.3/1.8	1.66	7.5YR 2.0/0.5	0.40	8.1YR 3.7/0.6
61 - 90	0.63	6.5YR 4.1/1.3	0.33	9.3YR 4.6/1.8	0.56	7.7YR 2.8/0.5	1.93	7.2YR 3.2/1.9
91 - 120	0.80	6.5YR 2.6/1.5	0.20	9.1YR 4.5/1.3	2.45	4.1YR 1.4/0.7	0.47	8.7YR 3.1/1.5
121 - 150	0.73	7.8YR 3.3/1.9	0.20	8.6YR 3.9/1.7	0.60	8.2YR 2.3/1.5	0.30	9.1YR 2.7/1.3
151 - 180	0.73	7.6YR 3.2/1.5	0.23	9.3YR 4.2/1.6	0.30	8.2YR 2.3/1.5	0.60	8.2YR 2.5/1.3
				High N				
	Plot 2				Plot 4			
0 - 30	2.22	6.8YR 1.8/0.7	0.97	7.2YR 2.5/0.8	0.86	7.4YR 2.4/0.8	1.34	6.1YR 2.0/0.9
31 - 60	1.79	7.0YR 2.2/0.7	0.73	8.8YR 3.1/1.3	0.99	7.4YR 1.8/0.8	0.81	7.0YR 2.2/0.7
61 - 90	1.13	6.6YR 2.9/0.9	0.17	0.1YR 4.0/1.2	1.19	8.0YR 2.8/0.4	0.63	6.6YR 2.9/0.9
91 - 120	0.36	8.1YR 3.2/1.4	0.07	0.3YR 5.0/0.8	1.68	7.5YR 2.1/1.0	1.13	8.1YR 3.2/1.4
121 - 150	0.43	8.9YR 3.0/1.3	0.10	8.9YR 4.1/1.0	0.99	7.0YR 2.1/1.1	0.20	8.9YR 3.0/1.3
151 - 180	0.69	7.7YR 2.5/1.0	0.27	8.9YR 3.5/1.0	1.19	7.4YR 2.6/1.3	0.56	8.2YR 2.5/1.2

[z]Munsell notation: Hue (e.g. 6.9YR), Value (e.g. 2.6) and Chroma (e.g. 0.7). Describes color by a standardized numerical system (USDA Soil Survey Manual, 1951).

Table 5. Analyses of leaves collected in July 1996, from low and high nitrogen plots in the experimental grove (means of 4 samples).

	Percent						Parts per million							
	N	P	K	Ca	Mg	S	Na	Fe	Mn	Zn	Cu	Cl	B	Mo
Low N	2.33	.114	1.17	3.91	.413	.260	412	43	30	30	8	391	105	2
High N	2.47	.110	1.31	3.70	.383	.267	407	49	26	27	6	402	108	1
	NS[z]	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]NS = not significant.

Table 6. pH and concentration of NO_3-N, P, K, Na, and Cl in surface drainage waters around the experimental grove (means 1/95 to 8/96).

	Parts per million						
	pH	NO_3-N	P	K	Na	Cl	TDS[z]
North end	4.5	0	4	4	11	8	45
East ditch	4.6	0	1	10	14	32	154
West ditch	4.7	0	2	7	13	27	123
Combined drainage	4.3	1	8	5	19	36	144

[z]TDS = Total dissolved solids.

matter is associated with lower soil nitrate (Buckman and Brady, 1960) but in this case, the organic matter is completely decomposed humus. The differential fertilizer applications resulted in slightly higher leaf N and K (Table 5) in the high N plots, but had no other effects.

The lack of pollution of the drainage water (Table 6) from the grove puts the environmental importance of the occasionally elevated NO_3-N levels under the trees in doubt. Even where appreciable NO_3-N entered the drainage ditch on the east side of Plot 3, there was little or no detectable NO_3-N a short distance downstream. The water entering from the forest area increased in dissolved solids after passing through the cultivated grove, but nitrate was not one of the constituents responsible for that. The sharpest increase was in chlorides, which is a particularly good indicator of fertilizer salts entering groundwater (Canter, 1996), and in some cases in potassium and phosphorus. Results could be different in the ridge and other areas of Florida, but it appears that at the experimental site, fertilization had little impact on the environment around the grove.

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LEAF MINERAL CONCENTRATION, GROWTH, YIELD, FRUIT QUALITY, AND ECONOMICS OF 'AMBERSWEET' ORANGE ON TWO ROOTSTOCKS

MONGI ZEKRI
Jack M. Berry, Inc.
P.O. Box 459
LaBelle, FL 33935

Additional index words. Citrus, juice color, nutrition, tree canopy volume.

Abstract. **Because of the many concerns about fruit quality and productivity of the 'Ambersweet' cultivar, a study has been conducted in Florida to evaluate the performance of this cultivar budded on two citrus rootstocks and grown in three locations (central Ridge, east coast, west coast). The effects of Cleopatra mandarin (CM) rootstock on leaf mineral concentration, tree growth, yield, fruit quality, and economics were compared to those of Swingle citrumelo (SC). Earlier fruit maturity and higher soluble solids and juice content were obtained from trees grown on the flatwoods (east and west coasts) compared with trees grown on the central Ridge. Rootstocks were found to influence tree canopy shape and affect juice color score. With the exception of magnesium, no consistent difference in leaf mineral concentration was found between the two rootstocks. No difference was found in tree canopy size but significant differences in yield, fruit size, and fruit quality were found between the two rootstocks. Fruit produced on CM were large with rough, thick peel and poor color. Swingle citrumelo rootstock promoted higher yield, earlier fruit maturity, and better fruit and juice quality than CM. In 1995, the ratio between SC and CM in terms of yield was 13 to 1, 19 to 1, and 3 to 1 for the west coast (LaBelle), the east coast (Fellsmere), and the central Ridge, respectively. This study also revealed the financial advantage of SC over CM as a rootstock for 'Ambersweet' orange.**

'Ambersweet' is the first recorded orange cultivar developed through hybridization. It is a hybrid of [*Citrus reticulata* Blanco × (*C. paradisi* Macf. × *C. reticulata*)] × midseason orange [*C. sinensis* (L.) Osb.] developed by the USDA breeding program in Florida. This cross makes 'Ambersweet' fruit 1/2 orange, 3/8 mandarin and 1/8 grapefruit (Hearn, 1989).

Limited data through the years of development of 'Ambersweet' orange cultivar revealed several attributes and good characteristics. The tree is moderately cold hardy. The fruit ripens quite early in the season and serves both the fresh and processing markets. The fruit has good peel color and texture and is easy to peel. The juice has excellent flavor and a dark-orange color (Hearn, 1989). Because 'Ambersweet' juice exceeds the minimum color standards, it can be mixed with other juices that do not meet the government color requirements (Barros et al., 1990). This could make the processing industry less dependent on imports and/or on 'Valencia' juice that has to be stored from the previous year to blend with poorer colored 'Hamlin' juice.

'Ambersweet' orange was released to growers in February, 1989. Because it has many desirable qualities and attributes, this most recent released citrus cultivar was rapidly propagated and extensively planted throughout the Florida citrus industry. The inventory at the end of 1992 was estimated at more than five million planted 'Ambersweet' trees (Hearn, 1992).

For the past several years, without taking into consideration tree age, Florida citrus growers, fresh fruit shippers and juice processors have had concerns about the quality of fruit and juice from 'Ambersweet' trees. There has even been a perception that fruit productivity has been low. In general, 'Ambersweet' has not performed as well as expected by some people in the Florida citrus industry and a few growers pulled out or topworked their 'Ambersweet' trees.

Several more years of observations are needed to make fair evaluations on the role and performance of 'Ambersweet' trees. Evaluation of 'Ambersweet' trees under different field conditions, cultural practices, and stresses are very important to help make wise decisions in managing 'Ambersweet' successfully. Since on-site evaluation has many potential benefits for the local grower, a study was initiated to assess the performance of 'Ambersweet' trees budded on two popular rootstocks and grown in three different major locations representing the Florida citrus growing region.

Materials and Methods

Three experiments were conducted in three distinct locations: west coast (LaBelle, Hendry county), east coast (Fellsmere, Indian River county), and the central Ridge (Polk county) in Florida to evaluate 'Ambersweet' trees on two popular rootstocks. These ex-