Table 5. Mean yield and fruit quality by treatments for samples taken in December of each year (n=5).

ID	Mean fruit weight g/fruit	Juice content %	Acid %	Brix %	Brix to acid ratio	Solids per box lbs	Boxes per tree	Boxes per acre
1989/90								
CR-20	502	58.1	1.30	9.6	7.4	5.6	2.4b[z]	209b
CR-36	487	57.4	1.33	9.8	7.4	5.6	3.0a	261a
TRAD	476	60.7	1.30	9.8	7.6	6.0	2.7ab	235ab
1990/91								
CR-20	387	63.2	1.19	9.9	8.3	5.7	—	—[y]
CR-36	380	63.1	1.18	10.3	8.7	5.8	—	—
TRAD	377	58.8	1.19	10.3	8.7	6.0	—	—
1991/92								
CR-20	492	56.2	1.13b	9.3b	8.3	4.3b	5.6	488
CR-36	483	55.3	1.12b	8.9b	8.0	4.2b	5.6	488
TRAD	474	58.2	1.21a	9.6a	7.9	4.8a	6.2	539
1992/93								
CR-20	460a	57.8b	1.21	9.3b	5.0b	7.7	4.1	357
CR-36	432b	58.7ab	1.20	9.2b	5.1b	7.6	4.6	400
TRAD	393c	59.6a	1.26	9.8a	5.5a	7.8	4.6	400

[z]Means within columns for the same season followed by the same letter are not significantly different (P=0.05) according to the Duncan's Multiple Range Test.
[y]Fruit was not picked from the trees in the 1990/91 season.

per unit of N of the blend would be considerably lower than the straight CR material, and a higher per acre rate of N could be economically applied. A late winter or early spring application of the blended product would probably be most beneficial. More N would be available to the trees early in the season than if CR alone was used. The lessened potential for leaching of soluble N in the dry season should help to achieve higher fertilizer efficiencies. However, research on the ratio of CR to soluble fertilizers to achieve maximum economic gain needs is lacking and detailed recommendations cannot be made.

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EVALUATION OF A RESIN COATED NITROGEN FERTILIZER FOR YOUNG CITRUS TREES ON A DEEP SAND

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Abstract. **Although nitrogen (N) is an important nutrient for citrus tree growth, the portion of N that is not utilized by the trees in the soil potentially can contaminate the groundwater. Soil, rainfall and irrigation conditions have an impact on leaching loss of nitrate-N. The potential for minimizing leaching loss of nitrate-N was evaluated in a replanted old grove**

site on a typical deep sandy soil condition. 'Pineapple' orange (*Citrus sinensis* (L.) Osbeck) trees on Swingle citrumelo (*Citrus paradisi* Macf. × *Poncirus trifoliata* (L.) Raf.) rootstock were planted. Various rates of 17-6-12 (N-P_2O_5-K_2O) blend were applied to result in N rates of 0.04 to 0.34 lb/N/tree/year, during the first year of planting using a controlled-release fertilizer (resin coated; Meister, Helena Chemical Company) and conventional dry soluble fertilizer sources. Considering the importance of maintaining a constant ratio of $N{:}K_2O$, no attempt was made to maintain constant rate of P_2O_5 and K_2O across all N rate treatments. The fertilizer rates were doubled during the second year. Reduced rate of fertilizer application had no adverse effects on either tree canopy expansion, trunk growth, or concentrations of mineral elements in spring flush during both years. During the second year, the fruit weight and juice quality parameters were also not influenced by drastic reduction in fertilizer rates. An increased leaching loss of nitrate-N was evident when using dry soluble fertilizers as compared to slow release fertilizer as indicated by elevated concentrations of nitrate-N in leachate sampled at 5 ft below ground level under the trees.

The influence of nitrogen (N) on growth and yield of citrus is greater than that of any other elements. Nitrate-N is highly mobile in soils. In much of the citrus producing area on the central Florida ridge, soils are deep and sandy and rainfall is poorly distributed and often intense during summer months. These conditions favor increased leaching of nitrate-N. The portion of nitrate-N leached below the root zone is a net loss of that nutrient. These N losses represent wasted expenditures on production as well as potential groundwater contamination.

Nitrate contamination of groundwater has become a growing concern in sandy soils in several major citrus producing counties in central Florida. Groundwater quality monitoring programs in these counties have shown an increase in nitrate contamination of surfacial aquifer during recent years. Out of 3446 drinking water wells sampled in 6 Florida counties, nitrate-N concentration exceeded the maximum contaminant level (MCL; 10 ppm) in 544 wells (16%) (Department of Environmental Protection, 1993, unpublished data).

Considerable research has been done on N nutrition of citrus, mostly using dry soluble fertilizers (Koo et al., 1984). Nitrogen recommendation for 1- and 2-yr-old citrus trees can vary from 0.30 to 0.60 and 0.56 to 0.90 lb N/tree/yr, respectively (Koo et al., 1984). For mature orange trees, N recommendation is based on estimated fruit yield. Accordingly, a grove with the potential for producing 800 box/acre, the recommended N application rate is 320 lb/yr. However, N removal by 800 box/acre fruit would account for only 95 lb for 'Valencia' (Smith and Reuther, 1953) and 78 lb for 'Hamlin' (Alva, 1993, unpublished data) oranges. Therefore, it appears that a substantial portion of N applied is not accounted for by fruit production.

Recent developments in fertilizer formulation and application techniques could facilitate reduction of leaching loss of nitrate-N and minimize the contamination of ground and surface water. The use of controlled-release materials can reduce fertilization rate and frequencies (Ferguson et al., 1988; Koo, 1988). A single application of some controlled-release material was as effective in promoting growth of young trees as 5 to 6 applications of dry soluble fertilizer applied at higher rates (Ferguson et al., 1988).

Formulation chemistry of controlled-release fertilizer has improved considerably with the use of polyolefin resin coating of a soluble nutrient source. The release of nutrients in this formulation is controlled by moisture permeability of the resin coating, which is a function of soil water and temperature (Fujita et al., 1989).

The objectives of this study were to evaluate: (1) the growth response and leaf N concentration of young citrus trees to substantially reduced rates of N application using resin-coated fertilizer, and (2) to examine the differential leaching of nitrate-N below the root zone of trees receiving various N rates as resin-coated and dry-soluble fertilizers.

Material and Methods

These data were obtained from a large-scale field experiment (on a Candler fine sand in Polk County, Florida) designed to evaluate several controlled-release and dry soluble fertilizers for young citrus trees ('Pineapple' orange trees on Swingle citrumelo rootstock; planted in August 1990 at 25 × 10 ft spacing). For the purpose of simplicity and clarity of illustration of differences between the controlled-release and dry-soluble fertilizers in this paper, we have discussed the data for a resin-coated fertilizer (Meister; Helena Chemical Company, 17-6-12-1.5-2-6-0.03-0.2-0.02-0.45-0.2 of N-P_2O_5-K_2O-Ca-Mg-S-B-Cu-Fe-Mn-Zn; derived from coated urea, triple superphosphate, coated sulfate of potash, sulfate of potash-magnesia, sodium borate, copper sulfate, Fe-EDTA, manganese sulfate, zinc sulfate) and a dry-soluble fertilizer (similar nutrient ratio as in Meister, derived from ammonium nitrate, triple superphosphate, muriate of potash, sulfate of potash-magnesia and other micronutrient sources as in Meister) blend only. Meister used in this study was developed to release over 270 days. However, the extreme environmental conditions in Florida may affect the total duration for nutrient release from this formulation. Part of the results from this study are presented elsewhere (Alva and Tucker, 1993).

The resin-coated and dry-soluble fertilizer blends were applied at rates equivalent to 0.04, 0.08, 0.17 lb, and 0.17, 0.34 lb N/tree/yr, respectively, during 1991-92. The N rates were doubled during 1992-93. Although this experiment was designed to evaluate the effects of varying rates and sources of N on young tree growth, citrus trees require approximately 1:1 ratio of $N{:}K_2O$. Therefore, with various N rates, rates of P_2O_5 as well as K_2O also varied. The treatments are unbalanced, i.e., there was only 1 similar rate between the 2 sources. This was specifically designed to accommodate extreme low rates of resin-coated fertilizer and a rather high rate comparable to that of currently recommended rate of N (Koo et al., 1984) for 1- or 2-yr-old trees. The range of N rate recommended for 1-yr-old trees is 0.3 to 0.6 lb/tree/yr using dry soluble fertilizer source. The objective of this experiment was to examine the effects of moderate reductions in fertilizer rate using dry-soluble fertilizer and substantial reductions using resin-coated fertilizer source. The cost of the latter source is considerably greater than that of the former source. Therefore, from the economical standpoint, it was necessary to determine if extreme rate reductions of resin-coated material would be feasible and not compromise tree growth.

The dry-soluble fertilizer was applied in 4 equal doses in February, May, August, and October, while the resin-coated fertilizer was applied once during February of each year. During the first year, Meister was applied in a band of about 12 inches wide and 18 inches long on either side of the tree using a specially designed mechanical applicator (Helena Chemical Company). This applicator also incorporated the Meister about an inch deep in the soil. The dry-soluble fertilizer was applied using young tree fertilizer spreader (Conibear Equipment Co., Lakeland, FL). During the second year, both materials were applied using the young tree fertilizer spreader. Meister was incorporated in the soil manually. During both years, no attempt was made to incorporate dry-soluble fertilizers. The trees were irrigated using Maxijet Deflector Jet which delivers 10 GPH at 20 psi pressure. During the first year, irrigation was applied as needed for 5 hr twice a week. During the second week, irrigation was cut back to approximately once a week which ran for 3 to 5 hr with few exceptions. A completely randomized design was followed with 4 replicate plots of 12 trees each. Analysis of variance was calculated for the response data using statistical analysis system (SAS) and mean separation was calculated using least significant difference (LSD) between the means.

Five-mo-old spring flush leaves were sampled in August 1991 and 1992. The leaves were washed in detergent solution, rinsed in distilled water, soaked in 5% HCl for 20 sec, followed by 3 to 4 rinses in distilled water, and then dried at 70°C for 48 hr. The dried leaves were ground, and concentrations of N were determined by the Kjeldahl method.

Trunk diameter, tree height, and canopy width were measured once a year. The canopy volume was calculated by the following formula:

$$\textit{canopy volume} = \frac{4}{3} * 3.14 * \frac{\textit{Tree height}}{2} * \left(\frac{\textit{Canopy width}}{2}\right)^2.$$

Soil solution was collected at 5 ft below the soil surface. Two suction lysimeters constructed using porous ceramic cylinders (1 Bar, high flow; Soil Moisture Equipment Corp., Santa Barbara, CA) were installed per plot at 2 ft from the tree trunk. The ceramic cylinder was connected to a PVC pipe which extended above ground and also another capped piece which was below the porous cylinder which acted as solution collection cup. A tygon tube was inserted down to the bottom of the solution collection cup. The entire assembly was vacuum tight. The tygon tube was connected to a portable hand vacuum pump which enabled application of vacuum. Since it was a hand pump, the amount of vacuum is unknown. The tygon tube was clamped and removed from the vacuum pump. After 2 weeks with the vacuum pump assembly, the leachate collected at the collection cup was extracted. When all the leachate was extracted, additional vacuum was applied to facilitate collection of subsequent leachate. It is not known how long the vacuum was maintained in the suction lysimeter or the duration required for the leachate to be collected. The soil solution samples were taken at approximately 1 to 2 wk intervals and concentration of nitrate-N was determined by ion chromatography (DX 100, Dionex Corp.) (Pfaff et al., 1991).

During 1992-93 season, 40 to 50 fruits were taken from each plot to measure fruit weight, percent juice, % acid, and pound solids. Since this was the first year of fruit bearing, no attempt was made to record the fruit yield data. This is an on-going experiment, hence fruit yield will be measured during the subsequent years.

Results and Discussion

In treatments that received high rates of N, either as resin-coated or as soluble fertilizer, the concentration of N in the leaves were within the optimal N concentration (Obreza et al., 1992) during both years (Table 1). At reduced rates of N, the leaf N concentration tended to decrease slightly, but these differences were not significant. Despite substantial reduction in rate of N during both years, the concentration of N in the leaves did not fall in the deficient range (< 2.2%; Obreza et al., 1992).

Willis et al. (1990) evaluated the effects of various N rates (0.13, 0.24, and 0.50 lb N/tree/yr) on leaf N concentrations of 'Hamlin' orange trees on Carrizo citrange rootstock, 8 months after planting. Application of the above rates of N as dry-soluble fertilizer (5 applications/yr) decreased the leaf N concentrations from 3.6 to 2.7 with decrease in N rates from 0.50 to 0.13 lb N/tree/yr. For the corresponding N rates using fertigation, the changes in leaf N concentrations were 3.4 to 3.3 and 3.2 to 3.0 for 10 and 30 split applications/yr, respectively. Although all of the above N concentrations were above the critical optimal N concentration (Koo et al., 1984), the results suggested that the effect of decreased N rate application was less marked when the frequency of application was increased.

The leaf analysis results also showed very little effect of these treatments on the concentration of P and K in the leaves. The concentrations of P in the leaves were within the optimal range (0.12-0.17%) during both years regardless of fertilizer source or the rates. This was also true for leaf K status only during the first year. During the second year, however, the leaf K concentrations were in the deficient range (< 0.7%) in all treatments. Leaf Ca concentrations were within the optimal range (3.0-4.0%), while leaf Mg concentrations were in the low range (0.20-0.29%).

Table 1. Effects of N sources and rates on concentrations of N, P, K, Ca, and Mg in 5-mo-old spring flush of 'Pineapple' orange on Swingle citrumelo rootstock during the first and second year of planting.

Nitrogen source	Nitrogen rate lb N/tree/yr	Concentrations in spring flush (%)				
		N	P	K	Ca	Mg
		1991-92				
Resin coated	0.04	2.44	0.18	1.22	3.25	0.27
	0.08	2.32	0.22	1.29	3.11	0.26
	0.17	2.57	0.20	1.21	3.17	0.30
Dry soluble	0.17	2.44	0.21	1.17	3.17	0.25
	0.34	2.58	0.20	1.18	2.97	0.26
LSD (P=0.05)		0.45	0.06	0.22	0.31	0.11
		1992-93				
Resin coated	0.08	2.47	0.21	0.59	3.75	0.28
	0.17	2.35	0.24	0.70	3.92	0.25
	0.34	2.60	0.19	0.67	3.70	0.27
Dry soluble	0.34	2.34	0.18	0.63	3.90	0.25
	0.68	2.51	0.18	0.59	4.36	0.24
LSD (P=0.05)		0.40	0.06	0.21	0.52	0.10

There was no significant difference in tree growth parameters (tree height, trunk cross-section, and canopy volume) either due to fertilizer formulations or fertilizer rates (Table 2). The tree growth parameters did not show any significant reduction due to reduced rate of fertilizer application. The lack of response to reduced N application during the first year after planting was also reported in earlier studies (Ferguson et al., 1988; Obreza, 1990; Willis and Davis, 1991). In the study of Obreza (1990), young citrus trees were grown on a newly developed pasture land. The study showed very little difference in tree growth between fertilizer applied and the control treatments that received no inorganic source of N. Therefore, it appeared that mineralization of soil organic N was adequate to supply N requirement of the trees during the first year. In the current study, however, the new planting was done on an old grove site with a trunk to trunk herbicide program. Grove soils under this condition contain very little organic matter. Therefore, potential for mineralization of organic N was very minimal in the current study.

A recent survey by Castle and Rouse (1990) revealed that some citrus nurseries are under high N fertilization program. Therefore, the N content in the trees prior to planting was possibly very high. The N reserve in the trees could support the tree growth during the first year after planting if the trees are grown under low N fertilization programs. In the current study, the N content of the trees at planting is not known. However, it is unlikely that N reserve in the nursery trees can last for 2 yr. Therefore, we could conclude that the N requirement for young trees can be decreased substantially as compared to what is currently being recommend (Koo et al., 1984).

Fruit samples were analyzed for juice quality parameters during the second year of the study. Nitrogen nutrition has been reported to have positive effects on juice content, soluble solids, and percent acid content in the juice (Koo, 1982). However, in the current study, the rate or formulation of N had minimal effects on fruit weight, acid, or brix content (Table 3). Since this was the first year's fruit, the results of effects of N on juice quality should be interpreted with caution. The most valuable response parameter is fruit production, which will be evaluated during subsequent years.

Figure 1 shows the concentration of nitrate in the leachate sampled at 5 ft depth for the high and low N rate treatments of the coated and soluble fertilizers. During the first year of planting, the leachate sampling begun 55 days

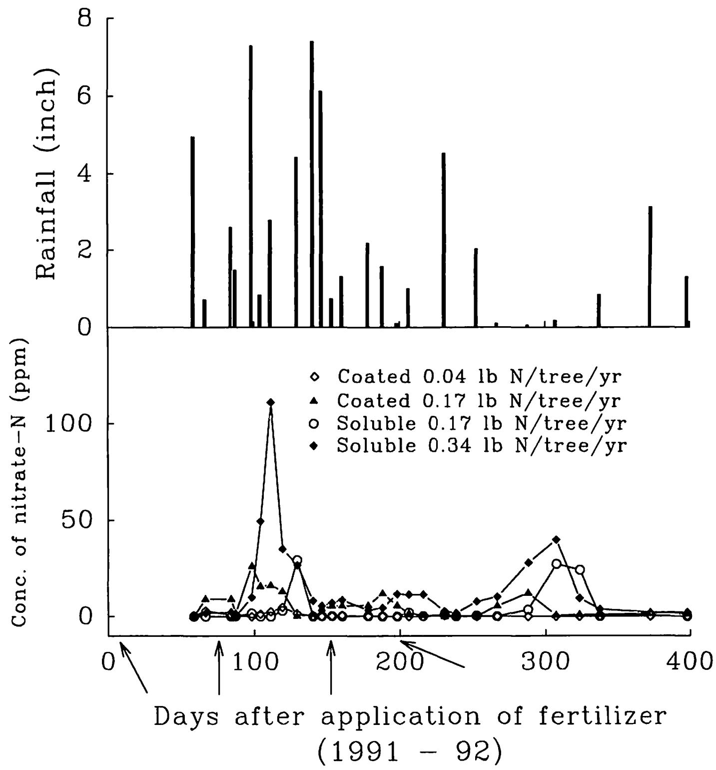

Fig. 1. Concentration of nitrate in leachate collected at 5 ft below ground level near citrus trees on a Candler fine sand treated with various rates of N as dry soluble fertilizer or as resin coated fertilizer during 1991-92. Cumulative rainfall data between leachate sampling dates are also shown. Arrows along x-axis indicate the days of fertilizer application.

Table 2. Effects of N sources and rates on tree growth of one and two year old trees of 'Pineapple' orange on Swingle citrumelo rootstock.

Nitrogen source	Nitrogen rate	Tree height	Trunk cross section area	Canopy volume
	lb N/tree/yr	ft	in^2	ft^3
		1991-92		
Resin coated	0.04	4.7	1.37	35.6
	0.08	4.5	1.47	35.9
	0.17	4.4	1.47	40.0
Dry soluble	0.17	4.2	1.37	35.0
	0.34	4.0	1.53	27.7
LSD (P=0.05)		0.6	0.19	14.1
		1992-93		
Resin coated	0.08	5.6	1.91	105.0
	0.17	5.4	1.94	102.0
	0.34	5.4	2.01	97.1
Dry soluble	0.34	5.2	1.96	95.0
	0.68	5.0	1.96	93.2
LSD (P=0.05)		0.6	0.15	12.2

Table 3. Effects of N sources and rates on fruit weight and juice quality of 'Pineapple' orange trees on Swingle citrumelo rootstock (1992-93).

Fertilizer source	N rate lb/tree/yr	Fruit wt. lb/fruit	Percent juice	Acid	Brix	Ratio	Solids lb/box
Resin coated	0.08	0.33	57.3	0.64	11.3	17.65	5.83
	0.17	0.35	57.9	0.66	11.5	17.42	5.99
	0.34	0.33	57.0	0.63	11.5	18.25	5.90
Dry soluble	0.34	0.34	61.0	0.64	11.3	17.66	6.20
	0.68	0.33	59.5	0.70	11.4	16.29	6.10
LSD (P=0.05)		0.03	4.4	0.09	0.80	2.60	0.76

after application of first dose of fertilizer. Cumulative rainfall data between each sampling date are also shown in the figure. Generally, the concentration of nitrate in the leachate was high in the treatments which received soluble fertilizer at high rates. These elevated peaks followed each event of fertilizer application and also the nitrate peaks were proportional to the rainfall following fertilizer application. The leachate analysis data during the second year support the above conclusions (data not presented). The *leachate was collected* at 5 ft below ground, therefore, the nitrate in the leachate at this depth cannot be utilized efficiently by the tree roots. The deep sandy soils are typically well drained throughout the vadose zone. This precludes any potential for denitrification of nitrate-N. As a result, nitrate in the leachate can potentially transport to the groundwater resulting in nitrate contamination. Additional studies are in progress to evaluate the nitrate leaching into groundwater under mature tree conditions with variety of production practices.

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THE INFLUENCE OF CULTIVAR AND HIGH NITROGEN AND POTASSIUM FERTILIZATION ON FRUIT QUALITY TRAITS OF YOUNG ORANGE TREES

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Additional index words. Citrus, Hamlin, navel, Valencia, Ambersweet, granulation, peel thickness, solids, acidity.

Abstract. **The 1992 Commercial Citrus Tree Inventory showed that 32% of the orange trees in Florida are nonbearing. Substantial increases in plantings of 'Hamlin', navel, and 'Valencia' orange trees began in 1986 and planting of 'Ambersweet' began in 1990. During the past several years, some growers have shifted emphasis from processed orange products to fresh fruit. Young orange trees usually produce poor quality fruit that improves as the trees become older. High levels of fertilization, especially nitrogen and potassium, are used with supplemental irrigation to attain maximum growth of young trees. High nutrition levels stimulate vigorous vegetative growth with correspondingly reduced fruit quality, especially with cultivars such as navel, 'Valencia', and 'Ambersweet' oranges. High nutrition rates in combination with frequent supplemental irrigation can extend the time that young orange trees produce poor quality fruit. Growers face cultural management decisions for young trees that must include cultivar as well as the age, desired vegetative growth, and associated quality and quantity of fruit produced and how it will be marketed. The quality of juice can be adjusted to some extent during processing but the quality of fruit marketed fresh is largely set at harvest.**

Introduction

The most recent tree inventory, 1992, shows that 32% of the orange trees in Florida are nonbearing, 3 years old or younger. Prior to 1950, trees 5 years old or younger were considered nonbearing, and from 1951 through 1988-1989 trees 4 years old or younger were considered nonbearing. The nonbearing age was reduced to 3 years beginning in 1989-1990 (Fla. Ag. Statistics Ser., 1992). From the early years of the Florida citrus industry until the 1950's, when concentrated orange juice became a major market product, the fruit were marketed mostly fresh. Fruit quality is most important in fresh fruit, and fruit from very young trees usually were not marketed

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