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A COMPARISON OF CONTROLLED-RELEASE TO CONVENTIONAL FERTILIZER ON MATURE 'MARSH' GRAPEFRUIT

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Abstract. **A four-year study was conducted to compare two rates of controlled-release (CR) fertilizer applications to conventional fertilizer with soluble granular applications. The study site was a block of 'Marsh' grapefruit on sour orange rootstock planted in 1973 in a bedded grove in St. Lucie County. Fertilization treatments consisted of annual applications of: 1.3 lb tree^{-1} of 20-3-17 Osmocote CR fertilizer (20 lb N ac^{-1}), 2.3 lb tree^{-1} of 20-3-17 Osmocote (36 lb N ac^{-1}), and split applications of 10-4-12 granular soluble fertilizer (134 lb N ac^{-1}). The soluble fertilizer was applied each year in equal applications in the spring and fall. The CR fertilizer was applied in a single application in the spring of each year. Leaf nutrient analysis showed higher N in the conventionally-fertilized plots in two out of the four years (P = 0.05). Only minor differences were noted in juice quality parameters and fruit yield between treatments, even though there was a large difference in the quantity of N applied.**

Citrus growers are continually looking for ways to reduce production costs while still maintaining profitable production. In recent years, controlled-release (CR) fertilizers have become more widely used on young trees. Although the cost per unit nitrogen (N) in CR fertilizers is considerably higher than that for the conventional soluble forms of N, the reduced leaching potential and the relatively constant rate of N release over time makes the CR materials desirable for citrus production.

Studies have shown that young trees can have equivalent growth using less N per tree with CR fertilizers compared to traditional fertilization with soluble fertilizers. Reduced rates of CR fertilizer can achieve equivalent growth to traditional soluble fertilizers on young 'Hamlin' orange trees (Ferguson et al., 1988; Marler et al., 1987; Obreza and Rouse, 1991). Zekri and Koo (1992) reported enhanced growth on young 'Valencia' orange trees using CR fertilizers compared to conventional fertilization. The labor savings afforded by a single annual application of CR fertilizers have made it very attractive for use on young trees, especially for use on trees reset into a mature grove.

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CR fertilizers or a combination of CR and soluble fertilizers can offer an effective and economic program for young trees. Research on the utilization of CR fertilizers on mature citrus, however, is lacking. The objective of this study was to compare CR fertilizer applications at substantially reduced rates to traditional fertilization practices on a mature Flatwoods grapefruit grove.

Materials and Methods

A field experiment was initiated in the spring of 1989 on a block of 'Marsh' grapefruit trees on sour orange rootstock located about 4 miles south of White City in St. Lucie County, Florida. The experiment was conducted as a randomized complete block design with 3 fertilization treatments, each replicated 5 times.

The block was planted in 1973 on a Wabasso sand series soil (sandy, siliceous, hyperthermic, Alfic Haplaquods). Trees were planted at a density averaging 80 trees acre^{-1}. One replication of the treatments was on single-row beds (20 trees per plot), three were double-row beds (20 trees per plot), and the other replication was on triple-row beds (30 trees per plot). Within-row tree spacing was 15 ft, and across-row spacing was 26 ft on the single- and double-row beds, and 22 ft on the triple-row beds. The across-water-furrow distance between rows was 28 ft on the multi-row beds.

Prior to the experiment, the trees in the block had been fertilized with split spring/fall applications totaling about 130-150 lb N acre^{-1} with soluble granular material. This traditional treatment (TRAD) was continued in the experiment with fertilizers derived from ammonium nitrate, diammonium phosphate, and muriate of potash. The TRAD applications were made each year in April or May and again in October or November (Table 1).

CR treatments of 20 lb N acre^{-1} (CR-20) and 36 lb N acre^{-1} (CR-36) of Osmocote fertilizer (Grace-Sierra Company) were applied during the spring of each year. These rates represent about 15% (CR-20) and 27% (CR-36) of the TRAD rates of N applied. The N-P-K analysis of the CR material applied varied over the 4-year study (Table 1) since the original 20-3-18 analysis product was discontinued. However, the amount of N applied per unit area remained constant within each CR treatment over the study period.

Fertilizer was broadcast between tree rows on the multi-row beds and a shield was used to direct the material onto the bed tops (tree rows) on the single-row beds. The required quantity of fertilizer for each plot was weighed out, and broadcast uniformly throughout the plot with a small spreader mounted on an ATV.

All other cultural operations including herbicide, fungicide, and insecticidal spray materials were uniform

Table 1. Fertilizer application dates and amounts.

Treatment	Application date	Fertilizer analysis (N-P-K)	Fertilizer applied (lb/tree)	N applied (lb/acre)
1989				
CR-20	5 April	20-3-18	1.3	20
CR-36	5 April	20-3-18	2.2	36
TRAD	5 April	12-2-12	8.0	77
	25 Oct.	10-4-12	8.0	64
1990				
CR-20	14 May	20-3-18	1.3	20
CR-36	14 May	20-3-18	2.3	36
TRAD	14 May	10-4-12	8.8	70
	15 Nov.	10-4-12	8.0	64
1991				
CR-20	3 May	16-6-9	1.6	20
CR-36	3 May	16-6-9	2.8	36
TRAD	3 May	10-4-12	8.8	70
	27 Oct.	10-4-12	8.0	64
1992				
CR-20	14 April	16-5-16	1.6	20
CR-36	14 April	16-5-16	2.8	36
TRAD	14 April	10-4-12	8.8	70
	1 Oct.	10-4-12	8.0	64

throughout the block. Trees in the block were hedged in February 1991, with up to 24 inches of growth removed. Irrigation was applied when required with 15-ft diameter coverage emitters, one per tree. The water source was a Floridan Aquifer well.

Soil samples were taken from several areas throughout each plot in October 1989. The composite samples from each plot were analyzed by the University of Florida Analytical Research Lab in Gainesville for common soil minerals (Table 2). No statistical differences were noted for any of the parameters among the treatments (P=0.05). The pH of the soil in the top foot within the block averaged 5.5.

Leaf samples were collected for mineral analysis during August or September of each year following IFAS guidelines (Koo et al., 1985). Leaf analysis was conducted using standard procedures by Pioneer Lab in 1989, 1992 (except N), and 1993; and by the University of Florida Analytical Research Lab in 1990, 1991, and 1992 (N only).

Samples consisting of 40 fruit from each plot were collected during the first week of December in each year. The juice of these fruit was analyzed by the Florida Department of Citrus Lab in Lake Alfred. The grove was commercially picked 13 March 1990, 24 February 1992, and 28 May 1993. The trees were not picked during the 1990/91 season, and the fruit dropped from the trees and rotted on the ground. Yields for each plot were measured volumetrically from four representative trees in each plot during the 1989/90 season and from two trees in each plot during the other seasons.

Table 2. Mean soil mineral content by fertilization treatment (sampled 13 October 1989, n=5).

Treatment	Ca ppm	Mg ppm	K ppm	P ppm	Na ppm	pH
CR-20	780	85	53	18	11	5.5
CR-36	666	56	42	17	10	5.3
TRAD	720	96	54	25	10	5.6

On 23 January 1993, ten pieces of size-36 fruit were randomly selected from each plot. The fruit were cut in half, and the peel thickness was measured in each quadrant with a caliper. These measurements were averaged for each fruit.

Results were analyzed by standard analysis of variance techniques using Statistical Analysis System computer software (SAS, 1985). Treatment mean separation was determined using Duncan's Multiple Range Test (Duncan, 1955) with a 95% confidence level (P=0.05).

Results

Climatic factors affecting production

The 1989 rainfall of 37 inches was much below the long-term average of about 52 inches in the Ft. Pierce area (Table 3). The only significant period of extended plentiful rainfall was in October. A very dry spring in 1990 followed. The last half of 1990 received above normal rain, resulting in a total of 44 inches for the year. Rainfall was adequate through most of the 1991/92 and 1992/93 seasons, with 67 inches in 1991 and 57 inches in 1992. Only minimal irrigation was required throughout most of the year in either of these 2 seasons.

Cold temperatures on 24 February 1989 destroyed much of the fruit set potential for the year since trees had broken dormancy early and had set blooms. The 27°F minimum temperature, which had come amid unseasonably warm temperatures, reduced typical grapefruit yields in the area by 50% or more. During the severe Christmas 1989 freeze, the temperature dropped to 22°F on the morning of 24 December. Damage to the grapefruit trees was confined to dropping about one quarter of their leaves and some die back of smaller twigs. However, the fruit had not been harvested from the trees prior to the freeze and about one-third of the fruit subsequently fell to the ground.

Strong winds associated with the 13 March 1993 "Storm of the Century" resulted in a significant fruit drop from trees in the block. About 1-2 boxes of fruit were estimated to have dropped from each tree.

Production and Juice Quality

Leaf N was above normal (>3.0%) for all treatments in 1990 while all were very low (<2.0%) during 1991 (Table

Table 3. Ft. Pierce AREC monthly rainfall (inches).

Month	1989	1990	1991	1992	1993
Jan	2.2	1.0	6.6	1.5	8.2
Feb	0.2	1.5	4.2	2.6	3.5
Mar	2.6	1.3	4.1	1.8	7.4
Apr	4.3	0.9	6.1	2.6	1.6
May	2.8	3.0	5.8	1.0	4.6
Jun	2.3	4.2	5.6	17.6	—
Jul	2.3	9.5	13.9	3.5	—
Aug	5.7	5.1	8.1	6.5	—
Sep	5.2	10.3	6.1	5.8	—
Oct	5.0	3.6	4.5	3.7	—
Nov	1.1	2.7	0.9	8.1	—
Dec	3.5	0.2	1.3	1.9	—
Total	37.2	43.5	67.2	56.6	25.3[z]

[z]The total for 1993 is only for the January-May period when data was collected from the experiment.

4). Leaf N was significantly higher in the TRAD trees as compared to the CR-20 trees in 2 out of 5 years. The 5-year average leaf N content was 2.6% for both of the CR treatments and slightly higher at 2.8% for the TRAD plots. Significant (P=0.05) differences in leaf P levels were noted in the 1989/90 season, but not in subsequent years. Leaf K, Ca, and Mg contents were not different among treatments in any of the years.

Juice quality was generally unaffected by the fertilizer treatments (Table 5). During the 1991/92 and 1992/93 seasons, trees under the TRAD treatment had higher Brix content than the CR treatments. In the 1992/93 season, the TRAD plots also had a higher Brix:acid ratio. During the 1991/92 season, the higher Brix content of the TRAD juice was offset by higher acid content, resulting in no difference in the Brix:acid ratio as compared to the CR plots.

The 4-year average fruit weight ranged from 460 g for the CR-20 treatment to 430 g for the TRAD treatment trees, with the CR-36 average of 446 g midway between these weights. This fruit size relationship is probably due to the slight differences in amount of fruit produced by each fertilizer treatment. No differences between treatments were noted in the 4-year average juice content, which averaged 59%.

Significant (P=0.05) yield differences were only noted in the 1989/90 season, when the CR-20 yields were less than the other treatments. However, yields for all treatments were quite low due to lack of fruit set associated with the sub-freezing temperatures on 24 February which killed the advanced bloom that was present. Highest production occurred during the 1991/92 season when rainfall was adequate throughout most of the year. Three-year average yields were 351 boxes acre^{-1} for the CR-20, 383 boxes acre^{-1} for the CR-36, and 391 boxes acre^{-1} in the TRAD plots.

Both CR treatments had similar solids per box for each season. The TRAD treatment trees had higher solids per box during the 1991/92 season as compared to the other treatments. Four-year average solids were 5.8 lb box^{-1} for CR treatments and 6.2 lb box^{-1} for the TRAD treatment.

Peel thickness, measured only in January 1993, was significantly greater (P=0.05) on fruit of trees receiving TRAD fertilizer as compared to CR-20 and CR-36 plots. Mean peel thickness was 6.8 mm for TRAD, 6.4 mm for CR-36, and 6.3 mm for CR-20 treatments.

Table 4. Leaf tissue nutrient content means by treatments for leaves sampled in August/September each year (n=5).

ID	N %	P %	K %	Ca %	Mg %
1989/90					
CR-20	2.8	0.18a[z]	1.7	4.4	—
CR-36	2.7	0.17a	1.8	3.9	—
TRAD	2.8	0.15b	1.6	4.3	—
1990/91					
CR-20	3.1b	0.13	1.4	4.0	0.34
CR-36	3.3ab	0.13	1.3	4.1	0.37
TRAD	3.6a	0.14	1.4	3.9	0.34
1991/92					
CR-20	1.9	0.10	0.83	3.5	0.30
CR-36	1.8	0.10	0.90	3.5	0.28
TRAD	1.9	0.11	0.78	3.6	0.28
1992/93					
CR-20	2.4b	0.14	1.5	3.8	0.36
CR-36	2.5b	0.14	1.5	3.5	0.33
TRAD	2.8a	0.14	1.4	3.7	0.35
1993/94					
CR-20	2.8	0.06	0.71	1.6	0.17
CR-36	2.6	0.07	0.66	1.7	0.16
TRAD	2.9	0.06	0.69	1.6	0.17

[z]Means within columns followed by the same letter for the same year are not significantly different (P=0.05) according to the Duncan's Multiple Range Test.

Discussion

Differences in visual appearance of the trees were not apparent throughout most of the year. However, during the last two years of the study, there appeared to be lighter leaf color on the CR treatment trees late in the year. The fall flush on the CR treatment trees tended to have smaller leaves which were paler in color compared to the TRAD plots. This difference was especially noted on the CR-20 plots in the late October and early November time period. When the fall flush on these trees hardened off, the differences in appearance between treatments were not visually noticeable and no long-term adverse effects were noted.

The material and application costs of fertilizer and the expected resultant production affect decisions concerning fertilization. Charges for spreading the TRAD material would be expected to be about $8 acre^{-1} for each application (Muraro, 1993). The cost to spread CR fertilizer would be lower since only about ¼ as much material would be required per acre. Assuming a $6 acre^{-1} charge for the CR treatments, there would be an advantage of about $10 acre^{-1} for the trees fertilized once per year with the CR material compared to the two applications of the TRAD treatment.

Bulk fertilizer cost is presently about $125 ton^{-1} for the 10-4-12 and $1275 ton^{-1} for the 16-5-16 Osmocote (B. Cofer, Diamond R Fertilizer Co., personal communication). Therefore, annual fertilization costs (material plus application) for the fertilizer treatments used in this experiment would be about $100 acre^{-1} for TRAD treatments, $88 for CR-20, and $149 for the CR-36. For the 375 box ac^{-1} yr^{-1} production level of the experimental block, any of the 3 fertilizer programs would be adequate based only on non-significant differences in boxes produced.

Even though the drastically reduced N application rates in the CR treatments did not result in any appreciable differences in production during the 4 years of this study, they may eventually develop. Fudge (1939) reported that 'Marsh' grapefruit on rough lemon rootstock removed about 2.12 lb N with each ton of fruit. Using this N removal rate, the annual N application rate of 20 lb acre^{-1} in the CR-20 was only 63% of 32 lb N ac^{-1} removed with its average production of 351 box ac^{-1}. The 36 lb ac^{-1} of N applied on the CR-36 trees, which had an average yield of 383 box ac^{-1}, would remove about 35 lb N ac^{-1} yr^{-1}. Use of N for leaf replacement and tree regrowth as well as losses of the applied N due to leaching, volatilization, or improper placement would probably result in reduced yield or N deficiency symptoms eventually developing in the CR plots. In contrast, the nitrogen removed for the TRAD average yield of 393 box ac^{-1} would be slightly more than 35 lb N ac^{-1}, or 26% of the applied N rate.

If a single application per year fertilization program is desired, a blended combination CR and soluble materials would probably be a better option than CR alone. The cost

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**