SL-243

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Advancements with Controlled-Release Fertilizers for Florida Citrus Production: 1996 -2006[1]

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Introduction

Advances in fertilizer technology have resulted in a series of products that slowly release nutrients into the root zone using a number of different strategies. The intent is to minimize the amount of fertilizer nutrient that is exposed to potential loss from the root zone and to maximize the amount that is taken up by the plant. Controlled-release fertilizers (CRF) may have a place in cropping systems in Florida, especially in perennial crops such as citrus.

This document addresses citrus nutrition and its relationship to controlled-release fertilizers. The objectives are:

1. To describe CRF sources and their potential beneficial uses in citrus production;
2. To report the findings from a series of experiments in commercial citrus groves using both traditional and CRF sources relating to observed effects on tree growth and fruit yield.

The target audience for this document dealing with citrus nutrition and CRF sources includes Certified Crop Advisers, fertilizer dealers, citrus producers, and other parties interested in citrus fertilization practices.

Overview of Florida's citrus industry

In 2004, Florida's citrus industry consisted of more than 97 million trees on 748,555 acres (Figure 1). The industry produced 12.6 million tons of fruit with a farm gate value of $746 million. Florida's citrus industry comprised 73% of the total citrus production in the United States, and 18% of world production.

The citrus industry is a valuable, relatively environmentally friendly neighbor to Florida's growing population (Figure 2). Much of Florida's citrus is grown on prime land for urban expansion. This fact, coupled with additional pressures from the spread of diseases such as citrus canker and citrus greening, is prompting the industry to improve production efficiency, including an effective means of supplying nutrients with proper timing to satisfy crop nutrient requirements while avoiding inappropriate environmental consequences.

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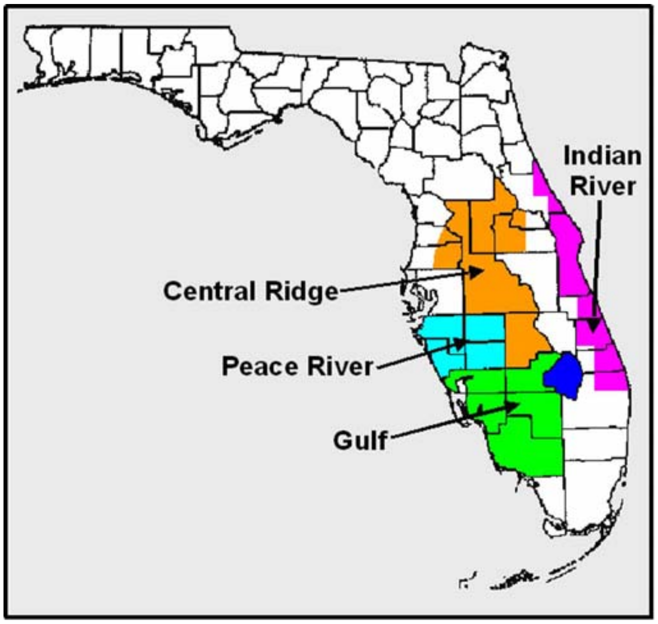

Figure 1. Citrus production areas of Florida.

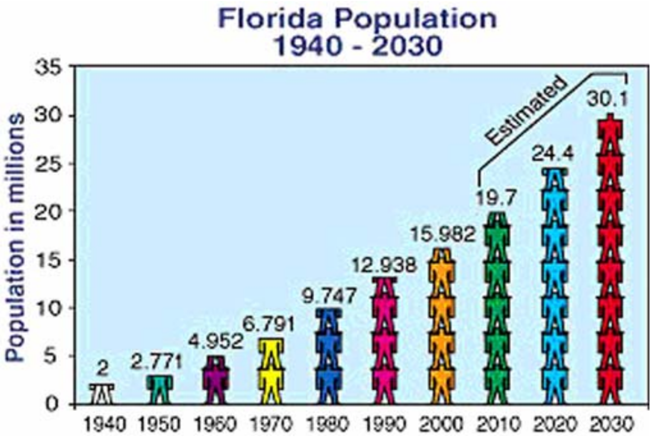

Figure 2. Florida human population growth from 1940 to 2000 and projected through 2030.

Soils in Florida's Citrus Growing Areas and Related Environmental Issues

Ridge soils

Florida's Lake Wales ridge, running generally north and south through the center of the peninsula, is characterized by deep, well drained soils comprised mostly of sand (Figure 3). These soils permit rapid infiltration of rain and irrigation water, setting the scene for nutrient movement out of the citrus root zone. When nutrients are leached downward, they are no longer available to the plant, and may become an environmental concern.

Evidence supporting this concern is reflected in water quality measurements on the ridge. Of 3,949 statewide drinking water wells surveyed by the Florida Department of Agriculture and Consumer Services in the late 1980s, 584 wells (15% of all tested wells) contained nitrate-nitrogen concentrations greater than the regulatory maximum of 10 mg nitrate-nitrogen per liter. The majority of these wells (520) were located in Lake, Polk, and Highlands counties (Figure 3). Although it has never been proven that groundwater nitrate contamination beneath the Lake Wales ridge was caused by citrus fertilization, groves within these three counties are receiving considerable scrutiny because of the deep, well drained soils on which they have been planted.

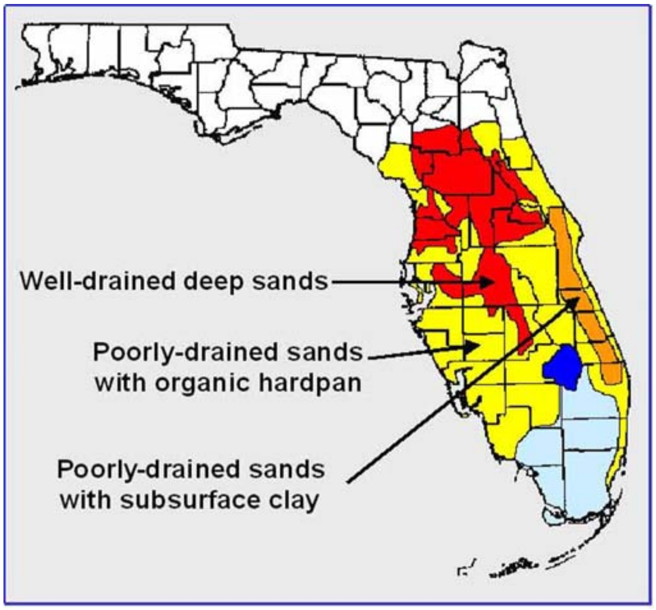

Figure 3. Soils in citrus production areas of Florida.

Flatwoods Soils

The so-called flatwoods soils are located on both the east and west sides of the Florida peninsula (Figure 3). These soils are characterized by poorly drained conditions, often requiring bedding and other field drainage structures to permit economical yields and quality citrus fruit juice. The striking differences in drainage and depth to a water table between ridge soils and flatwoods create entirely different conditions for the fate of soluble nitrogen fertilizers. While the potential for nitrate leaching does exist in these soils, conditions in these regions often reduce this potential substantially. “Nitrate concentrations were below the drinking-water standard (10 mg/L) in

108 south Florida wells (Biscayne and other surficial aquifers), except for two shallow wells in the unnamed surficial aquifer of the citrus area.” (McPherson et al., 2000). Low nitrate-N concentrations found in well water beneath the flatwoods were most likely due to:

1) Denitrification in the shallow water table a few feet below the soil surface; and 2) Drainage water most likely ending up in surface water bodies as opposed to groundwater due to intensive artificial surface drainage of agricultural land.

General citrus nutrient management

Fertilizers are important for commercially viable citrus production in both the ridge and flatwoods areas. By far, nitrogen is the most used nutrient in citrus production (Table 1) based upon Florida fertilizer use in the 2002-through-2003 production season. However, Florida's citrus industry consumes a relatively small amount of the total fertilizer sales in the United States (Table 1), utilizing a number of different nitrogen-containing fertilizer sources to satisfy the crop nutrient requirements for commercial citrus production. Traditional water-soluble nitrogen sources are made up of dry granular fertilizers and solution fertilizers. Dry granular fertilizers include the two most popular sources: ammonium nitrate and ammonium sulfate. Urea is by far the most popular solution fertilizer.

Controlled-release fertilizers (CRF)

Controlled-release fertilizers are relative newcomers, both to national and Florida fertilizer markets. An older, but synonymous term for these types of fertilizers is slow-release fertilizers. While some of these compounds have been available since the 1950s, most of the advances have been made in the 1980s and 1990s. The first CRF sources to become commercially available were strictly nitrogen sources. The CRF technology has expanded to include potassium, phosphorus, and other nutrients including micronutrients (known as such because they are required by the plant in small amounts).

Slow-and controlled-release fertilizers employ several mechanisms to reduce the amount of nutrient that is available from the fertilizer at any one time.

Isobutylidene diurea (**IBDU**), which contains 31% nitrogen, was developed in the 1970s. This compound undergoes hydrolysis, splitting the IBDU molecule, to form urea. This hydrolysis process does not require microbial decomposition.

Sulfur-coated urea (**SCU**, 30 to 40% nitrogen) is designed to allow water from the soil solution to penetrate the sulfur coating, slowly dissolving the encapsulated urea. Some SCU sources contain a wax sealant to further retard urea release; however, microbes are required to degrade this wax sealant. Additionally, a number of earlier CRF products (methylene urea, nitroform, and ureaform) require microbial decomposition to provide nitrogen for plant uptake.

Other CRF products use **polymer-coated** nitrogen sources, and go by brand names such as Osmocote, Meister, Multicoat, and Polyon. These products all contain a semi-permeable membrane surrounding the water-soluble fertilizer. Water passes through the outer membrane dissolving the fertilizer, which, in turn, diffuses into the soil solution and subsequently is taken up by the plant.

Examples of current CRF uses are found that relate to tree age. Young-tree fertilizers often contain IBDU or methylene urea in combination with additional water-soluble nitrogen. Bearing-tree fertilizer blends may contain some SCU to extend the period within which nitrogen is available to the trees. In some citrus-growing areas, polymer-coated materials are added to the planting hole during reset operations.

Current Nitrogen Recommendations for Citrus

Recently, a nitrogen rate Best Management Practice (BMP) has been established for citrus production in Florida (Table 2). These fertilizer application rates are based on field studies that contain a water-quality and a yield component, most of which have used traditional dry or solution nitrogen fertilizer sources.

Reasons (for and against) Use of Controlled-release Fertilizers

Positive Aspects of CRF Use

Managers should be interested in CRF products because of their potential efficiency in delivering nutrients. The citrus industry as a whole has shown a preference for the use and application of dry fertilizer sources. Most CRF products are also produced as a dry product, and would fit into current fertilizer application methods. These products have demonstrated higher nitrogen fertilizer efficiency compared with more soluble fertilizer sources resulting in equal or better citrus production, sometimes at a lower nitrogen rate. Because of the persistence (controlled release), the number of fertilizer applications is reduced compared with traditional fertilizer sources. This advantage is especially important when the grove manager must fertilize a considerable number of re-plants within the grove. In addition to the environmental advantage of maintaining nutrients within the root zone, there may eventually be a cost-sharing BMP to encourage the use of CRF sources.

Negative Aspects of CRF Use

As with any new technology, the cost per ton of CRF products is higher than traditional water-soluble fertilizer sources. This apparent disadvantage is offset somewhat by the potential for adding less CRF material to satisfy the crop nutrient requirements, as well as the potential BMP cost-sharing mentioned above. Because the body of research is small concerning CRF sources, grove managers are justified in questioning CRF performance, compared with traditional fertilizer sources. Many CRF sources need only be applied once per year, which is unheard of in the citrus industry. The common practice is three to four applications per year of standard soluble fertilizers. A common question about CRF products is: “Can I really apply fertilizer only once or twice a year and provide all of the necessary nutrition required for maximum production?” To address that important question, a series of experiments were conducted in commercial citrus groves using both traditional and CRF sources.

Experiments with CRF on Citrus in Central Florida

In 1996 (Wang and Alva, 1996), several CRF sources were tested in a simulated rainfall experiment, applying 40 inches of water in a 30-day period (Table 3). Findings indicated that for both a ridge Entisol and a flatwoods Spodosol, both CRF sources reduced nitrogen leaching considerably compared with the traditional ammonium nitrate source.

Selected CRF products were tested in 1998 on 20-year-old Hamlin/Cleo citrus in Highlands county (Alva and Paramavisam, 1998). The CRF source (added once per year) compared favorably with either the dry granular or the fertigation sources when rates were similar (Figure 4). In this study, the expected benefits of lower CRF rates were not demonstrated. However, the CRF source showed an advantage when considering the number of applications in the growing season.

The amount of nitrogen leached below the root zone was studied in groves in 2001 (Paramasivam et al., 2001). Higher leaching of N applied by fertigation compared with dry granular fertilizer was explained by multiple instances of high rainfall events immediately following fertigations (Table 4). Much less nitrogen was leached from the CRF source compared with either the dry granular fertilizer or the fertigation practice. This finding indicates that the CRF source was effective in maintaining nitrogen within the root zone and/or it incurred more N losses by volatilization.

Controlled-release Experiments in southwest Florida

To further address CRF effects on citrus production and nitrogen fertilizer efficiency, three experiments were conducted in southwest Florida. The objectives of these experiments were to evaluate citrus tree growth and yield response to fertilizer programs containing both water-soluble nitrogen and controlled-release nitrogen, and to analyze the economics of using controlled-release fertilizers for citrus.

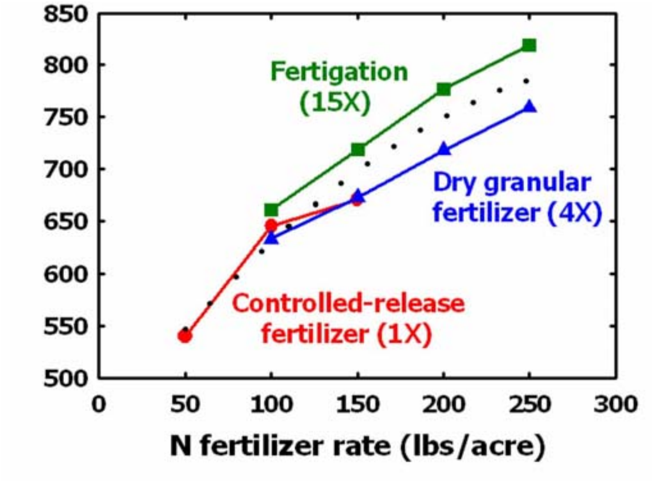

Figure 4. Orange yield (Hamlin) with nitrogen fertilizer rate from CRF applied once per year, dry granular applied in four equal amounts per year, and fertigation applied in 15 equal increments per year.

These experiments were conducted using young, healthy, irrigated, solid-set blocks of orange trees in commercial groves. Fertilizers, regardless of source, were hand applied to 3- to 5-trees per plot. Both orange yield and juice quality were measured, and used to calculate the pounds solids (sugars) yield per tree. Regression analyses included the generation of a quadratic plateau yield-response model to estimate the critical nitrogen application rate. The critical nitrogen application rate was defined as that rate above which citrus yield did not increase. In other words, adding additional nitrogen above the critical rate did not increase yields, but did increase cost of production. The cost of using CRF was compared with the traditional water soluble nitrogen program costs.

Experiment 1

In Experiment 1, Hamlin orange trees on Carrizo citrange rootstock were planted on a flatwoods soil in 1989 at 194 trees per acre. This grove received sub-surface irrigation. Water-soluble phosphorus and potassium fertilizers were applied at the same time as the nitrogen. A randomized complete block design using four trees per plot was used for 4 years (1992 through 1995), and juice quality and yield data were collected. Treatments (Table 5) included blends of ammonium nitrate, IBDU, and/or methylene urea. Rates were 0, 40, 80, 160, and 280 pounds of nitrogen per acre.

Statistical analyses identified a mathematical nitrogen response between 230 and 250 pounds of nitrogen per acre; however, a practical response was found at approximately 200 pounds of nitrogen per acre (Figure 5). Up to that point, additional rate increased the boxes of fruit per acre, which in turn increased the pounds solids (sugars in the juice) per tree. There was a slight production advantage for the ammonium nitrate/IBDU combination compared with either ammonium nitrate alone or the ammonium nitrate/methylene urea combination. Perhaps the most significant finding was that CRF-containing materials resulted in similar nitrogen responses, but with approximately half the number of applications. Reducing the number of applications also reduces production costs.

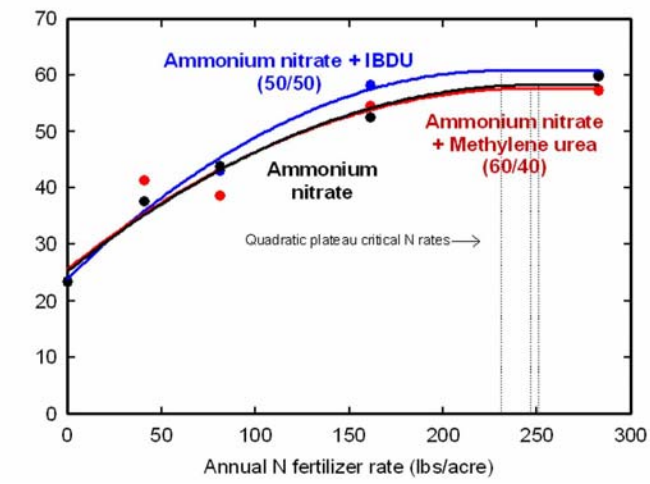

Figure 5. Mixtures of ammonium nitrate and either IBDU or Methylene urea rates used to produce 4-year cumulative pound-solids per tree.

Experiment 2

This experiment used valencia orange trees on Swingle citrumelo rootstock planted on a flatwoods soil in 1991 at 151 trees per acre. The grove was irrigated with micro-sprinklers. As with Experiment 1, this experiment used a randomized complete block design with three trees per plot. Production costs were calculated for 6 years starting at planting (1991 through 1996). Yield and juice quality were measured for 4 years (1993 through 1996). Treatments included a conventional fertilizer and five CRF products (Table 6). Rates were 0, 20, 40, 80, and 160 pounds of nitrogen per acre. Fertilizer applications during the 6-year experiment are shown in Table 7.

Findings included the fact that similar yield results, as measured by the 4-year average pound solids per tree, were obtained with the CRF products with fewer number of fertilizer applications (Figure 6). The conventional ammonium nitrate source achieved the highest pound solids per tree value at only 76% of the full nitrogen rate (Figure 6). The quadratic plateau critical nitrogen rates (Figure 7) show a range from approximately 120 pounds per acre for the ammonium nitrate source up to a maximum of 150 pounds per acre for the Escote source.

Prokote and Sierra produced higher pounds solids yield and subsequent dollar return compared with the traditional ammonium nitrate source (Table 8). Based upon the economics measured in this experiment, using coated CRF sources exclusively to fertilize citrus was not economically feasible.

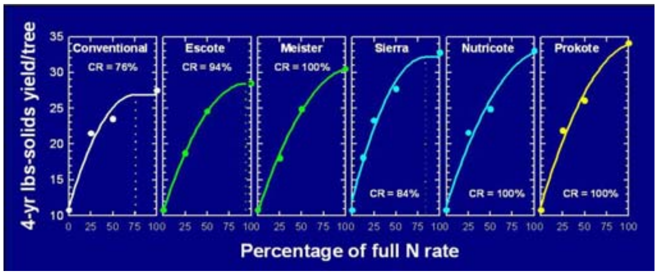

Figure 6. Comparison of five controlled-release fertilizer sources with conventional fertilization showing resulting 4-year pound-solids per tree responses.

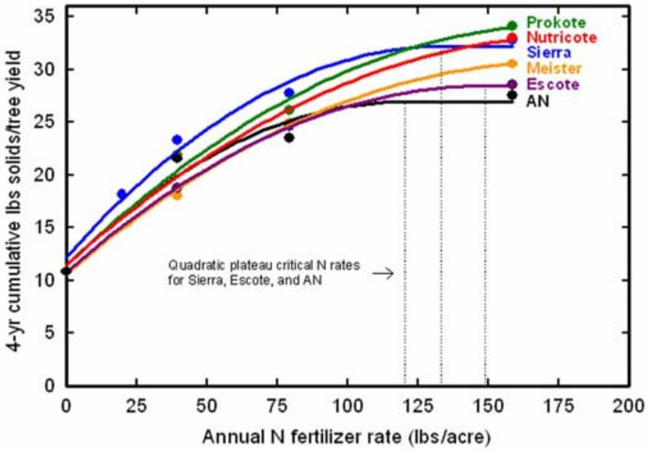

Figure 7. 4-year pound solids/tree as a function of annual nitrogen fertilizer rate. Regression analysis shows practical range of response to annual nitrogen fertilizer rate. Note that ammonium nitrate (AN) has the lowest critical nitrogen rate (120 pounds nitrogen per acre).

Experiment 3

In a third experiment using Hamlin orange trees on Swingle citrumelo rootstock planted in 1990 at 151 trees per acre, yield and juice quality was measured for five years (1996 through 2000). As with the other two experiments, a randomized complete block was used, and in this case five trees per plot. Trees in this grove were irrigated using micro-sprinkler technology. Treatments (Table 9) included water soluble ammonium nitrate and several new technology CRF sources.

In 1999, leaf tissue samples were collected and analyzed for nitrogen, phosphorus, and potassium concentrations (Table 10). All nitrogen sources/treatments provided sufficient nitrogen to satisfy the crop nutrient requirements (Table 10). Phosphorus was also found to be at or above the sufficiency range; however, in all cases potassium was at or below the sufficiency range.

Yield response (Table 11) showed that CRF technology has been improving with time. In this experiment, citrus responded more positively to fertilizer rate from CRF sources than from the water-soluble nitrogen source (Figure 8). This experiment also identified the difference in performance between the two CRF technologies. CRF sources applied once per year were more efficient nutrient sources for citrus than water-soluble fertilizer applied three times per year. When applied at 90 pounds of nitrogen per acre, the CRF source was as effective as water-soluble nitrogen applied at 180 pounds of nitrogen per acre (Figure 8).

Current research

As of 2004, several field trials with commercial growers were underway. Studies involve the release rate of CRF sources in field conditions (Figure 9) as well as in the more controlled laboratory environment (Figure 10). Findings of these experiments will be reported in future documents and presentations to the citrus industry.

Summary

The Florida citrus industry remains viable despite the pressures of disease, pests, and

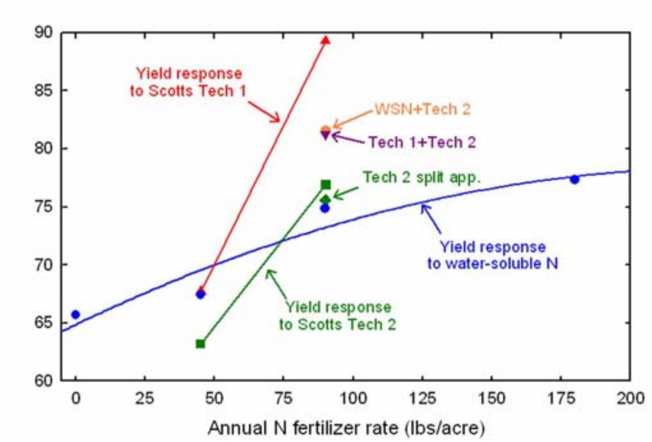

Figure 8. Experiment 3, showing a 5-year cumulative pounds solids per tree average as a function of the annual nitrogen fertilizer rate from water-soluble nitrogen, CRF sources, and the combination of these sources.

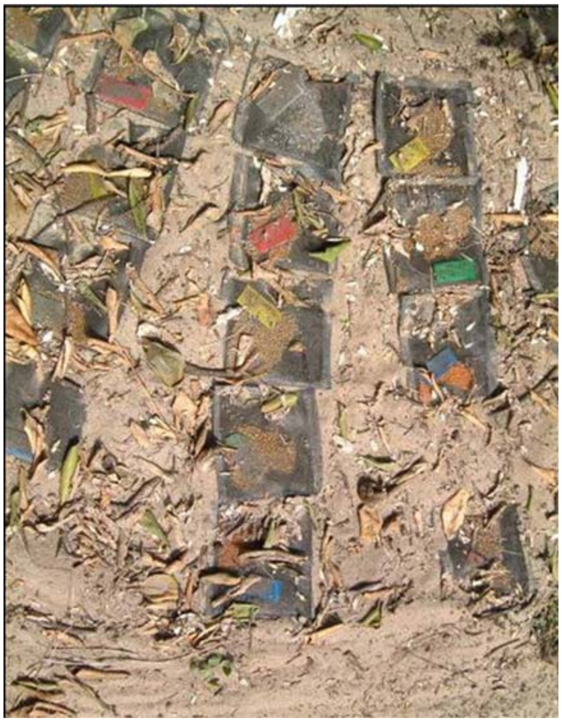

Figure 9. Current research showing porous bags containing CRF nutrient sources. Materials within the bag are exposed to both rainfall and irrigation. Contents of the bags are analyzed at selected time intervals to indicate the nutrient release rates of the CRF sources.

developmental land-use opportunities. Many citrus growers are interested in ways to improve production efficiency and at the same time address application of best management practices in their groves. Growers know that nitrogen and potassium are the top two mineral nutrients affecting citrus yield and quality, primarily because Florida's sandy soils hold both water and nutrients poorly. Research findings generated in commercial groves summarized in this document indicate that modern CRF sources are both horticulturally and environmentally effective but not economically viable. The reduced number of nitrogen fertilizer applications using CRF technology does reduce application costs; however, this technology must be implemented by a larger number of growers to reduce manufacturing costs incurred by CRF producers.

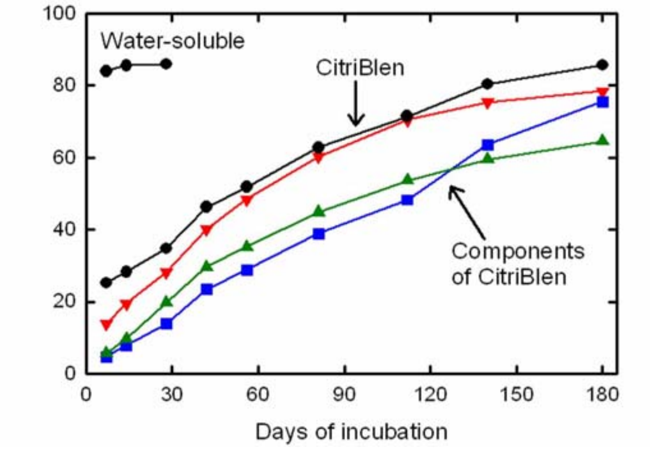

Figure 10. Current research showing results from a controlled laboratory experiment involving nutrient release from selected CRF sources with time.

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Table 1. General citrus nutrient management in Florida, 2002 through 2003.

Nutrient	Tons	% of North American consumption
N	194,363	1.5
P_2O_5	8,792	0.2
K_2O	43,867	0.9

Table 2. Nitrogen rate (citrus trees greater than seven years old: BMP).

NITROGEN	**lbs N/acre**
Max. yearly N rate	240
Max. single dry app., dry season	65
Max. single dry app., wet season	40
Max. single fertigation, dry season	15
Max. single fertigation, wet season	10
POTASSIUM Apply K_2O at 100 to 125% of the N rate	

Table 3. Leaching of water-soluble and controlled-release N following 40 inches of simulated rainfall in 30 days (Wang and Alva, 1996).

N source	Percentage of applied N fertilizer that leached	
	Candler sand	Wabasso sand
Amm. Nit.	100	88
IBDU	32	27
Meister coated	12	12

Table 4. Estimated N leached below the root zone (Paramasivam et al., 2001).

N rate	Dry granular fertilizer lbs/acre	Fertigation	CRF
		lbs N/acre/year	
50	---	---	0.8
100	11.1	16.3	2.9
150	11.8	21.5	7.1
200	12.2	27.1	---
250	19.0	31.3	---

Table 5. Experiment 1.

Treatment	No. of applications in 7 years
100% Ammonium nitrate	31
50% Ammonium nitrate 50% IBDU	16
60% Ammonium nitrate 40% Methylene urea	14

Table 6. Experiment 2, Treatments and number of applications, placecountry-regionValencia on Swingle citrumelo, 1993 through 1996.

Treatment (Trade name and analysis)	No. of applications in 6 years
Conventional (8-4-8)	24
Prokote Plus (20-3-10)	6
Nutricote 360 (17-6-8)	6
Sierra (16-6-10)	6
Meister (17-6-12)	6
Escote (19-6-12)	6

Table 7. Experiment 2 nitrogen applications by year for both traditional and CRF fertilizer sources.

Year	Ammonium nitrate	Coated fertilizers
1991	6	1
1992	5	1
1993	4	1
1994	3	1
1995	3	1
1996	3	1
Total	24	6

Table 8. Experiment 2, production cost analysis by nitrogen fertilizer source, 1991 through 1996.

Fertilizer	6-yr fert cost ($/tree)	Cumulative lbs solid/tree	Gross return ($/tree)
Prokote	15.49	27.7	28.90
Sierra	19.20	27.0	28.25
Nutricote	19.85	26.5	27.47
Meister	15.81	25.8	26.41
Escote	14.90	24.9	25.98
Conventional	5.06	24.2	25.40

Table 9. Treatments used in Experiment 3.

Fertilizer	**Analysis**	**(lbs N/ac/yr)**	**App./yr**
No nitrogen	0-5-16	0	3
Water-soluble N (“WSN”)	16-5-16	45	3
	16-5-16	90	3
	16-5-16	180	3
Scotts AGROCOTE® (Resin-coated, “Tech 1”)	16-5-16	45	1
	16-5-16	90	1
Scotts AGROCOTE® (Poly-S-coated, “Tech 2”)	16-5-16	45	1
	16-5-16	90	1
	16-5-16	90	2
AGROCOTE® 50/50 combo of “Tech 1” and “Tech 2”	16-5-16	90	1

Table 10. Experiment 3, leaf tissue values from the 1999 and growing season by treatment.

Fertilizer source	**N rate lb/acre**	**N (%)**	**P (%)**	**K (%)**
Desirable ranges	=	2.5-2.7	0.12-0.16	1.2-1.7
None	0	2.6 ab*	0.26 a	1.44 a
WSN	45	2.6 ab	0.18 bc	0.64 c
WSN	90	2.4 ab	0.18 bc	0.84 bc
WSN	180	2.6 ab	0.20 b	0.87 bc
Tech 1	45	2.3 b	0.18 bc.	0.71 bc
Tech 1	90	2.5 ab	0.17 c	0.88 bc
Tech 2	45	2.5 ab	0.18 bc	0.76 bc
Tech 2	90	2.7 a	0.18 bc	0.91 bc
Tech 2 split	90	2.6 ab	0.17 bc	0.87 bc
Tech 1/Tech 2	90	2.5 ab	0.17 bc	0.97 bc
WSN/Tech 2	90	2.5 ab	0.16 c	0.83 bc
* Letters within the same column reflect statistical differences (P=0.05).				

Table 11. 5-year pound solids per tree production from fertilizer sources at the indicated annual rates, Experiment 3.

Fertilizer	**N rate lbs/ acre**	**1996-2000 lbs solids/tree**
Standard without N	0	65.7
WSN	90	74.8
Scotts Tech 1	90	89.3
WSN + Tech 2	90	81.6
Tech 1 + Tech 2	90	81.2
Tech 2	90	76.9