

Improved Fertilizer use Efficiency with Controlled Release Sources on Sandy Soils in South Florida

FDACS Contract 013960

Task 1: Field Evaluation of CRF

Deliverable 1: Report N fertilizer Biomass Efficiency and Seasonal Crop N Status Using Stalk Counts, Leaf N Content and Annual Yield

Submission Date: January 7, 2009

Principle Investigator: Kelly T. Morgan

University of Florida

Soil and Water Science Department

Southwest Florida Research and Education Center

2686 SR29N

Immokalee, Fl 34142

ABSTRACT

Sugarcane grown on sandy soils in south Florida typically under-produce sugarcane grown on muck soils due to poor water holding and nutrient retention capacities of these soils. Use of controlled released fertilizer that satisfies crop nutrient demand has the potential for improve yields and reduce nutrient leaching. The fertilizer nitrogen (N) source (standard soluble), controlled release fertilizer (CRF), controlled release N with soluble P and K (CRN), and the combination of soluble and CRF) serve as the main plot factor with rate being the sub plots. The soluble fertilizer plots were applied based on 100% and 75% of an annual N rate of $290 \text{ kg ha}^{-1} \text{ yr}^{-1}$, resulting in 290 and $218 \text{ kg ha}^{-1} \text{ yr}^{-1}$ in three to five splits per year. A 12 month CRF formulation was applied to plots at planting. A product containing controlled release N was blended with soluble sources of P and K to produce a CRN treatment and was applied at planting. To investigate a management program combining both soluble fertilizer and CRF, a fourth set of plots had 20% of the same annual N rates applied as soluble N at planting or first fertilizer application per year with the remaining 80% applied 3 months later as CRF with a 6 month release formulation. The CRF and CRN products and the combination soluble and CRF fertilizers were applied at annual N rates based on 75% and 50% of the $290 \text{ kg ha}^{-1} \text{ yr}^{-1}$ base N rate, resulting in 218 and $145 \text{ kg N ha}^{-1} \text{ yr}^{-1}$. The statistical design was a randomized complete block. Equal amounts of phosphorus and potassium were applied to all plots each year. The test hypotheses for this study are: the use of CRF in sugarcane production can 1) reduce annual application costs, 2) reduce annual N application rates, 3) provide adequate N nutrition for growth and carbohydrate accumulation, 4) maintain adequate yields, and 5) reduce the potential loss of N to the environment. Leaf N for all treatments and rates were nearly equal through mid-summer except the CRN 50% treatment was significantly lower ($P>0.05$) than other treatments. The soluble fertilizer 100% treatment was significantly higher than all other treatments after an application then fell to similar leaf N concentrations between applications. Cane dry biomass prior to harvest was not significantly different ($P>0.05$) for any fertilizer source or rate. Two years of harvest indicate that the CRF 75% and combination soluble fertilizer and CRN 75% treatments had significantly greater yields compared with the soluble N 100% treatment. With recent increases in fertilizer prices, reduced rates of controlled release forms and reduced application costs can save growers money with no reduction in sugar yield per acre.

INTRODUCTION

Florida is the nation's number one sugar producing state. Sugarcane, Florida's most valuable row crop, is produced on a total of approximately 172,000 ha. The majority of sugarcane is grown on Histisols (muck soils) in the Everglades Agricultural Area; however, approximately 40,500 ha of sugarcane are grown on sandy Spodosols southwest of Lake Okeechobee. Sugarcane grown on sandy soils typically under-produce sugarcane grown on muck soils due to the poor water holding and nutrient retention capacity of the Spodosols compared with those of Histisols.

A three year nitrogen rate study by Muchovej et al. (2004) found no significant yield (stalk weight or sugar) increase at N rates above $170 \text{ kg ha}^{-1} \text{ yr}^{-1}$. However, sugarcane production increased by $9 \text{ Mg ha}^{-1} \text{ yr}^{-1}$ between 170 and $350 \text{ kg ha}^{-1} \text{ yr}^{-1}$ N rates, or a net increase of 12%. Additionally, N application rates above 62.5 pounds per acre per year significantly increased groundwater nitrate-N concentrations above the 10 ppm drinking water maximum contamination

limit. A recent survey of sugarcane growers accounting for the majority of the production on sandy soils found growers use to be between 250 and 320 kg N ha⁻¹ yr⁻¹. Therefore, better N rate and timing information is needed to optimize sugarcane production, by improving N use efficiency, while reducing N leaching on these highly leachable soils.

In a three year study, Obreza et al. (1998) found that applying the same amount of N 13 times on an annual basis increased yield by 12.8 % when compared to 7 applications. Therefore, a delivery system such as CRF, capable of providing a more or less continuous supply of N over a prolonged period of time should produce superior yields compared to current commercial practices of 3 to 5 applications per year. Increased fertilizer costs associated with CRF could be offset by increased production and augmented by reduced application costs if the fertilizer source were applied in only one or two applications per year. Key aspects of best management practices (BMPs) address concerns related to contamination of some surface and aquifer water resources. Increased nutrient uptake efficiency of sugarcane through the use of controlled released fertilizer (CRF) and improved irrigation management is essential to development of these BMPs and improved competitiveness.

Current costs of CRF are \$2.05 - \$2.30 per pound of N, while soluble fertilizers are \$0.75 to \$0.90 per pound N. At a rate of 260 pounds of N per acre, the costs of soluble and CRF would be approximately \$220 and \$572, respectively, or a \$352 differential in fertilizer costs alone. Rouse et al. (1999) and Obreza et al. (1998b) indicated that a potential fertilizer savings of up to 50% for citrus production could be obtained using CRF. If fertilizer savings approached 50% in sugarcane the differential in fertilizer costs between soluble and CRF would decrease to \$66.00 per acre. Yearly application costs would be approximately \$75 and \$15 per acre for soluble and CRF, respectively, assuming costs of \$10 to \$20 per acre per application. This would represent an annual potential production costs savings of approximately \$60 per acre. Thus the increase in production costs due to CRF use would be nearly offset by savings in application costs. The objective of this study was to determine if use of CRF in sugarcane production can 1) reduce annual application costs, 2) reduce annual N application rates, 3) provide adequate N nutrition for growth and carbohydrate accumulation, 4) maintain adequate yields, and 5) reduce the potential loss of N to the environment.

MATERIALS AND METHODS

The statistical design is a randomized complete block. The fertilizer nitrogen (N) source (standard soluble), controlled release fertilizer (CRF), controlled release N with soluble P and K (CRN), and the combination of soluble and CRF) serve as the main plot factor with rate being the sub plots. The soluble fertilizer plots were applied based on 100% and 75% of an annual N rate of 290 kg ha⁻¹ yr⁻¹, resulting in 290 and 218 kg ha⁻¹ yr⁻¹ in five splits, including a final aerial application. Two sources of CRF formulated to release over a period of 12 months was be applied to separate CRF plots at planting. A product containing controlled release N was blended with soluble sources of P and K to produce a controlled release N (CRN) treatment and was applied at planting. To investigate a management program combining both soluble fertilizer and CRF, a fourth set of plots had 20% of the same annual N rates applied as soluble N at planting with the remaining 80% applied 3 months later as CRF with a 6 month release formulation. The two CRF products and the combination soluble and CRF plots were applied at annual N rates

based on 75% and 50% of the 290 kg ha⁻¹ yr⁻¹ base N rate, resulting in 218 and 145 kg N ha⁻¹ yr⁻¹. Equal amounts of phosphorus and potassium will be applied to all plots.

Each plot consists of four rows of cane 2500 feet long or approximately 1.25 acres in size. Monthly stalk counts were taken from January to May with counts at two month intervals from May to harvest. The number of stalks per 3 meters of row were counted at two points in each plot and averaged to determine the stalk density per 30 cm of row. Stalk counts are used to determine the effect of treatment on cane germination and plant population density over time. The cane was large enough to begin leaf blade tissue sampling in March and continued monthly to harvest. Monthly tissue samples will be used to determine crop nutrient status relative to the applied treatments. Cane and leaf biomass samples were collected in late November, 20 stalks from each plot were subsequently dried and weighed to determine tissue dry weight accumulation in leaves and stalks. Another set of 20 stalks from each plot were tested for sugar content to determine sugar yield per acre.

RESULTS AND DISCUSSION

Few sources of original data have been found for N rate studies conducted in Florida between 1960 and 1990. In Everglades Research Station Reports, Le Grand and Hortenstine (1961) suggested 100 to 112 kg ha⁻¹ of N be applied annually on sands of less than 5% organic matter (OM). The recommendation decreased to a side-dressing of 34 kg ha⁻¹ as OM increased. In a later report, Gascho and Freeman (1971) restated the recommendation to be 100 to 123 kg ha⁻¹ for sands and mucky sands. In subsequent reports, Gascho and Freeman (1974) and Gascho and Kidder (1975) later increased their N recommendation to 156 to 168 kg ha⁻¹ for sand. Supplemental application in case of excessive rain was maintained at 22 kg ha⁻¹ bringing the annual maximum N application to 190 kg ha⁻¹, and is the current sugarcane recommendation for sandy soil in Florida. The earlier studies were conducted on soils higher in organic matter (mucky sands) compared with the sandy soils farmed today with very low organic matter (<2%). In a recent poll of growers by the University of Florida, Sugarcane Fertilization Task Force (personal communication) current commercial rates of N are in the 250 to 340 kg ha⁻¹ yr⁻¹ range. Therefore the 100% base rate used in this study represents a commercially acceptable level of N fertilizer application.

Visual inspection indicated no apparent difference in fertilizer source or rate treatments. Cane density, height and color in all plots were comparable with the 100% soluble N treatment and appropriate compared with cane grown under grower practices in adjacent blocks. Stalk count density increased with time from just after first harvest (December) to March (Fig. 1). Stalk density remained nearly constant from March to December. The lower N rate of each fertilizer source tended to produce lower densities at each sampling date, however, were not significantly difference among fertilizer source, N rate or interaction of N source and rate.

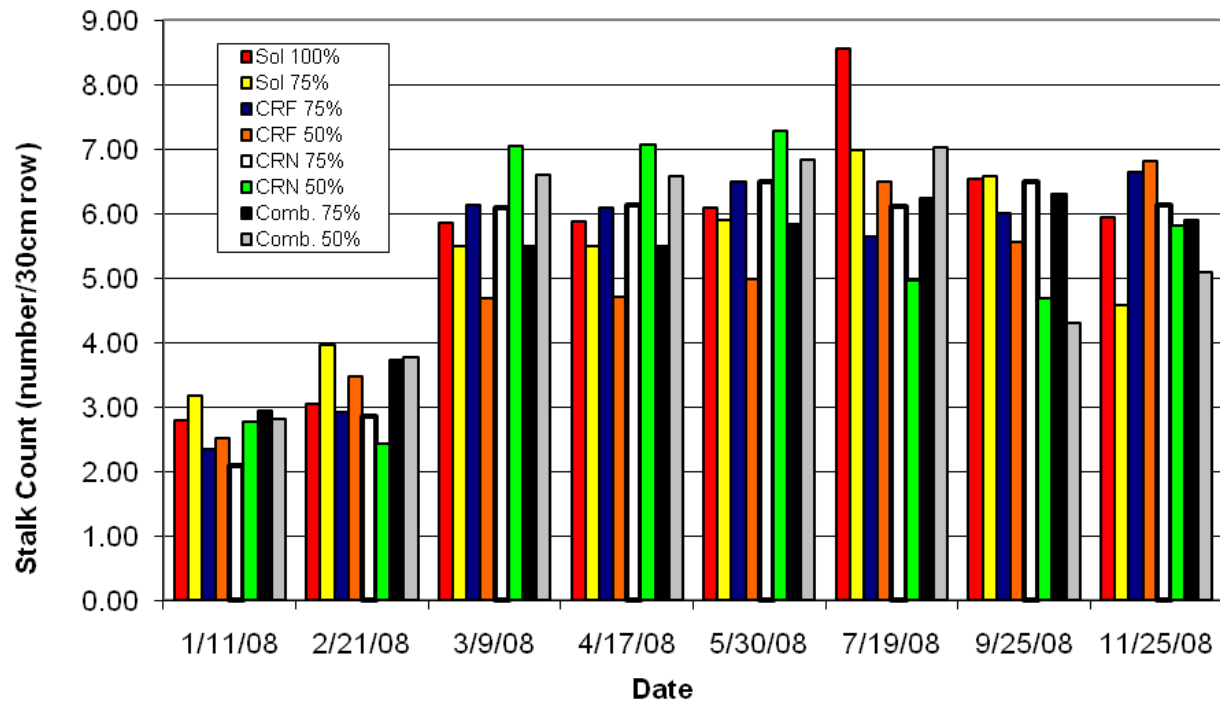


Figure 1. Sugarcane stalk counts per 30 cm of row for N treatments of four fertilizer sources and two rates.

In a review by Anderson (1990), he stated that N is an essential nutrient for sugarcane growth having a critical nutrient level (defined as the nutrient concentration level in a plant below which yield will likely decline by 5 to 10%) of 1.8%. The critical nutrient level is normally determined at stage 4 (expansion of the plant internodes and increases in plant height) which normally occurs in Florida between May and August. Leaf N for all treatments and rates were not significantly different from the critical value in March, April and July through October with the exception on the CRN 50% treatment significantly lower ($P>0.05$) than other treatments in April (Fig. 2). The soluble fertilizer 100% treatment was significantly higher ($P>0.05$) than all other treatments in September after an application earlier in the month. Leaf N concentrations were significantly lower ($P>0.05$) than the critical value among all treatments in May, November and December. These are typical responses to two different phenological stages in sugarcane growth. The lower leaf N in May is due to the rapid growth of leaf and cane tissue in May associated with the “Grand Growth Stage” of development. Tissue is accumulated at a rate higher than the plant has the ability to supply with nutrients. Leaf nutrient status normally recovers in subsequent months due to reduced growth of new tissue and continued uptake of nutrients. The lower leaf N status in November and December is due to the natural maturation process of the cane and preparation for flowering. Wood et al. (1996) found that low leaf N concentration limited leaf photosynthesis and thus sugar yields. Under non-limiting N conditions (325 kg N ha^{-1} , in a single application), a relationship of leaf N and total crop N with days after planting or ratoon re-growth was found to exist for growing conditions on an unspecified soil in Queensland, Australia. Data in this study was similar to the cited report in that Wood et al. (1996) found N accumulation ceased before biomass accumulation. As a result, crop N accumulation reached a maximum at 198 and 151 days (July-August in the current study) after planting or ratoon growth, respectively, and did not change over the next 150 and 200 days of an 18 month sugarcane

variety, however, biomass continued to accumulate over this period. Leaf N concentration decreased throughout the study from approximately 2% just after planting or start of ratoon growth, to a range of 1.5 to 1.3% from 100 to 300 days after planting or ratoon re-growth.

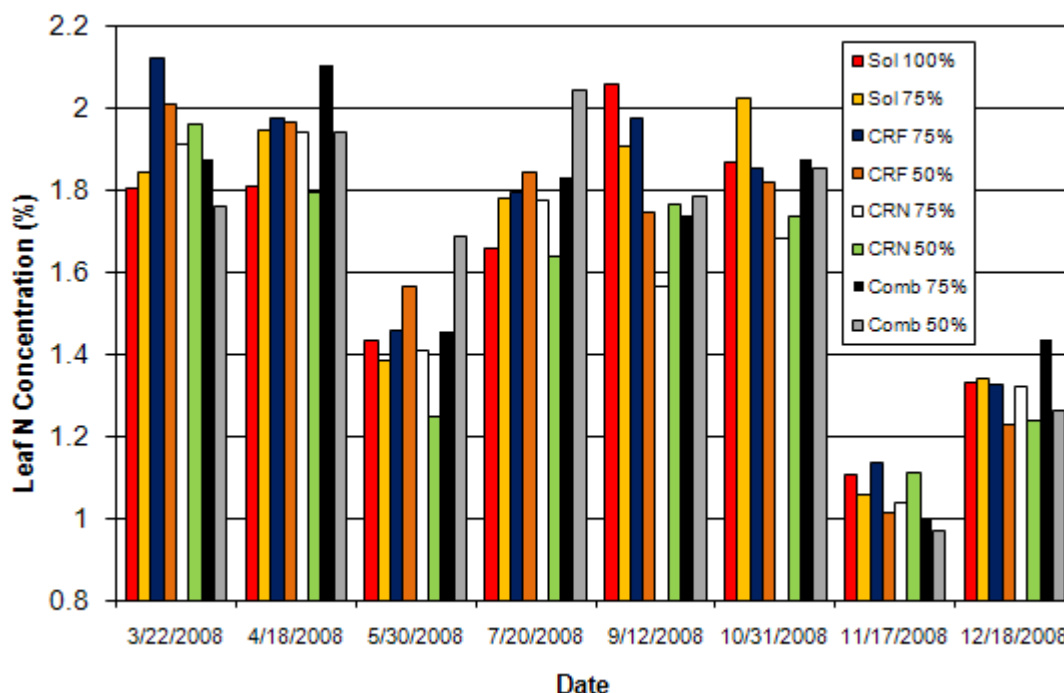


Figure 2. Seasonal sugarcane leaf N concentration change among N rates and sources.

Cane dry biomass was not significantly different ($P>0.05$) for any fertilizer source or rate at harvest (Fig. 3). However, both 75% rate of CRF and CRN were greater than the both 100% and 75% rates of soluble fertilizer N. These results would indicate that biomass accumulation did not differ greatly between the two soluble N source rates and the 50% base rate of controlled release fertilizer treatments. Nutrient uptake efficiency (NUE) or the amount of sugar produced per amount of N applied (t kg^{-1}) would thus, be similar for these selected sources and rates indicating adequate nutrition at the base rate of soluble N fertilizer and 50% base rate of N using controlled release materials. Biomass accumulation and thus NUE was greater for the 75% controlled release materials compared with the 100% N rate of the soluble source. The impact of these results would be evidence of lower leaching potential with use of controlled release products without reduction in cane biomass. Muchow et al. (1996) reported increased cane yield with increased annual N rate using 56, 107, and 268 kg ha^{-1} on fine sandy loam in Queensland Australia. However, stalk sucrose concentrations were reduced with increasing N rate resulting in similar sugar yields at all annual N rates. Crop sugar yield was nearly equal for all N rates resulting in reduced NUE with increased N rate. In this study, stalk N concentration increased with N rate, indicating little correlation between cane N concentration above the critical level and sugarcane growth and yield.

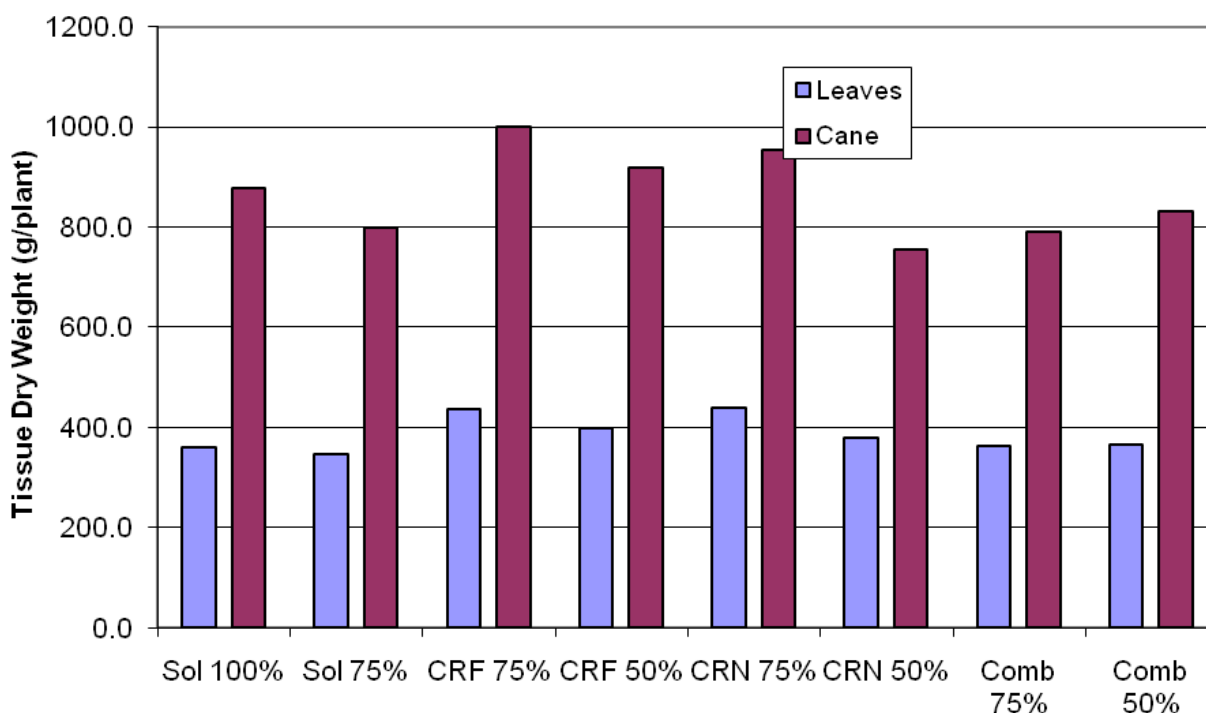


Figure 3. Sugarcane dry tissue accumulation at harvest for selected N sources and rates.

Few recent reports of annual N rate affect on yield under sandy soil conditions in Florida have been written. One recent N rate study on sandy soils in Florida by Muchovej et al. (2004) found no significant yield (stalk or sugar weight) increase at annual N rates above 170 kg ha⁻¹. Three year average cane weight yield was 68.5 and 77.0 Mg ha⁻¹ for November and January harvests, respectively. While yearly sugar yield was not significantly greater with increased N rate, nearly 11.5 Mg ha⁻¹ increase in yield (15%) was observed when yields at annual application rates of 170 and 390 kg ha⁻¹ were compared. In a three year study on sandy soils in Florida, Obreza et al. (1998) found that applying the same amount of N 13 times on an annual basis increased yield by 12.8% when compared to seven applications. On a 3-yr average basis, the high N frequency treatment annually yielded 75.8 Mg ha of sugarcane and 9.4 Mg ha⁻¹ of sugar, compared to 66.5 Mg ha⁻¹ of sugarcane and 8.2 Mg ha⁻¹ of sugar with the low N frequency treatment. Therefore NUE can be increased by increased numbers of applications possibly by use of fertigation though drip irrigation or use of controlled release forms of N. Both cane weight and sugar weight yields in the current study were greater than the studies cited above (Table 1). Cane weights per hectare were significantly greater for all controlled release sources at the 75% of base rate compared with the 100% and 75% base rates using soluble N sources in 2007. However, this was not the case in 2008. This year the 100% soluble source treatment was similar to the 75% rate of CRF and the Combination of soluble fertilizer followed by CRF. The 50% rate of the all three controlled release sources and the 75% of the CRN sources were significantly lower than the 100% soluble fertilizer treatment but were not significantly different from the 75% soluble source cane weight. The CRN treatment included soluble sources for both phosphorus and potassium. Greater rainfall in 2008 compared with 2007 may have caused leaching of either or both of these nutrients and thus reduced growth compared to the other two controlled release sources and soluble fertilizer treatments. Similar reduction in growth would not be expected for

the soluble source treatment in high rain years because of the multiple applications per year compared with the single application in the CRN treatment.

Table 1. Sugarcane stalk and sugar weight yields and fertilizer N use efficiency for selected N rates and sources.

Treatment	Cane Weight (Mg/ha)		Sugar Weight (Mg/ha)		Efficiency (kg sugar/kg N)	
	2007	2008	2007	2008	2007	2008
Soluble 100%	97.6 b	101.3b	16.3 b	14.3a	56.2 e	49.3d
Soluble 75%	93.3 b	93.0bc	15.6 b	12.5b	74.9 d	57.6cd
CRF 75%	107.6 a	106.7b	17.7 ab	14.6a	81.4 cd	67.3c
CRF 50%	102.8 ab	93.8bc	16.9 ab	12.7b	116.9 a	87.6a
CRN 75%	116.2 a	82.5c	20.7 a	10.4bc	94.9 c	47.9d
CRN 50%	83.9 c	77.1c	14.9 c	9.7c	103.0 b	66.9c
Combination 75%	113.0 a	118.7a	20.0 a	14.6a	91.7 c	67.3c
Combination 50%	77.1 c	85.06c	13.6 c	11.5b	94.1 c	79.3b
Significance (P value)	0.001	0.001	0.0005	0.001	<0.0001	0.001

Sugar weights were similar for both N rates of the soluble fertilizer in 2007 but increased with higher N rate in the higher rainfall year of 2008 indicating the potential of N leaching. In both years, the 100% rate of soluble N and 75% CRF and combination CRF and soluble N fertilizer indicating improvement in NUE with significantly higher efficiency of the controlled release sources compared with the soluble N sources. The yield of CRN treatments are contradictory with significantly higher yields in 2007 and significantly lower yields in 2008 compared with the soluble N sources. These data may indicate a problem with a single application of soluble phosphorus and potassium in high rainfall years.

CONCLUSIONS

Similar stalk counts, leaf N and biomass accumulation for CRF, CRN and combination treatments compared with higher N rates of soluble fertilizer indicate that NUE of sugarcane can be improved with the use of controlled release fertilizers. The combination of improved N rate effect and N accumulation data will provide the information needed to determine N BMPs for sugarcane production that will insure sustainable yields while protecting the water quality of south Florida. Leaf N concentration levels during the highest cane growth rates between March and June indicate that N concentrations are being diluted by the increase in vegetative growth. Therefore, additional data need to also be collected on biomass and N accumulation over time at the selected annual N rate to determine the proper timing of fertilizer release rate from the controlled release material because of the low leaf N concentrations in May. The seasonal fluctuations in leaf N content may be corrected through different CRF release rates and could potentially lead to increased cane growth and yield. Improved cane and sugar yields with

controlled release fertilizers indicate a potential to reduce fertilizer N application, grower application costs, and water contamination.

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