SOIL FERTILITY RESEARCH IN SUGARCANE IN 2003

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in cooperation with
St. Gabriel Research Station, the Louisiana Cooperative Extension Service and Sugarcane Farmers

SUMMARY

Six different field experiments were conducted in 2003 to test the effects of fertilizer inputs on the yield and yield components of current sugarcane varieties.

Results of a multi-location outfield test to determine the optimum rate of N fertilizer for LCP 85-384 indicated the optimum rate was on the low end of present recommendations. Results of ratoon crop response to N application rates were similar to those of previous years in this large outfield study. Cane yield optimized between 80 and 100 lb N/acre on light soils and 100 to 120 lb N/acre on heavy soils. Sugar yields were optimized at slightly lower rates. Overall, the data indicate optimal response occurs for the variety LCP85-384 at rates 20 to 40 lb N/acre less than now recommended. Nitrogen fertilizer rates from 60 to 180 lb N/ac had minimal effect on cane or sugar yield of first ratoon crops for three varieties. Nitrogen use efficiency for biomass declined with increasing N rate, but tended to be higher across rates for LCP85-384 than the other varieties. Applying a range of N fertilizer rates in early April vs late May for 3rd ratoon LCP85-384 harvested in late September resulted in a slight N rate x timing interaction for cane yield. When applied in April, cane yield from 40 lb N/ac application was less than 80 lbs and above. There were no significant differences among N application rates applied in May. Sugar yield and CRS were unaffected. Broadcasting full or split applications of stabilized urea (Super U) in early February and/or sidedressing full or split applications of regular urea in April into plots where harvest residue remained, was swept to middles, or burned resulted in interaction. Yield of 3rd ratoon LCP85-384 was generally significantly lower when grown where the harvest residue remained. However, the application of 120 lb N/acre as Super U in February resulted in yields statistically equivalent to the check (120 lb N/acre applied as sidedressed urea in April). The best yields occurred on burned residue with a split application of 60 lb N/acre as broadcast Super U followed by the same rate as sidedressed urea in April. Cane yields were 8% more than the check, and sugar yields were 29% more. The use of starter fertilizer applications at planting did not produce a response in plant cane nor any consistent response in first ratoon for LCP85-384. The use of 4 or 6 T/acre silica slag on cane that was subsequently used for planting resulted in significantly lower yields than when cane supplied for planting was grown without slag. Results may have been confounded by billet planting rate differences among the plant material.

OBJECTIVES

This research was designed to provide information on soil fertility in an effort to help cane growers to produce maximum economic yields and to increase profitability in sugarcane production. This annual progress report is presented to provide the latest available data on certain practices and not as a final recommendation for growers to use all of these practices. Recommendations are based on several years of research data.

RESULTS AND DISCUSSION

Starter fertilizers

Averaged across two planting dates, the use of some starter fertilizers on billet-planted LCP 85-384 improved first ratoon cane yield compared to others(Fig.1). The reason partial starter fertilizers were numerically to statistically better than complete starters this year is not known. The year-to-year variability in response makes it difficult to make a recommendation for the use of starter fertilizers.

Rates of spring-applied N fertilizer:

The effect of N fertilizer rate on yield of LCP 85-384 was tested at four large outfield locations. The N rate for optimum yield ($\geq$ 90% of maximum yield and not statistically different) was below the lower end of the recommended range (Fig.2) and reflected what has been found in the previous two years of this study. The response of CRS varied with location. Sugar yield response reflected that of tonnage with optimization at a slightly lower N rate than cane yield (Fig. 3).

The variety LCP85-384 produced numerically but generally not significantly higher cane yield than CP70-321 and HoCP91-555 (Fig.4). This indicated a trend for higher average (but not statistically significant) N-use efficiency relative to the other two varieties (Fig.5). LCP85-384, however, had a slower growth rate than the other varieties through much of the growing season (data not shown), which would suggest the reason for the lack of significantly higher NUE this year.

N applied later in the season (late May) had less response to differences in rate than when N was applied in early April for 3rd ratoon LCP85-384. When applied in April, cane yield from 40lb N/acre application was less than 80lb and above. There were no significant differences among N application rates applied in May (Fig.6). The differences in sugar yield were not significant.

N application and Harvest Residue Management :

Cane yield of 3rd stubble LCP85-384 tended to be lower when grown under the previous harvest's residue. The winter application of stabilized urea ('SuperU'™) did improve the response under those conditions to an equivalent with the check (120lb spring-applied N, burned residue)(Fig.7). The split application of stabilized urea in winter and regular urea in spring on burned residue resulted in the highest sugar yield (Fig. 8).

Silicon application to seed stock:

Application of Calcium Silicate slag at planting to cane earmarked for future seed stock was hypothesized as a way to improve planting efficiency when using billets. The results indicated the hypothesis was not true. Yields and population declined as Si application increased to the seed stock (Fig.9). This may have been confounded by a biased difference in planting rate for each treatment. Even if this is the case, it points out that billet planting efficiency is not improved by increasing the amount of Si available to seed stock.

Acknowledgements

The authors wish to express appreciation for the financial support by the American Sugar Cane League.

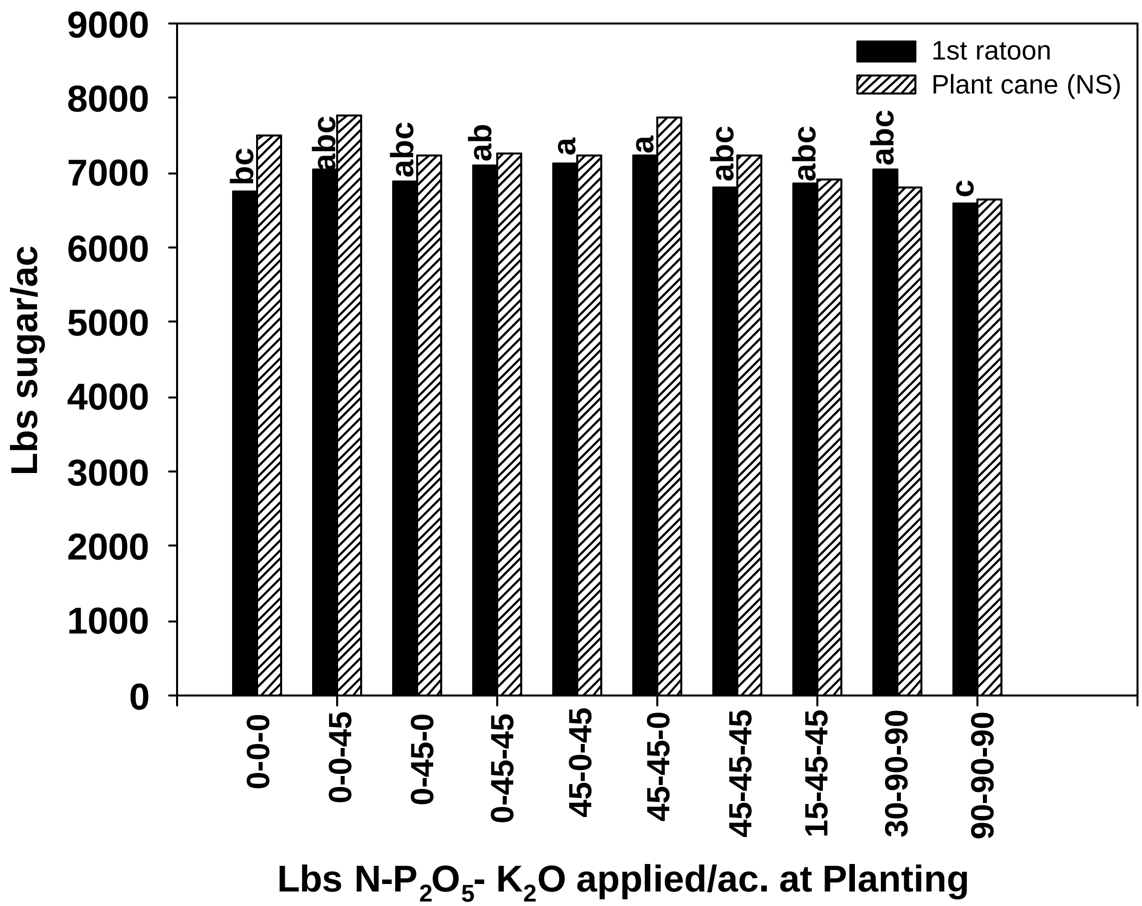


Fig.1. The effect of at-planting starter fertizer on subsequent yields of LCP85-384.

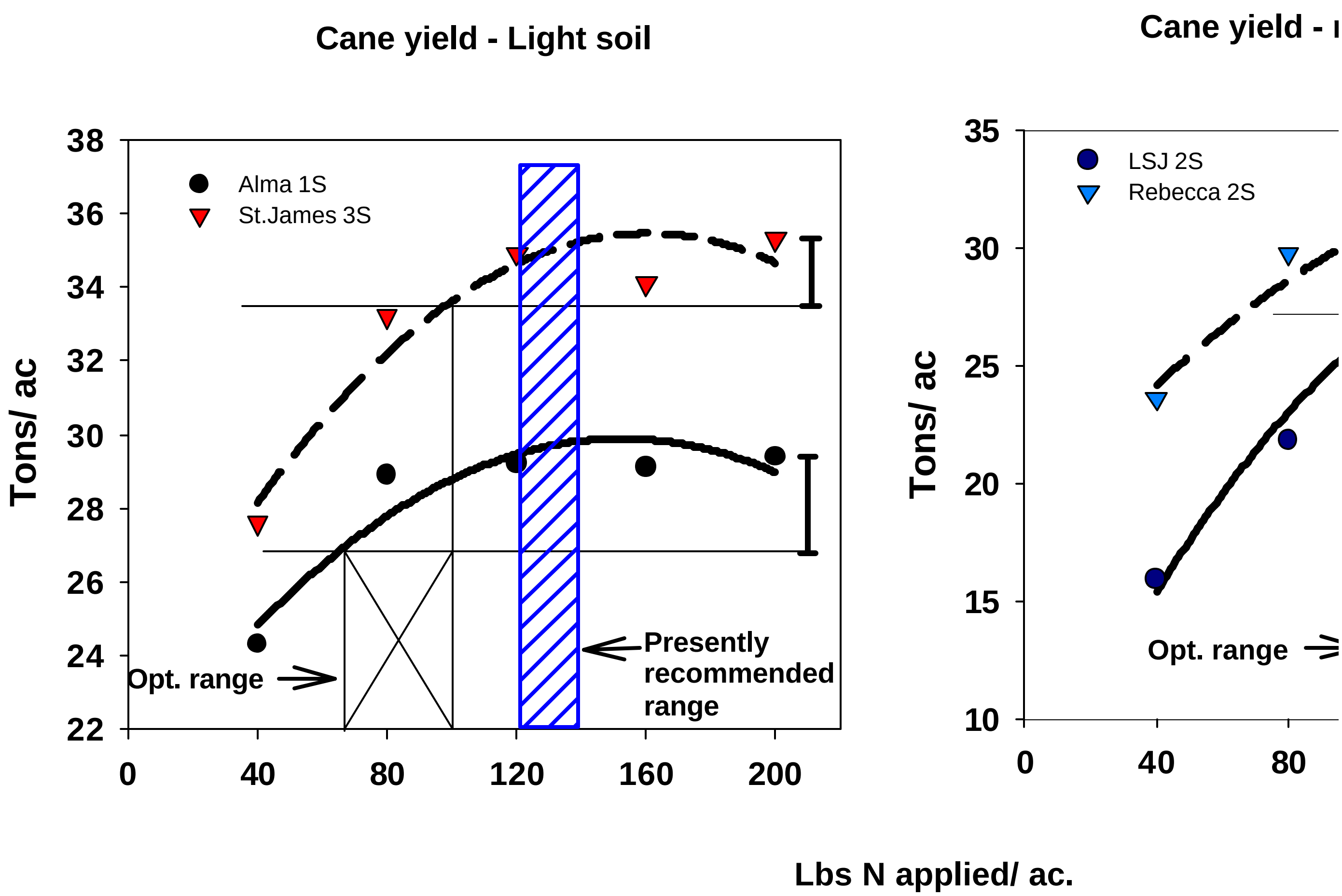


Fig. 2. Response of LCP85-384 ratoon crops to N application rates.

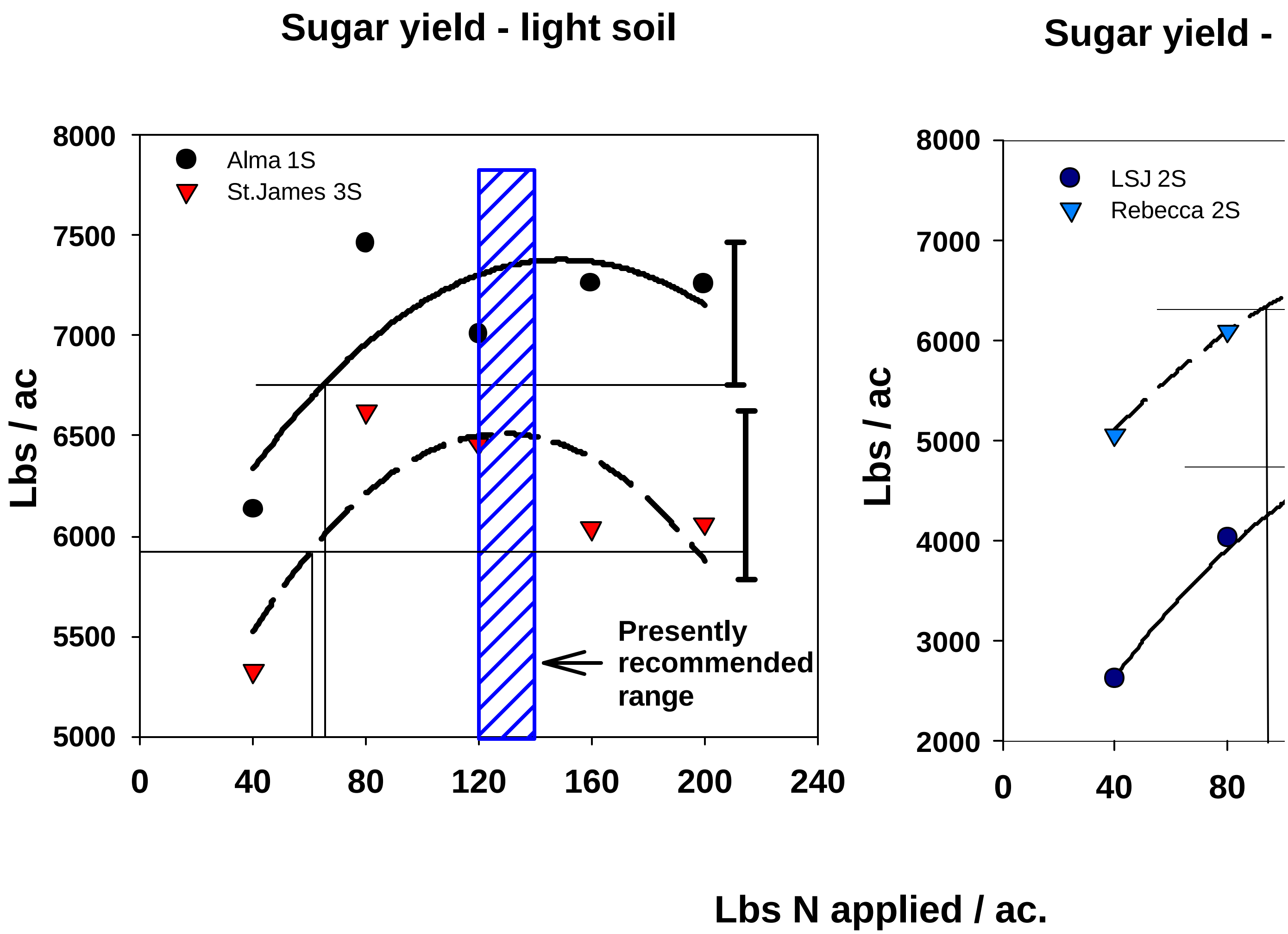


Fig. 3. The sugar yield response of LCP85-384 rato
crops to N application rates.

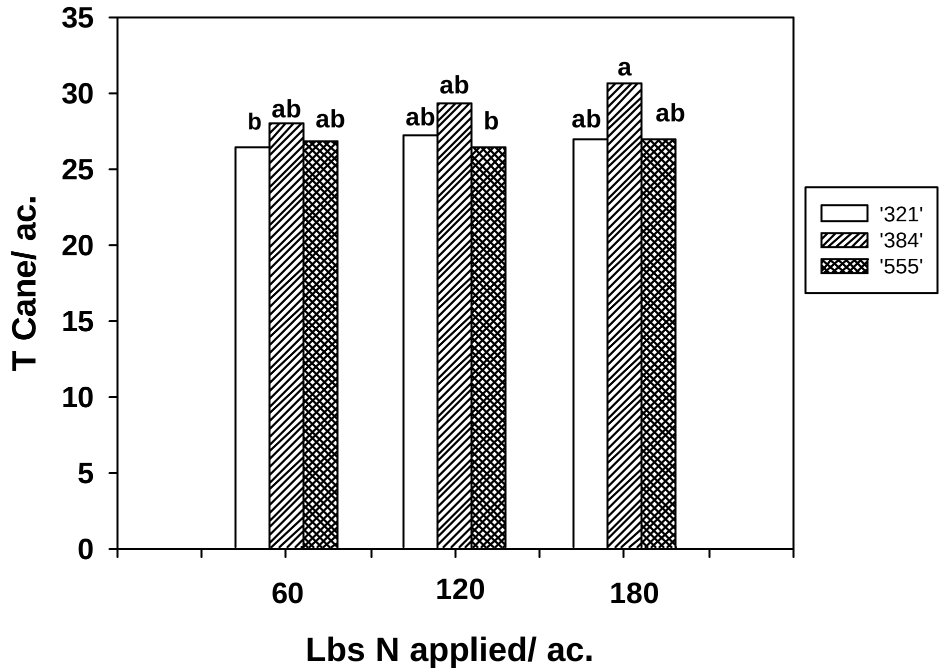


Fig. 4. Cane yield response of three varieties to N application rates. Bars topped by the same letter are NS ($P \leq 0.05$).

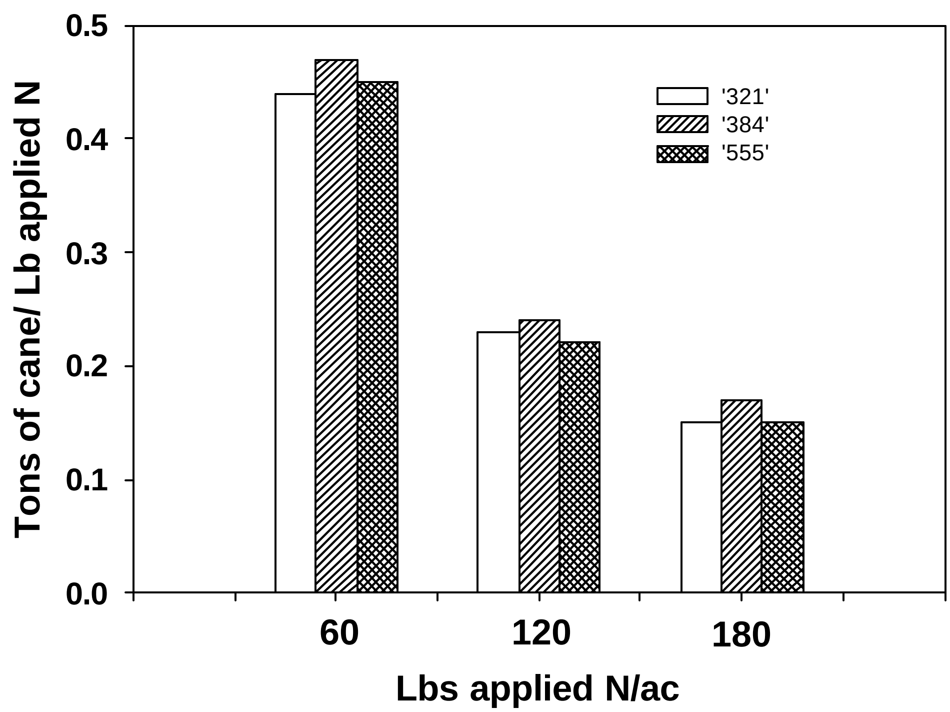


Fig. 5. N-use efficiency of three varieties at different applied N rates. There were no sig. variety differences.

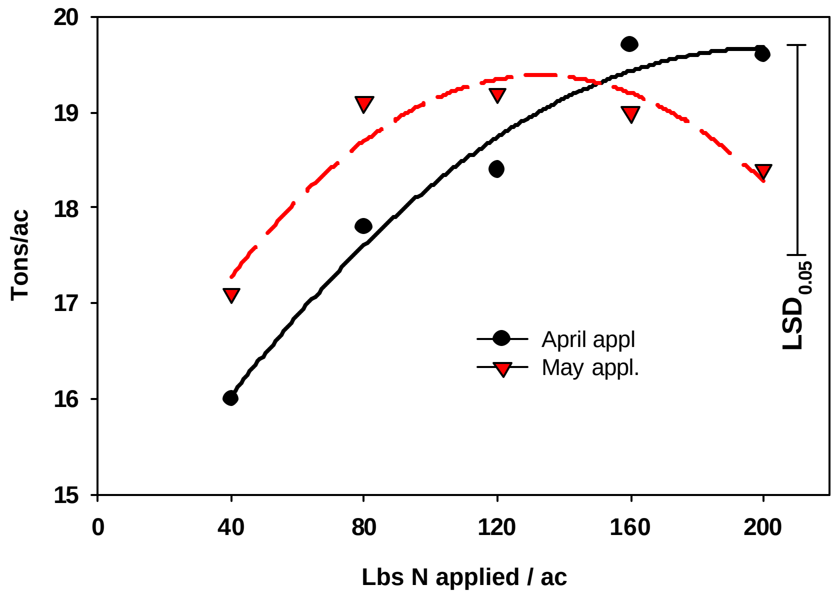


Fig. 6. The cane yield response of 3rd stubble LCP85-384 to rates and timing of applied N fertilizer.

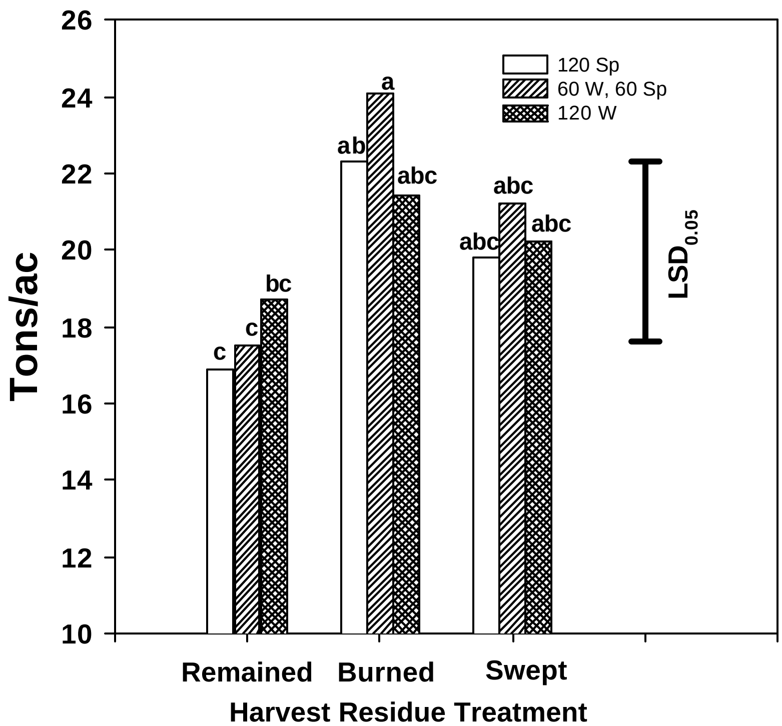


Fig.7. Cane yield response to residue management and N fertilizer type and method for 3rd stubble LCP85-384. All received 120lb N/ac. 'W' = winter applied 'SuperU'. 'Sp' = spring applied regular urea.

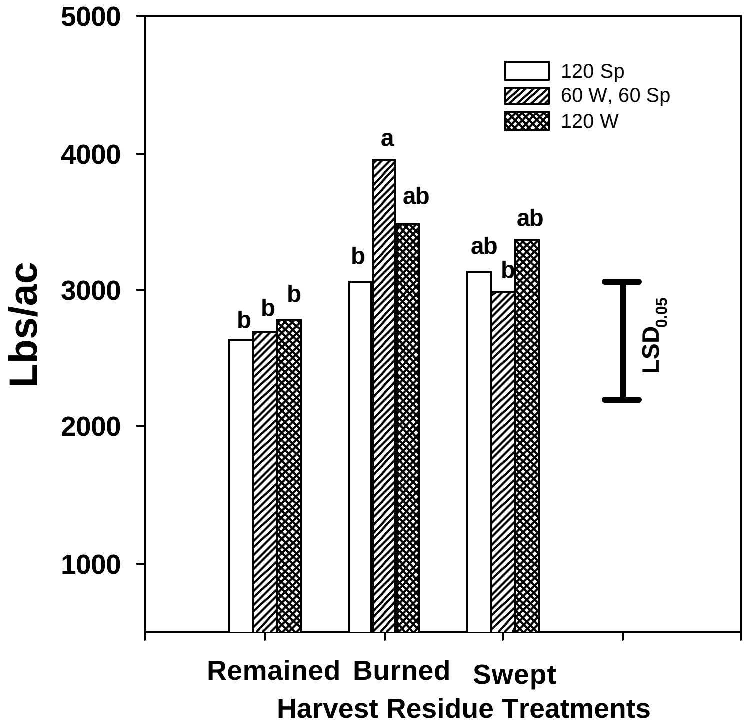
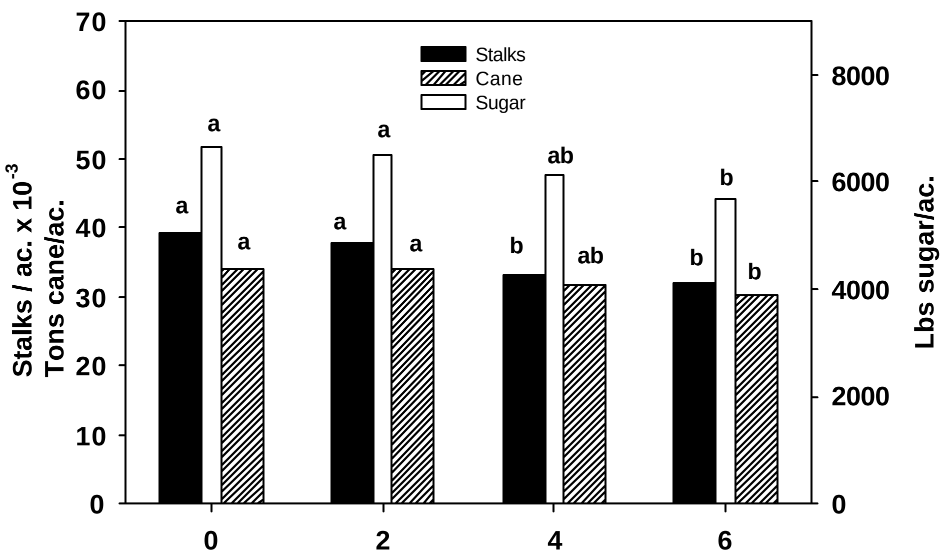


Fig.8. Cane yield response to residue management and N fertilizer type and method for 3rd stubble LCP85-384. All received 120lb N/ac. 'W' = winter applied 'SuperU'. 'Sp' = spring applied regular urea.



Tons silica slag applied/ac to seed source at the time of its planting.

Fig.9. Response of LCP85-384 plant cane to silica applications applied to the billeted seed source.

EFFECT OF CALCITIC LIME AND CALCIUM SILICATE SLAG RATES AND PLACEMENT ON LCP 85-384 PLANT CANE, FIRST-STUBBLE AND SECOND-STUBBLE YIELD PARAMETERS ON A LIGHT-TEXTURED SOIL

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SUMMARY

As an average of all three crops in the production cycle, all rates (1 or 2 tons per acre) and placements (mixed in row or placed underneath the seed pieces at planting) of calcium silicate slag produced significantly higher (P=.03) tons of cane per acre than the check plot. The failure of the 2 tons/acre calcitic lime treatment to produce statistically comparable yields to the 2 tons/acre slag treatment suggests that the yield response to slag was caused by silica and not calcium. Other equivalent-rate slag and lime comparisons were not as convincing, though all slag treatments were numerically higher than the lime treatments. The test site was chosen for its low soil silica content of 13.5 ppm. Several other plant cane experiments this year did not produce positive results, but soil silica levels were all above 35 ppm, evidently too high to elicit a yield response in plant cane on the soils chosen for the evaluations.

INTRODUCTION

Silica (Si) is one of the most plentiful elements in the Earth's crust. In the soil, Si is generally abundant as mineral quartz and clays, but its concentration in a soluble form is highly variable. Monosilicic acid is soluble in the soil, and it influences the chemical, physical, and biological properties of soils and plants. Soluble Si (monosilicic acid) apparently increases plant resistance against attack by insects and diseases and enhances plant tolerance to cold and water stress. Increasing soil silica can result in increased phosphorus uptake by plants, while decreasing the soil concentration of some toxic elements. Depending on the crop, production responses to silicate fertilizers can improve from 10% to 100%. Substantial sugarcane yield responses to silica have been obtained in Florida and Hawaii. Agricultural activity removes large quantities of Si (over 100 lb/acre each year) from soil. Monosilicic acid is used by the plant rapidly, and unless replenished in the soil solution, plant available Si can be depleted. Crops under stress do not use Si efficiently, and Si-deficient crops do not use other nutrients efficiently. Also, successive ratoon yields decrease more dramatically when plant available Si is low. Silica can also be used as a liming agent. Recent analysis of Si in 22 Louisiana soils shows that all were deficient or very deficient in monosilic acid.

Research supported by grants from the American Sugar Cane League and Pro-Chem.

OBJECTIVE

To compare the effect of calcitic lime and calcium silicate slag rates and placement on soil and plant silica and sugarcane yields.

MATERIALS AND METHODS

A sugarcane study was planted in September 2000 with first progeny Kleentek variety LCP 85-384 billets. The six calcitic lime (Domino by-product) and calcium silicate slag (a by-product of the steel industry) treatments are given in Table 1. These treatments were replicated six times in a Latin square experimental design. Treatments 2, 3, 4, and 5 were incorporated into the rows before planting, and treatment 6 was placed under the cane at planting. Experimental plots consisted of three 5 foot 10 inches by 40 foot rows with a 10 foot alley at the ends of each plot. All experimental plots were separated by three border rows on each side of the plots.

The Domino lime and calcium silicate slag materials showed a calcium carbonate equivalent of 84.28% for the lime and 78.51% for the slag. The silicon content of the materials was 39,400 ppm for the lime and 133,000 ppm for the slag. The respective analysis of the lime vs. slag was: 0.39 vs. 0.50 ppm for arsenic; 0 vs. 0 ppm for cadmium; 53,970 vs. 8,430 ppm for calcium; 0.16 vs. 0.33 ppm for nickel; 1.12 vs. 8.05 ppm for copper; 0.57 vs. 0.73 ppm for lead; 5.95 vs. 14.38 ppm for iron; 0.03 vs. 0.04 ppm for zinc; 1.21 vs. 4.53% for organic matter; 788 vs. 378 ppm for magnesium; 0.20 vs. 0.94 ppm for manganese; 12.05 vs. 8.38 for pH; 1.99 vs. 5.74 ppm for phosphate; 112 vs. 56 ppm for potassium; and 61 vs. 23 ppm for sodium. Soil samples were taken from each plot and analyzed for monosilic acid. Plant leaf tissue was taken in August 2001 and analyzed for silica concentration.

The experiment was grown to maturity using standard cultural practices. The plots were harvested using a combine harvester and a weigh rig. Ten stalks were taken from the middle row of each plot immediately before harvest for determination of stalk weights and CRS.

RESULTS AND DISCUSSION

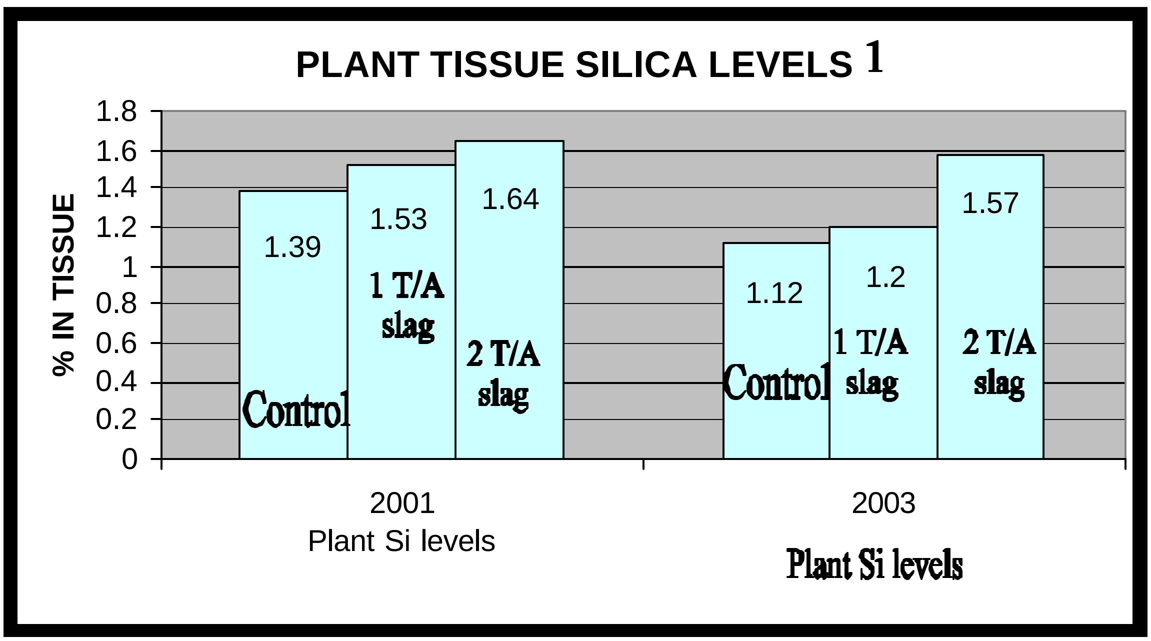
Sugarcane benefiting from the incorporation of calcium silicate slag, either one or two tons/acre, into the soil before planting or underneath the planted seed produced significantly ($P<.03$) more tons of cane per acre, as an average of the plant cane and both stubble crops, than the check. The significantly higher tonnage resulting from the application of 2 tons/acre of calcium silicate slag compared to the 2 tons/acre calcitic lime treatment is an indication that the yield response was silica induced and not calcium induced.

Ongoing research elsewhere in the AgCenter is attempting to correlate soil silica levels with plant response. Analyses needed to identify silica deficient soils are being evaluated for our environment.

Table 1. The effects of treatments on the yields of LCP 85-384 average over three crops in the cycle.

Treatment no.	Lime	Silica slag[1]	Placement	Sugar	Tonnage
	T/A	T/A		Lb/A	T/A
1	0	0	-	9,303	35.9
2	1	0	Mixed into rows	9,104	35.3
3	2	0	Mixed into rows	9,039	36.4
4	0	1	Mixed into rows	9,599	37.6
5	0	2	Mixed into rows	10,260	39.7
6	0	1	Placed under cane	9,671	39.2
LSD (.05) =				NS	3.01

[1] = Soil test indicated silica was critically (13.5 ppm) deficient.



1 - Data provided by Pro-Chem

EFFECT OF ZINC FERTILIZATION ON SUGARCANE (LCP 85-384) YIELDS

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SUMMARY

Two field experiments were conducted in 2003 to test the effects of zinc fertilizer application on sugarcane yield. One acid and one calcareous soil that tested low in available zinc by DTPA method were chosen for the study. Ground application of zinc (Zn) as zinc sulfate ($ZnSO_4$) at 4-8 lb/A significantly (P<0.05) increased cane and sugar yields of LCP 85-384 by 27-32% in acid Dundee soil and by 23-26% in calcareous Jeanerette soil. Zinc spray treatment increased yields at both sites but only statistically significant at acid soil site (by 23 and 29% for cane and sugar). These test results suggest that Zn application as $ZnSO_4$ in Louisiana soils low in DTPA test-Zn benefit sugarcane production significantly.

INTRODUCTION

Zinc is one of most important micronutrients that crops need for healthy growth. Different crops or even different varieties within a crop can have quite different Zn use efficiency and sensitivity to Zn levels in soils. Soil test with adequate calibration is a key to predict Zn deficiency or toxicity that a specific soil Zn level may impose on a crop. The benefit of Zn fertilization has been reported for sugarcane in different parts of world. However, currently there is no zinc fertilizer recommendation for sugarcane production in Louisiana. A recent survey by the LSU AgCenter Soil Testing and Plant Analysis Laboratory showed that many regions of Louisiana including sugarcane-producing areas are low to medium in soil Zn content. Therefore, an evaluation of Zn fertilization for sugarcane production is important and necessary.

OBJECTIVE

This research was designed to provide a comprehensive evaluation of Zn fertilization on sugarcane production in both acid and alkaline soils.

MATERIALS AND METHOD

One acid soil at Levert-St. John Farms, St. Martinville, and one alkaline soil at Herbert Farms, Jeanerette, were selected in this study. The acid soil was a Dundee silt loam (16% clay, 63% silt, and 21% sand). Soil tests for the Dundee silt loam showed a pH of 5.40, organic matter of 1.0%, sulfur of 5.28-6.24 ppm (low) and Zn of 0.26-0.59 ppm (low), respectively. The sugarcane at the acid soil site was first stubble of LCP 85-384. The alkaline soil was Jeanerette silt (2% clay, 88% silt, and 10% sand). Soil tests for the Jeanerette silt showed a pH of 8.1, organic matter of 1.1-1.6%, sulfur of 7.26-11.52 ppm (low-medium) and Zn of 0.21-0.35 ppm (low), respectively. The sugarcane at the alkaline site was second stubble of LCP 85-384. All plots consisted of three 6 foot by 50 foot rows. The experiment consisted of 5 rates (0, 4, 8, 16, and 32 lb Zn /A) of solid zinc sulfate ($ZnSO_4$) ground application, and one rate of spray application (1.2 lb Zn/A as 0.5% liquid $ZnSO_4$). One rate of sulfur (18 lb S/A) as gypsum was also used to check the effect of sulfur caused by $ZnSO_4$. All ground treatments were applied to the inner off-bar of each plot row. All plots also received equal amounts of N and P based on soil tests. All treatments were replicated four times. Ground applications were carried out before May 8, 2003, and spray applications before July 3, 2003. The plots were harvested on November 14 and 19, 2003, respectively. The numbers of millable stalks in each sugarcane plot were counted. Twenty stalks were randomly selected from each plot to measure average stalk weight and commercially recoverable sugar (CRS).

RESULTS AND DISCUSSION

The results are shown in Tables 1 and 2. Ground application of zinc as $ZnSO_4$ at 4-8 lb/acre significantly (P<0.05) increased cane and sugar yields by 27-32% in acid Dundee soil (Table 1) and by 23-26% in alkaline Jeanerette soil (Table 2). Because of micronutrient dichotomy, application of Zn > 8 lb/acre showed apparent yield reduction, even though no visible symptom was observed. Optimum rate may be further fine-tuned by applying smaller increments of Zn rates between 2-10 lb/acre. Spray treatment increased sugarcane yields at both sites but only statistically significant (P<0.05) at the acid soil site (by 23% and 29% for cane and sugar, respectively). Application of sulfur also significantly (P<0.05) increased both cane and sugar yields by 27-31% in the acid soil and 19-21% in the alkaline soil. Previous study found that sulfur application was most effective in heavy-textured soils. This study showed that application of sulfur in light- to medium-textured soils can also increase sugarcane yields. The sulfur treatment (18 lb/A) applied as gypsum corresponded to the amount of sulfur brought in by the highest Zn treatment. Since 4-8 lb/A of zinc application as $ZnSO_4$ brought in only 2.25-4.5 lb/A of sulfur (a much smaller amount than normal sulfur application), it would be reasonable to attribute all the yield effect to Zn. Nonetheless, the study could not rule out a possible effect of zinc-sulfur interaction on sugarcane yields. Further study is needed to demonstrate if this interaction exists. Overall one-year result of this study suggests that zinc application as $ZnSO_4$ in Louisiana soils low in DTPA test-Zn benefit sugarcane production significantly. DTPA test, a common test used for alkaline soils, worked well also for predicting Zn deficiency in acid soils for sugarcane.

ACKNOWLEGMENTS

This research was supported in part by a grant from the American Sugar Cane League.

Table 1. Effect of Zinc and Sulfur fertilizer on first stubble cane grown in acid Dundee soil.

Treatment	Pop	Stalk wt.	CRS	Cane yield (weighed)	Sugar yield
Lb Zn /A (as $ZnSO_4$)	1000/A	lb/stalk	lb/T	T/A	lb/A
0	19.3	2.11	231.3	18.9	4344
4	19.7	1.83	240.5	23.4	5637
8	19.1	2.15	240.5	24.0	5763
16	19.9	1.71	234.0	19.8	4615
32	18.3	1.97	234.0	19.8	4645
Spray (0.5% $ZnSO_4$)	20.5	1.75	240.2	23.4	5608
18 lb Sulfur /A	18.9	1.91	237.3	24.1	5709
LSD 0.05	NS	0.3	NS	5.0	1233

Table 2. Effect of Zinc and Sulfur fertilizer on second stubble cane grown in alkaline Jeanerette soil.

Treatment	Pop	Stalk wt.	CRS	Cane yield (estimated)	Sugar yield
Lb Zn /A (as $ZnSO_4$)	1000/A	lb/stalk	lb/T	T/A	lb/A
0	37.9	1.30	211.0	24.4	5161
4	42.9	1.45	211.4	31.1	6541
8	41.4	1.44	215.3	29.8	6384
16	41.1	1.39	213.7	28.4	6070
32	38.5	1.35	217.0	26.0	5639
Spray (0.5% $ZnSO_4$)	38.7	1.40	211.7	27.3	5742
18 lb Sulfur /A	39.2	1.46	215.1	29.0	6243
LSD 0.05	4.4	NS	NS	5.1	1069

IMPACT OF PAPER MILL SLUDGE ON SUGARCANE PRODUCTION AND YIELDS

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ABSTRACT

Soil amendments can improve soil fertility and provide a reasonable means of disposing of some industrial by-products. The objective of this study was to determine the effect of paper mill primary clarifier sludge on sugar and cane yields when applied to fallow fields and subsequently planted to sugarcane. The experimental design was a randomized complete block design with a split plot arrangement of treatments. The paper mill sludge was applied at rates of 0, 22.5, and 44.7 Mg tons per hectare and served as whole plots. Spring (0-0-0, 90-0-0, and 180-0-0) and starter (0-0-0 and 17-50-50) fertilizer treatments (kg/ha) were the subplots. Spring fertilizer treatments produced significant responses for sugar yield, cane yield, and sucrose content in the stubble crops only. Sludge and starter fertilizer treatments did not affect sugarcane yields significantly. The significant crop by sludge by spring fertilizer application interaction showed that in the first-stubble crop, the highest sludge and the highest spring fertilizer rates produced significantly less sucrose content. Excess nitrogen can delay maturity in sugarcane. Therefore, if sludge is applied to sugarcane in Louisiana, less fertilizer nitrogen can be applied to the first-stubble crop. In the second-stubble crop, sludge and spring fertilizer rates did significantly affect sucrose content. Paper mill sludge appears to be a suitable soil amendment for sugarcane grown in Louisiana.

INTRODUCTION

The organic matter content of most Louisiana soils is considered low by most standards. Generally speaking, increased organic matter in the soil will increase water- and nutrient-holding capacity, improve water percolation through the soil, improve tilth, and reduce erosion. These factors can cause improved plant survival and growth. The result can be increased yields with lowered fertilizer requirements and less soil, pesticide, and nutrient loss in runoff.

Research has been conducted in the past to determine the effect of several soil amendments on sugarcane production. Viator et al. (2002) showed a neutral effect of municipal compost on cane and sugar yield when subsoiled into the row rather than placed onto the row. The authors also determined that by-product gypsum did not significantly raise or lower cane and sugar yield when applied at rates of 2.24, 4.48, and 8.96 Mg/ha. Other research has shown cane and sugar yield increases following the addition of organic amendments to soils (Bevacqua and Mellano, 1994 and Hallmark et al. 1995).

Golden (1983) summarized results from 1975 through 1979 for by-product gypsum experiments conducted in Louisiana. He found average cane yield increases ranging from 1.67 tons/acre for the plant-cane crop, 3.31 tons/acre for the first-stubble crop, 3.73 tons/acre for the second-stubble crop, and 4.84 tons/acre for the third stubble crop. Golden concluded that by-product gypsum was a suitable fertilizer source for S fertilizer. Sometimes the gypsum response can be erratic. Viator et al. (2002) determined that by-product gypsum did not significantly raise or lower cane and sugar yield when applied at rates of 2.24, 4.48, and 8.96 Mg/ha.

Golden (1975) reported on the application of filter press mud to sugarcane fields. Filter press mud is a by-product of sugar processing after juice clarification. It is primarily composed of field soil. Golden reported that filter press mud is high in total nitrogen, extractable phosphorus and potassium, calcium and magnesium. Application of filter press mud increased both cane and sugar yields in Louisiana. It was noted that weeds increased where filter press mud was applied.

Paper mills collect large volumes of short fiber (sludge) in the paper-making process in their wastewater treatment plants. This material is primarily composed of partially digested cellulose and hemi-cellulose fibers and algae bodies with some residual lime. It is a convenient material to use and apply. The paper industry is seeking ways to use this material rather than landfill the large volumes it produces. Paper mill fiber residue has been used as mulch, a lime source, and an amendment to increase soil organic matter content. Therefore the objective of this research was to determine the effects of primary clarifier sludge on sugarcane yield and soil.

MATERIALS AND METHODS

The paper mill primary clarifier sludge was obtained from Georgia-Pacific Corporation, Port Hudson Operations, 1000 West Mount Pleasant Road, Zachary, Louisiana. The paper mill primary clarifier sludge is material derived from the kraft pulping and elemental free chlorine free bleaching process with non-ink paper, bath tissue, and towel machine operations. The material is clarified in two primary clarifiers and dewatered to about 60% moisture content using screw press equipment.

The experimental design was a randomized complete block (four replications) with a split plot arrangement of treatments. Sludge treatments (0, 22.5, and 44.7 Mg tons per hectare) were the whole plots. Starter fertilizer treatments (0 and 17-50-50) and spring nitrogen treatments 0-0-0, 90-0-0, and 180-0-0 (kg/ha) were the subplots. The soil type at the experimental site was a Commerce silt-loam (fine-silty, mixed, nonacid, thermic Aeric Fluvaquent). Each of the 18 plots per replication was two rows wide (3.7 m) by 7.3 m long with a 1.2 m buffer between plots. Sludge and starter fertilizer treatments were applied in the furrow at planting on October 16, 2000, and spring nitrogen treatments were applied in early April of each crop year (2001 – 2003). Standard cultural practices were applied to the experimental area with respect to cultivation and the control of weeds and insect pests (Legendre, 2001).

Ten-stalk samples, taken at random along the row, were removed from each plot on December 3, 2001, in the plant-cane crop, December 18, 2002, in the first-stubble crop, and November 6, 2003, in the second-stubble crop. All stalks were stripped of all leaves and topped approximately 10 to 12 cm below the apical meristem bud. Data collected and/or calculated included mean stalk weight, Brix by refractometer, sucrose by polarimetry, purity as the ratio of sucrose to Brix, and the yield of theoretical recoverable sugar per mass of cane (g/kg) (Gravois and Milligan, 1992). Plots then were harvested on the same dates by a cane combine (Cameco Model 2500) operating at approximately 5.6 k per hour and an extractor fan speed of 950 rpm. All cane from each plot was weighed in a wagon fitted with load cells and the weights recorded. From these data, the cane yield (Mg/ha) and sugar yield (Mg/ha) were calculated for each plot. The data were analyzed with a mixed model analysis (SAS 8.2 PROC MIXED). Least square means were calculated and separated using least square mean probability differences ($P = 0.05$).

A sample of the primary clarifier paper mill sludge was analyzed for chemical content and properties at the LSU AgCenter Soil Testing Laboratory (Sample No. AH01166). The soil at the experimental site was sampled prior to the application of the treatments (September 2000), seven months later (April 2001), and at the conclusion of the experiment (January 2004). Soil samples were also analyzed at the LSU AgCenter Soil Testing Laboratory in the Agronomy and Environmental Management Department, Baton Rouge, Louisiana. Data collected for various soil parameters included pH, macro and micro nutrient content as well as organic matter content.

RESULTS AND DISCUSSION

The chemical analysis of the primary clarifier paper mill sludge is shown in Table 1. The paper mill sludge is high in organic matter along with a relatively high pH. With the exception of calcium, the macronutrient content of the paper mill sludge was low.

Soil test results just before and after the application of the paper mill sludge are shown in Table 2. It appeared that the pH of the soil showed only a slight increase at the 44.7 Mg sludge rate approximately seven months following the application. Further, there was an increase of over 35% (1365 to 1855 ppm) in the available calcium from the 0 to the 44.7 Mg rate when sampled in April following the sludge application the previous October. There was also a 48% increase (25 to 37 ppm) in available sodium comparing the 44.7 Mg rate to the control. The increase in available calcium and sodium for the 22.5 Mg rate was intermediate between the 0 and 44.7 Mg/ha rate. There appeared to be no effect of paper mill sludge on the availability of K, Mg, and P at either the 22.5 or 44.7 Mg rate. Further, there was a numeric increase for organic matter in the April 2001 sampling date as sludge rate increased (0.97% to 1.22% for the 44.7 Mg rate). Paper mill sludge increased soil pH only slightly.

January 2004 soil test results showed a numeric increase in soil pH as sludge rates increased (7.0 to 7.8), which corresponded to the increase in concentration of calcium. The paper mill sludge increased soil pH. Application of paper mill sludge would not be necessary because of the already higher soil pH at the beginning of the experiment. Increasing soils with inherent high pH might cause other problems such as rendering phosphorus unavailable to the sugarcane plant. By the conclusion of the experiment, soil tests indicated that the other macronutrients and organic matter content did not seem to be affected by the paper mill sludge treatments.

Mixed model analysis of fixed effect terms for the experiments conducted at the St. Gabriel Research Station for the three crops of the sugarcane variety LCP 85-384 is shown in Table 3. The main effect crop in the analysis was significant (P=0.05) for sucrose yield, cane yield, and sucrose content. In this experiment, crop and year are confounded. Nutrient response can be both soil and crop specific (Golden and Abdol, 1977). They summarized that the greatest yield response is observed with nitrogen, followed by potassium responses on light to medium textured soils, and then phosphorus responses on medium-heavy to heavy textured soils. Plant cane crops tend to respond less to nitrogen and potassium applications. The duration of this experiment included one of the wettest weather patterns recorded during the 2002 harvest. Sucrose levels in 2002 were low because of lodging. However, the test in 2002 was harvested under good harvest conditions.

Spring fertilizer treatments produce significant responses for sugar yield, cane yield and sucrose content. In contrast, starter fertilizer treatments did not significantly affect any yield component. Response to starter fertilizer in sugarcane grown in Louisiana has been inconsistent. The crop-by-spring interaction was significant for sugar yield, cane yield, and sucrose content. In addition, the three-way interaction (crop-by-sludge treatment-by-spring fertilizer) was significant for sucrose content. Thus, means were reported by each main effect combination as the interaction dictated.

For the plant-cane crop, there were no significant sugar yield or cane yield differences caused by spring nitrogen applications (Table 4). Both stubble crops exhibited significant sugar yield and cane yield decreases when no nitrogen was applied. Cane yield and sugar yield were not significantly different at the 180 kg/ha nitrogen rate when compared to the 90 kg/ha nitrogen rate. This result is consistent with work done by Kennedy et al. 2003, who showed that LCP 85-384 had a greater nitrogen use efficiency at lower nitrogen rates than other Louisiana sugarcane varieties such as CP 70-321 and HoCP 91-555. Because of a nonsignificant spring fertilizer-by-sludge interaction, it appears that the paper mill sludge was not a useful fertilizer supplement that affected either sugar yield or cane yield.

Means by crop, sludge treatment, and spring fertilizer application for sucrose content are reported in Table 5. In the plant-cane crop for the 0 and 22.1 Mg/ha sludge rates, the 90-0-0 spring fertilizer treatment had significantly less sucrose content than the 180-0-0 treatment. In the first-stubble crop for the 44.7 Mg sludge rate, the 180-0-0 spring fertilizer rate had significantly less sucrose content than the 0-0-0 and 90-0-0 spring fertilizer treatments. This indicated that the first-stubble crop may have obtained additional nitrogen from the high sludge treatment. Excessive nitrogen can delay maturity in sugarcane, resulting in lower sucrose content. These data indicated that nitrogen rates could be reduced when high rates of paper mill sludge are applied to sugarcane to avoid delayed sugarcane maturity. In the second-stubble crop, sludge and spring fertilizer rates did affect sucrose content significantly.

It is interesting to note that there was no significant deleterious effect of the paper mill sludge on any of the yield components. This, in itself, is considered positive because many un-stabilized organic amendments can actually show a negative impact on crop yield the year of application. The paper mill sludge could be applied to increase soil pH with no apparent effect on the sugarcane crop. In fact, the data indicate that nitrogen fertilizer rates in the first-stubble crop could be reduced with sugar yields being maintained.

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REFERENCES

1. Bevacqua, R.F., and V.J. Mellano. 1994. Cumulative effects of sludge compost on crop yields and soil properties. Commun. Soil Sci. Plant Anal. 25:395-406.
2. Golden, L.E. 1975. Effect of filter press mud on yield and nutrition of sugarcane. Sugar Bull., 53(20):12-19.
3. Golden, L.E. and I.B. Abdol. 1977. Effects of N and K fertilizers and soil type on yield components and nutrient uptake of four sugarcane varieties. Louisiana Agric. Exp. Station Bull. 700.
4. Golden, L.E. 1983. Twenty-five years of research in soil fertility and nutrition studies with sugarcane in Louisiana. Louisiana Agric. Exp. Stn. Agronomy Research Report 78.
5. Gravois, K.A. and S.B. Milligan. 1992. Genetic relationships between fiber and sugarcane yield components. Crop. Sci. 32:62-66.
6. Hallmark, W.B., S.E. Feagley, G.A. Breitenbeck, L.P. Brown, X. Wan, and G.L. Hawkins. 1995. Use of composted municipal waste in sugarcane production. Louisiana Agric. 38:15-16.
7. Kennedy, C., A. Arceneaux, B. Hallmark, B.L. Legendre, R. Ricaud, H. Cormier, J. Flannigan, J. Garrett, A. Guidry, B. Joffrion, and R. Louque. 2003. Soil fertility research in sugarcane in 2002. Sugarcane Research Annual Progress Report 2002, Louisiana State University, Agricultural Center, Baton Rouge, LA.
8. Legendre, B.L. 2001. Sugarcane Production Handbook – 2001. Louisiana State University Agric. Center Pub. 2859.
9. Viator, R.P., J.L. Kovar, and W.B. Hallmark. 2002. Gypsum and compost effects on sugarcane root growth, yield, and plant nutrition. Agron. J. 94:1332-1336.

Table 1. Chemical analysis of the primary clarifier paper mill sludge as analyzed by the LSU AgCenter Soil Testing Laboratory.

Analytical Parameter	Unit
Moisture content	56%
Organic matter (primarily pulp fiber)	43%
pH	9.2
Nitrogen	0.045%
Phosphorus	0.029%
Potassium	0.051%
Calcium	3.050%
Magnesium	0.108%
Sulphur	0.148%

Table 2. Soil test results conducted at the LSU AgCenter Soil Testing Laboratory for the experimental area (Commerce silt-loam) where the paper mill sludge was applied at the St. Gabriel Research Station.

	Sludge		Ca	K	Mg	Na	P	Bases	OM
Sample date	(Mg/ha)	pH	ppm					(meq/100g)	(%)
Sept. 2000†	0	7.1	1455	94	317	26	349	10.2	1.21
April 2001	0	7.3	1365	95	315	25	324	9.8	0.97
April 2001	22.5	7.4	1510	91	307	33	326	10.4	1.13
April 2001	44.7	7.4	1855	108	347	37	333	12.6	1.22
February 2004	0	7.0	1552	97	328	35	253	10.9	1.10
February 2004	22.5	7.4	1673	99	320	30	269	11.4	0.99
February 2004	44.7	7.8	2062	102	317	35	289	13.3	1.20

† The soil was sampled prior to the application of the paper mill sludge.

Table 3. Mixed model analysis of fixed effect terms for the experiments conducted at the St. Gabriel Research Station for the three crops of the sugarcane variety, LCP 85-384.

Source	Num df	Den df	Sugar yield (Mg/ha)	Cane Yield (Mg/ha)	Sucrose content (g/kg)
				Pr > F	
Crop	2	25	<0.001	<0.001	<0.001
Sludge	2	25	0.59	0.45	0.25
Starter	1	125	0.58	0.36	0.91
Spring	2	125	<0.001	<0.001	0.01
Crop*Sludge	4	25	0.73	0.91	0.47
Crop*Starter	2	125	0.31	0.46	0.23
Crop*Spring	4	125	<0.001	<0.001	0.04
Sludge*Starter	2	125	0.95	0.60	0.41
Sludge*Spring	4	125	0.44	0.44	0.42
Starter*Spring	2	125	0.50	0.54	0.59
Crop*Sludge*Starter	4	125	0.61	0.41	0.15
Crop*Sludge*Spring	8	125	0.66	0.60	0.04
Crop*Starter*Spring	4	125	0.44	0.33	0.07
Crop* Sludge*Starter*Spring	12	125	0.72	0.53	0.82

Table 4. Spring fertilizer treatment means across starter fertilizer and sludge treatments for sugar yield and cane yield for the three crops grown at the St. Gabriel Research Station.

Fertilizer Rate (kg/ha)	Sugar yield		Cane Yield	
	(Mg/ha)			
Plant cane				
0-0-0	9.57	A	98.8	A
90-0-0	9.36	A	98.7	A
180-0-0	9.46	A	96.7	A
First-stubble				
0-0-0	8.94	B	66.5	B
90-0-0	9.61	A	73.5	A
180-0-0	9.80	A	76.5	A
Second-stubble				
0-0-0	5.44	B	45.5	B
90-0-0	9.22	A	78.6	A
180-0-0	9.60	A	81.4	A

Table 5. Spring fertilizer by sludge treatment means across starter fertilizer treatments for sugar yield and cane yield for the three crops grown at the St. Gabriel Research Station.

	Sludge Rate (Mg)					
Crop (Spring Fertilizer Rate)	0		22.1		44.7	
	Sucrose Content (g/kg)					
Plant cane (0-0-0)	99.4	AB	95.4	AB	96.1	A
Plant cane (90-0-0)	96.4	B	92.2	B	96.4	A
Plant cane (180-0-0)	100.4	A	97.9	A	95.3	A
First-stubble (0-0-0)	133.7	A	134.8	A	135.4	A
First-stubble (90-0-0)	127.8	A	133.9	A	130.2	AB
First-stubble (180-0-0)	133.2	A	129.4	A	121.6	B
Second-stubble (0-0-0)	121.7	A	119.4	A	118.7	A
Second-stubble (90-0-0)	119.0	A	117.0	A	116.3	A
Second-stubble (180-0-0)	116.9	A	116.6	A	119.7	A