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PRESIDENT'S MESSAGE
FLORIDA DIVISION

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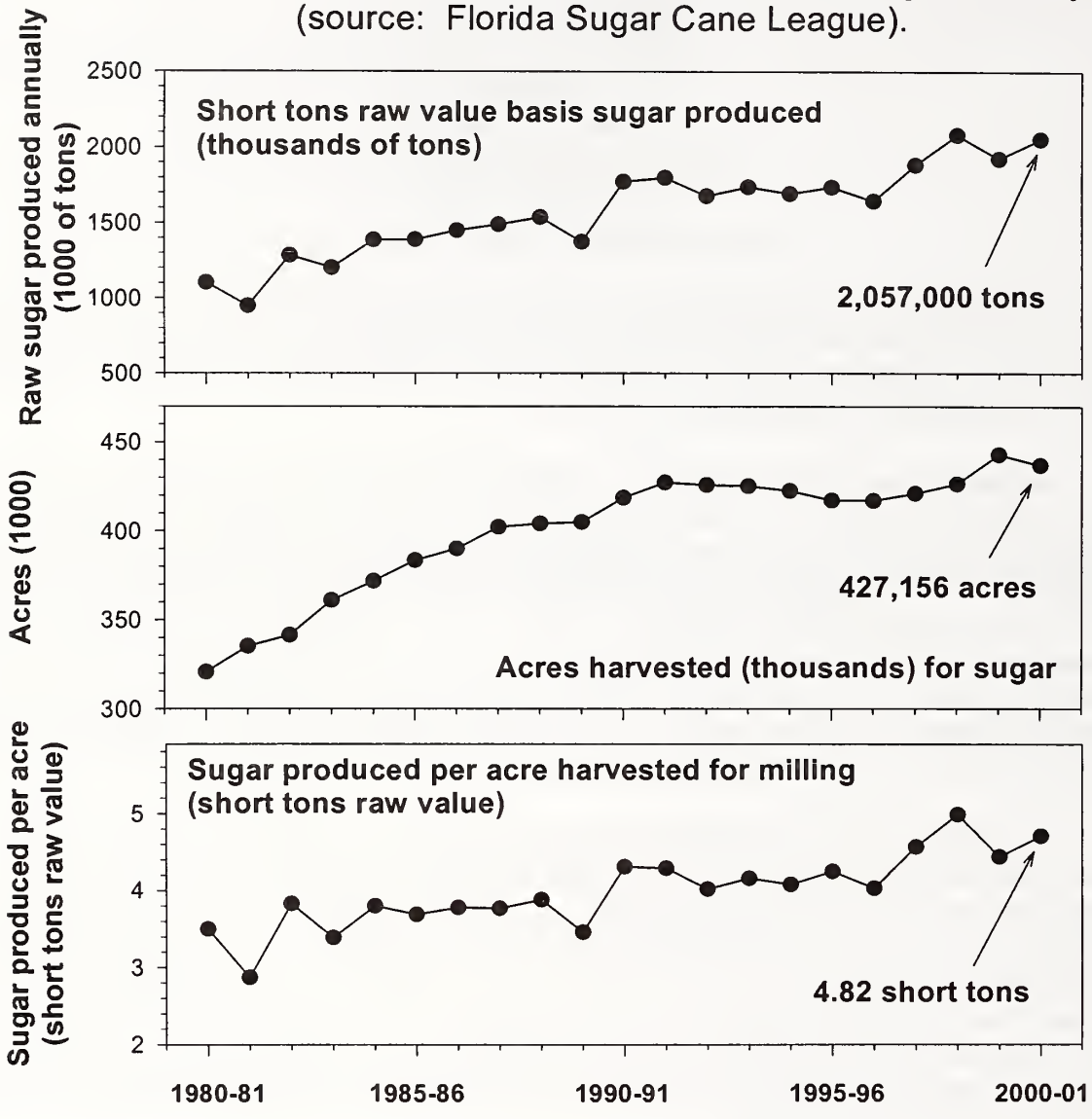
On behalf of the Florida Division of the American Society of Sugar Cane Technologists, I bring the Louisiana Division greetings and thanks for hosting this year's annual joint meeting. To my Florida colleagues, I thank you for giving me the opportunity to serve as your president this year. It has been a privilege and an honor.

Following our Society's tradition, I offer the following summary of the harvest season just completed in Florida. A total of 445,202 acres of cane was grown in Florida this past season, of which 427,156 acres were harvested for sugar. The first mill to begin grinding started on October 12, 2000, and the last mill to complete its crop finished on April 7, 2001. The 2000-2001 harvest season therefore spanned 177 days. On an individual mill basis, the shortest grinding season was 125 days and the longest was 172 days, with an average of 153 days across Florida's six mills. Two back-to-back hard freezes occurred during early January 2001, about mid-way through our harvest season. These freezes forced growers and mills to quickly prioritize the order in which to harvest the remaining fields.

The 2000-2001 harvest season was our second largest over the last 20 years with respect to raw sugar produced (Figure 1). According to records compiled by the Florida Sugar Cane League for the 2000-2001 harvest season, Florida sugarcane growers and mills produced 2,057,000 short tons raw value basis sugar and 106,500,000 gallons of 79.5° final molasses from 17,320,000 gross tons of cane. The average sugar recovery per net ton of cane was 251.7 pounds. The average cane yield for the harvest season was 40.6 gross tons of cane per acre with an average yield of 9,435 pounds of 96° sugar per acre. The January freezes reduced overall yield during the 2000-2001 harvest season and have hurt the yield potential of cane being grown for the 2001-2002 harvest season.

As every ASSCT member knows, the price of raw sugar took a dive early during 2000, dropping to a record low of 16 cents per pound of raw sugar. Although prices have improved somewhat, economists forecast that we may never again see raw sugar above 20 cents per pound. A permanent, large drop in value may occur if the sugar policy in the Farm Bill is not revamped, if the North American Free Trade Agreement (NAFTA) problems with Mexico are not resolved, and if the importation of molasses stuffed with sucrose from Canada continues.

Figure 1. Some harvest figures for the Florida sugar industry (source: Florida Sugar Cane League).



If sugarcane growers in the United States find themselves living with a permanently depressed sugar market, we will have to scramble to find ways to enhance productivity and reduce production costs. In this event, a number of avenues could be explored for both the milling and agricultural sides of our industry. These avenues include increased automation and mechanization; decision-making computer models; modified agronomic systems; biotechnology; and enhanced biological systems. In the face of these challenges (and because I am an entomologist), I would like to share with you a few thoughts about pest control. An underlying stimulus for my comments was the following question: If sugar prices drop, how can we reduce losses to pests and simultaneously reduce our expenditures on pest control without sacrificing productivity?

Pest problems in our sugarcane fields fluctuate from year-to-year and from decade-to-decade. This is true with respect to the specific pest species, the intensity of their damage, and

the regional spread of their infestations. Each of us knows the particular complex of pest species we need to be concerned about. Just because 1999 or 2000 was a light year with respect to infestations and damage by these pests does not mean they have gone away.

Wireworms are currently the most important insect pests of sugarcane in Florida. Fortunately, chemical control tactics for wireworms are effective. Two granular organophosphates are labeled for wireworm control: ethoprop (Mocap) and phorate (Thimet). Unfortunately, due to factors such as the Food Quality Protection Act passed by Congress and supported by our industry, the sugarcane labels for these two pesticides could soon be in jeopardy, perhaps as early as this year. Our industry therefore needs to be searching for alternatives. I call upon our universities, the United States Department of Agriculture and our friends in the chemical industry to assist us with this.

Florida sugarcane growers usually apply a pesticide for wireworm control once every three to five years when they plant a field unless they are planting after rice. The extent to which these insecticide applications are needed remains unclear. Growers would like to reduce their dependency and expenditures on insecticides for wireworm control in Florida, but they need help from scientists to do this.

The lesser cornstalk borer continues annually to be a common pest in some Florida sugarcane fields. Management guidelines and emergency control tactics are currently not available for this pest in sugarcane. We could use help from our universities, the USDA and the chemical industry in coming up with an effective, affordable management program for the lesser cornstalk borer.

The sugarcane borer is recognized as being a more important economic pest in Louisiana than in Florida. However, growers need to remember that the borer does cause economic losses in Florida sugarcane. Granted, the borer causes larger economic losses during some years than others, and outbreaks are more likely to occur in some areas than others. Some Florida growers lose money to the sugarcane borer, but they don't know it because they don't scout. While emergency control tactics are available for the borer, the cost of these in conjunction with the cost of a traditional scouting program may not be profitable during some years except in localized areas. Monitoring methods less expensive than traditional scouting might help with this problem.

This is the new millennium, the age of new and constantly changing technologies, computers and computer modeling. Researchers working in sugarcane pest control should take greater advantage of these technologies. It is possible that growers and scouting companies could reduce pest management costs and achieve satisfactory levels of pest control using technologies such as remote sensing and computer modeling to predict pest outbreaks in conjunction with either traditional scouting methods or new, nontraditional monitoring methods.

We have a good handle on control thresholds for two insects, the sugarcane borer and the sugarcane wireworm. We could use similar information for other insects pests such as the lesser cornstalk borer. Regardless of the particular insect pest, control thresholds need to be based not only on the value of pest damage but also on the costs of control and scouting. As the sugar

price decreases, the economic thresholds for pests increase. At or below some market value of sugar, pests may no longer cause economic losses large enough to justify expenditures on frequent scouting and emergency control, particularly if the cost of scouting and control increase. This would elevate the need for less expensive approaches to detecting and managing losses to pests. The development and implementation of low-cost, low-input management strategies such as pest-resistant clones and biological control could become critical.

Providing growers with sugarcane clones resistant to pests has been and will continue to be one of our most important strategies for pest control. This tactic could become essential for insect control if the market value of sugar drops. Louisiana has capitalized on plant resistance to the sugarcane borer, at least in the past. Economic damage by other pests--including the yellow sugarcane aphid and the lesser cornstalk borer--might be significantly reduced by growing varieties with even modest levels of pest resistance. Compromises may be necessary between yield and pest resistance. Conventional plant breeding programs need to be continued with increased emphasis on pest control. Although we do not know if or when we might be willing to market sugar from a genetically modified sugarcane, I believe we need to be developing transgenic clones with pest resistance and be prepared to implement them commercially.

Finally, the importance continues in intercepting sugarcane pests new to the United States. Four pests new to Florida sugarcane have been found over the past 25 years: the sugarcane aphid *Melanaphis sacchari*; the sugarcane delphacid *Perkinsiella saccharicida*, the sugarcane lacebug *Leptodictya tabida*, and the weevil *Metamasius hemipterus*. I commend Federal and State agencies for their daily efforts to catch exotic pests being imported into Florida, though increased resources are needed for these agencies to accomplish the job. This critical function is becoming harder and harder as foreign travel increases and more airports and marine ports accept foreign travel. Quarantining foreign plant material imported for scientific reasons remains critical. Ornamental and horticultural plants being brought into the United States must be screened for sugarcane pests. We need to support continued funding of quarantine facilities such as the APHIS Federal quarantine center in Beltsville and ensure they use the most modern methods available to protect our industry. With respect to sugarcane pests already present in some areas of the United States, let's guard against spreading them to other areas.

In summary, certain sugarcane pests continue to reduce the profitability of growing sugarcane in Florida and will continue doing so if management tactics are not fully developed and used. Non-chemical control methods are needed for sugarcane wireworms in Florida but, until these are available, we need to ensure chemical control methods remain available. If the market value of sugar decreases, expenditures on pest control will need to be reduced without decreasing productivity in order to maintain profits. This can only be accomplished through the development of new low cost, low input management tactics. The members of this society have the expertise to address these issues. In the meantime, let's hope no new insect pests of sugarcane find their way into the continental United States.

I thank you for your attention and hope that this 31st Annual Meeting of the American Society of Sugar Cane Technologists is one of our most fruitful.

PRESIDENT'S MESSAGE
LOUISIANA DIVISION

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On behalf of the members of the Louisiana Division of the American Society of Sugar Cane Technologists, I would like to express my most sincere welcome to the Florida division of the Society to the Thirty-First Annual Joint Meeting at New Orleans, Louisiana. I would also like to welcome all of the friends and family members of the Society and give thanks for their enduring support to what I consider the sweetest industry in the world. I will say with the highest degree of confidence that this year's meeting will engage prolific ideas and technology exchange to continually advance the U.S. Mainland sugarcane industry.

In reading the production report for the year 2000 in Louisiana, an anticipated record year turned into only a good year even though the Louisiana industry produced the second largest crop in the state's history. Eighteen factories producing 1,565,848 tons of sugar, raw value, ground a total of 15,497,457 tons of cane. This is about 100,000 tons of sugar less than 1999 record production with sugar recovery also dropping from 10.40% in 1999 to 10.10% in 2000. Approximately 460,000 acres of cane, a new state record, were harvested yielding a cane production of 33.7 tons per acre, down from 37 tons per acre the previous year.

The decline in production from the previous year can be summed up into one word, DROUGHT. The winter months of 1999 and 2000 were relatively dry and mild. This was ideal weather for the harvest season for 1999. Lay-by at the beginning of 2000 went very smoothly due to the dry conditions. With a record amount of acreage in cane and a mild winter behind them, the Louisiana sugarcane farmer was anxiously awaiting a record-shattering crop. The only two ingredients needed were rain and sunshine. The scorching sunshine did its job enthusiastically, while the timely rains took a long summer vacation. Drought conditions had carried over from 1999 and put a choke hold on South Louisiana in 2000. For some areas, 30-inch deficits were noted by September. The cane was stressed and below the average height nearing the end of the growing season. The new prediction for the 2000 harvest was as much as 20% below the earlier estimates. Finally, the rains did come but in September, which brought about an abnormally late growth period. Tonnage looked as though it would recover but sucrose content was sacrificed because of the late growth spurt. Natural ripening was delayed and the response to the chemical ripener, glyphosate (Polado) was reduced especially during the early weeks of the harvest. Sucrose content made a valiant, come- from- behind charge to present a respectable yield of 10.10% by the end of the crop; however, sucrose levels took a nose dive following a killing freeze on December 20. There were small areas in the state that received some timely rainfall and benefitted from early applications of Polado, which in turn increased sucrose yield from the start of the crop and continued through the end.

What's in the crystal ball for the Louisiana sugar industry? We must address the issues that are of major importance in the United States and in the world today. Look up the spot price on sugar

today and it is virtually unchanged from twenty years ago. Who among us would not love to go out and buy a new F-150 for ten thousand dollars or experience unchanged grocery prices over the last two decades. Reflect back a mere five years ago and track the retail prices of food that contain substantial amounts of sugar. Breakfast cereal prices are up 4%, candies, cakes and cookies up 8%; and ice cream up 14%. Sadly, we are all well aware of the stagnant price of sugar during the same time period. The food manufacturers have the audacity to cry to the legislature that the price of sugar is hampering their profits. There are a number of factors that deter us from true economic supply and demand. The current U.S. trade agreements that allow importation of up to 1.5 million tons of sugar from forty-one countries can easily exceed the demand, thus suppress prices. In addition, the United States quota system never envisioned sugar being smuggled into the country by way of "stuffed molasses" or other desugarization products. It will be a tough battle, but it appears our friends in Washington can potentially resolve these and other issues to bring a stable and fair market value to the sugar we produce, especially if we resolve to add our voices to their efforts.

What can be done here at home? Over the past ten years, our number one priority as producers was to increase volume. Put as much cane through our mills as possible and try to keep losses in sucrose to an acceptable Louisiana level. Various alterations were utilized to achieve record volumes, for instance, starting the harvest season earlier and finishing later, and acquiring larger process machinery. We were aware that these early starts could result in immature cane, low sugar content, and problems in the factory with starches and other impurities. But, with proper applications of chemical ripeners, we were able to bring this window forward to a degree. In addition, hardier varieties developed by the Louisiana Agricultural Experiment Station, USDA-ARS and the American Sugar Cane League, working cooperatively, were less vulnerable to marginal freezes over a short period of time, providing some peace of mind on the backside of harvest. During the 2000 harvest season, Mother Nature brought an early freeze in November that caused moderate damage to the northern parishes of the state, but surprisingly, spared most of the cane in the south. However, on December 20 the entire sugarcane belt experienced a killing freeze that ultimately, with subsequent freezes the first week of January, caused a dramatic reduction in recoverable sugar by the end of the harvest. It appears that we are willing to accept this inherent risk in an attempt to achieve higher volumes. Processing records tons of cane per day in an attempt to achieve over one million tones per season became the goal of many mills.

In today's market, we must not lose sight of the potential degree of greater sugar loss when production is increased. Keeping our focus on efficiencies as well as higher volume is imperative. In 2000 we saw sugar prices plummet to a 30 year low while watching natural gas prices skyrocket. How can an industry thrive with its product price so low and fuel costs exorbitantly high? Fortunately, as we reach mid-2001, sugar prices have rebounded some and natural gas prices have dropped slightly. Nonetheless, our priority remains yielding the most sugar with a low operating cost and minimal losses. Research is an invaluable tool that can heighten our abilities and thus keep us competitive in the domestic market as well as globally. Scientists with the Louisiana Agricultural Experiment Station, USDA-ARA and the American Sugarcane League, working cooperatively, have in recent years developed outstanding, high-yielding varieties such as LC 85-384 and HoCP 85-845, which now occupy over 85 percent of our planted acreage. These new varieties, especially LCP 85-384, led to the industry switching from whole-stalk to combine harvesting; this revolutionized our harvesting methods and minimized field losses while increasing sugar per acre. Ongoing research in processing is needed now more than ever to develop new technology and improve old technology.

Reducing labor requirements by implementing automation in various processes has been and will continue to be a positive result of ongoing research.

The Louisiana sugar industry with its uniquely short grinding season can ill afford to experiment with pioneering, unproven, process equipment. Theoretically, this new equipment could improve efficiencies, but losses could be significant if the equipment fails and processing stops. There are high expectations for the resurgence of Audubon Sugar Institute to provide new product research and practical solutions. With our assistance and cooperation, Audubon is positioning itself once again to be the premier sugar institute in the world. Through its highly qualified staff, training and educating factory personnel is an integral part of ASI's commitment to the sugar industry and its future success.

The time has come for the United States sugar industry to acknowledge that we can no longer survive on a razor thin profit margin. Increasing bureaucratic regulation, increased operational costs, decreasing qualified personnel, should motivate us as an industry to define and implement a course of action to move forward and create successes. Education, communication, cooperation, and motivation are key elements for any successful businesses facing future challenges. Throughout the history of the sugar industry challenges and obstacles have plagued us in one form or another but we have always persevered, overcome, and ultimately thrived. The resolution of problematic obstacles is relative to its place in history. No era exists in this industry that was without its tribulations. The technology and resources of these eras have historically resolved the problems of a particular time and more significantly forged the industry ahead to a higher level.

Meetings such as this, where all facets of the industry come together and share ideas, studies, experiences, and technology is an integral part of the future success of our beloved industry. Sugar has been in the Legendre family for four generations; therefore, one could surmise that it is in my blood to have chosen such a profession. That may have some validity, although a deeper bond comes from the character of its associates. The willingness to help out a colleague with technical information, lend equipment and assistance to get neighboring factories back on line, is a unique quality found in no other industry. This fraternal relationship generates a passion within our industry that can only result in future prosperity for generations come.

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EFFECT OF SILICON-RICH SLAG AND LIME ON PHOSPHORUS LEACHING IN SANDY SOILS

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ABSTRACT

Phosphorus (P) contamination of natural surface and subsurface waters draining from agricultural soils is a persistent environmental and economic problem in Florida. A silicon (Si) soil amendment (Si-rich slag) and lime ($CaCO_3$) were compared to determine their effects on P leaching from cultivated Spodosols, Entisols, and Alfisols in soil columns and in greenhouse experiments with Bahiagrass (*Paspalum notatum* Fluigge) grown under various levels of P fertilization. The Si slag reduced P leaching considerably more than lime in all soils investigated. Lime transformed plant-available P into plant-unavailable forms, while Si slag maintained P in a plant-available form. In greenhouse experiments, plant growth responses were greater from Si slag-treated soil than from P fertilization. The Si slag improved P availability and had a positive effect on the development of the Bahiagrass root system. Application of Si slag to sandy soils could help reduce P leaching and the potential pollution of natural waters.

INTRODUCTION

The lack of soil nitrogen (N), phosphrous (P) and potassium (K) is a major factor limiting plant growth on native sandy soils in Florida. Commercial fertilizers containing these elements plus other macro- and microelements are used to overcome this limitation.

Sandy soils often have low P retention due to: (1) the essential lack of alumino-silicates and metal-oxide clays in the albic E horizon (Harris, et. al, 1996), and (2) the presence of a seasonal shallow water table promoting lateral P transport within the E horizon (Mansell, et al., 1991). Frequent, heavy rainfall and widespread use of irrigation and drainage may lead to leaching of 20 to 80% of added P (Campbell, et al., 1985; Sims, et al., 1998). This problem has ecological, economic and animal health consequences. Leached P promotes eutrophication of natural waters and P deficiency in plants (Richardson and Vaithiyanathan, 1995). Nutrient leaching can cause soil nutrient deficiencies, giving rise to the need for additional fertilization. The present method for reducing P leaching from sandy soils is through the use of limestone (Sims, et al., 1998). Unfortunately, lime transforms plant-available P into plant-unavailable forms (Lindsay, 1979), which increases the need for P fertilization.

Silicon-rich biogeochemically active substances (Si soil amendments) usually exhibit a high adsorption capacity for anions (Rochev, et al., 1980). They can adsorb mobile P and render it in a plant-available form (Matichenkov, et al., 1997). Preliminary column experiments showed that

the application of various Si-rich materials reduced P leaching by 30 to 90% (Matichenkov et al., 2000).

The objective of this study was to compare the effect of Si slag (a finely processed calcium magnesium silica slag, PRO-CHEM Chemical Company, FL) with lime on P leaching from soils classified as cultivated Spodosols, Entisols, and Alfisols in column and greenhouse experiments.

MATERIALS AND METHODS

Soil samples representing two soil orders were collected at the University of Florida, Indian River Research and Education Center in Fort Pierce, FL. Soil samples were selected at the depth of 0-20 cm from a cultivated Alfisol (Winder series, fine-loamy, siliceous, hyperthermic Typic Grossaqualfs) and a cultivated Spodosol (Ankona series, sandy, siliceous, hyperthermic, orstein Arenic Haplaquods). Sampling sites for the Alfisol and the Spodosol were under citrus groves. Soil samples representing a third soil order - a cultivated Entisol (Margate series, sandy, siliceous, hyperthermic Mollic Psammaquents) were collected in Hendry county in a commercial sugarcane field at the depth of 0-20 cm.

The study involved both column and greenhouse experiments. The column experiment was used to model P leaching using Si slag and lime at 10 t ha^{-1} mixed with the different soils. The plastic column had a volume of 60 cm^3 and a diameter of 2.5 cm. Distilled water or a P-bearing solution (prepared from dissolving KH_2PO_4, 10 mg P L^{-1}) was added to the column at 6-8 mL h^{-1} using a peristaltic pump. The percolate was collected in 20 mL intervals. Collected solutions were placed in a refrigerator at 4°C after adding a drop of chloroform for reduction of microbial activity. A total of 300 mL of solution was applied to each column. Each column was replicated three times and triplicate analyses were made on each liquid sample. After the leaching experiment was completed, the soils were dried at 65°C and passed through a 1-mm sieve. Triplicate soil and sand samples were analyzed for water-extractable and acid –extractable (0.1 M HCl) P. Phosphorus concentration was determined according to the method of Walsh and Beaton (1973).

The greenhouse experiment was conducted with a cultivated Entisol. The soil was mixed with Si-rich slag or lime at the rates of 0 and 10 t ha^{-1}. The P fertilizer (ground superphosphate) was applied at the rates of 0, 50 and 100 kg P ha^{-1}. One kg of treated soil was then placed into plastic pots. Bahiagrass was used as a test plant (120 seeds per pot). Each variant had 2 replications. Irrigation was conducted with distilled water. After seeding and once a week thereafter, percolate samples were collected from the bottom of each pot and analyzed. The percolates and water and acid extracts of the soil were analyzed colorimetrically for P using a spectrophotometer at a wave length of 880 nm (Eaton, et. al., 1995).

All data were subjected to a statistical analysis based on comparative methods using the $P<0.05$ value obtained from a multiple comparison test of variance and Duncan's coefficients (Parl, 1967).

RESULTS AND DISCUSSION

Irrigation with distilled water in the column experiment was intended to represent the percolation of heavy rainfall (150-mm cm^{-2}). In the Entisol, the concentration of P in the percolate

gradually decreased from 5.2 to 1.6 mg P L^{-1} in the control, from 4.8 to 1.2 mg P L^{-1} in the lime-treated soil, and from 1.5 to 0.5 mg P L^{-1} in the Si-slag-treated soil (Figure 1). Irrigation with the P-bearing solution represented both heavy rainfall and P fertilization. The Entisol soil was gradually saturated with P (Figure 2). The concentration of P in the percolate solution increased from 4.5 to 8.7 mg P L^{-1} in the control, from 2.0 to 6.6 mg P L^{-1} in the lime-treated soil and from 0.4 to 0.7 mg P L^{-1} in the Si-slag-treated soil (Figure 2).

In the Spodosol treated with Si slag or lime, the P concentration in the percolate was relatively stable under irrigation with distilled water (Figure 3), while that for the control sharply increased and then decreased. In the Spodosol irrigated with the P-bearing solution, the P in the percolate sharply increased both in the control and in the lime-treated soil, while the soil treated with Si slag showed only a small amount of P leaching (Figure 4).

Phosphorus concentration in the percolate from the Alfisol under distilled water irrigation sharply increased from 0.5 to 0.9 mg P L^{-1} in the control and from 0.3 to 0.6 mg P L^{-1} in the lime-treated soil, but stayed relatively stable (from 0.3 to 0.4 mg P L^{-1}) in the Si-slag-treated soil (Figure 5). Under irrigation with the P-bearing solution, P in the percolate gradually increased from 0.8 to 9.7 mg P L^{-1} in the control and from 0.7 to 4.5 mg P L^{-1} in the lime-treated soil, but remained stable (from 0.6 to 0.7 mg P L^{-1}) for the Si-slag-treated soil (Figure 6).

The column experiment demonstrated that Si slag adsorbed mobile P considerably better than lime and had appreciably less P leaching than the lime treatment in all soils investigated (Figures 1-6). This effect may have been caused by the action of several mechanisms. For example, Si slag contains Si, Al and Fe compounds and it is possible that both chemical and physical P adsorption mechanisms by Si slag were involved.

Application of lime or Si slag along with P fertilizer (Figure 7, 8 and 9) influenced P leaching from the Entisol soil in the greenhouse experiment. Lime by itself slightly increased P leaching from the Entisol without P fertilization (Figure 7). Lime had its greatest effect in reducing P leaching from the Entisol treated with 50 kg P ha^{-1} (Figure 8). However, Si slag showed a greater reduction in P leaching than lime at all treatment levels of P fertilization (Figure 7, 8 and 9). These data support the results of the column experiment (Figures 1-6) in that Si slag adsorbs considerably greater concentrations of mobile P than limestone.

Addition of either P or Si slag to the soil increased the mass of shoots and roots of Bahiagrass (Table 1), whereas the lime treatment either had a negative or neutral effect on grass growth. A reduction of P concentration was shown in plants receiving the Si slag treatment (Table 2). For example, P concentration in Bahiagrass shoots decreased from 404 to 309 mg P $100g^{-1}$, from 422 to 239 mg P $100g^{-1}$, and from 481 to 339 mg P $100g^{-1}$ in the treatments with 0, 50 and 100 kg P ha^{-1}, respectively. Considering the significant effects of Si slag on the Bahiagrass mass (Table 1), the decreased plant P concentration may have been a dilution effect. The content of P in the shoots and the roots after 3 months of growth were examined to see if Si slag had increased P availability to the plants. Data on total P content per 100 plants confirmed this hypothesis (Table 3). The Si slag treatment increased the total amount of P in the shoots (except at 50 kg P ha^{-1}) and roots of Bahiagrass. Conversely, lime had the opposite effect on the shoots, but not roots of Bahiagrass.

The concentration of P in Bahiagrass was higher with the control and lime treatments than with the Si slag treatment (Table 2). However, the content of P in both the shoots and roots was greater with the Si slag treatment than with the control or the lime treatment (Table 3). These data can be explained by considering the magnitude of increase in the biomass of Bahiagrass (Table 1). When compared with the control and lime treatments, Si slag application essentially doubled the biomass of shoots and increased the biomass of roots approximately 7 times. Although Si slag application resulted in a P dilution effect in the shoots and roots, the Bahiagrass absorbed more P with the Si slag treatment than with the control or the lime treatment.

Data on water-extractable and acid-extractable P in the soil after the greenhouse experiment showed that the application of Si slag allowed P to remain in a plant-available form (Table 4). Liming resulted in a reduction in P leaching (Figure 8 and 9), but mobile P apparently was transformed into plant-unavailable P. Si slag also reduced mobile P leaching, probably by adsorption on the surface, but kept P in a plant-available form. Therefore, there appears to be a strong possibility that the application of Si slag to sandy soils could preserve natural waters from P contamination and improve P plant nutrition more efficiently than lime applications.

ACNOWLEDGEMENTS

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REFERENCES

1. Campbell, K.L., J.S. Rogers, and D.R. Hensel. 1985. Drainage water quality from potato production. Trans. ASAE, 28:1798-1801.

2. Eaton, A.D., L.S. Clesceri, and A.E. Greenberg (Ed). 1995. Standard Methods for Examination of Water and Wastewater, Am. Publ. Health As.

3. Harris, W.G., R.D. Rhue, G. Kidder, R.B. Brown, and R. Littell. 1996. Phosphorus retention as related to morphology of sandy coastal plain soil materials. Soil Sci. Soc. Am. J. 60:1513-1521

4. Lindsay, W.L. 1979. Chemical Equilibria in Soil. John Wiley & Sons, New York.
Mansell, R.S., S.A. Bloom, and B. Burgoa. 1991. Phosphorus transport with water flow in an acid, sandy soil. In Jacob B., and M.Y. Corapcioglu (Ed). Transport process in porous media. Kulwer Acad. Publ., Dorchester, the Netherlands, p.271-314.

5. Mansell, R. S., S. A. Bloom, and B. Burqua. 1991. Phosphorus transport with water flow in an acid , sandy soil. In Jacob, B. and M. Y. Corapcioglu (eds.). Transport process in porous media. Kulwer Acad. Publ., Dorchester, the Netherlands, pp. 271-314.

6. Matichenkov, V.V., V.M. Dyakov, and E.A. Bocharnikova. 1997. The complex silicon-phosphate fertilizer. Russian patent, registration No.97121543.

7. Matichenkov, V.V., D.V. Calvert, G.H. Snyder, B. Whalen, and Y. Wan. 2000. Nutrients leaching reduction by Si-rich substances in the model experiments. In Proc. 7th Inter. Conf. Wetland systems for water pollution control, Lake Buena Vista, Florida, Nov. 11-16, 2000, 583-592.

8. Parl, B. 1967. Basic Statistics. Doubleday & Co., Inc., Garden City, N.Y. p. 364.

9. Richardson, C.J., and P. Vaithiyanathan. 1995. Phosphorus sorption characteristics of Everglades soils along a eutrophication gradient. Soil Sci. Soc. Am. J. 59:1782-1788.

10. Rochev, V.A, R.V. Shveikina, G.A. Barsukova, and N.N. Popova. 1980. The effect of silica-gel on agrochemical soil properties and crop of agricultural plants. In Plant Nutrition and Programming of Agricultural Plants. Proceed. Sverdlovsky ACI, Perm, 60:61-68.

11. Sims, J. T., Simard R.R., and B.C. Joern. 1998. Phosphorus loss in agricultural drainage: historical perspective and current research. J. Environ. Qual., 27:277-293.

12. Walsh, L.M., and J.D. Beaton 1973. Soil testing and plant analysis. Soil Sci. Soc. Am. Inc., Madison, Wisconsin, USA.

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Table 1. The weight of fresh shoots and roots of Bahiagrass after growing 3 months in a greenhouse.

Variant	Without P Fertilizers		50 kg P ha^{-1} as superphosphate		100 kg P ha^{-1} as superphosphate	
	Shoots	Roots	Shoots	Roots	Shoots	Roots
	----------average weight (g) for 10 plants----------					
Control	0.57b	0.17b	0.84b	0.29b	0.89b	0.37b
Lime	0.47c	0.14b	0.59c	0.31b	0.92b	0.38b
Si Slag	1.12a	0.97a	1.14a	1.14a	1.48a	1.37a

Using Duncan's multiple range test, values within a column followed by the same letter are not statistically different ($P<0.05$).

Table 2. The concentration of P in shoots and roots of Bahiagrass after growing 3 months in a greenhouse.

Variant	Without P Fertilizers		50 kg P ha^{-1} as superphosphate		100 kg P ha^{-1} as superphosphate	
	Shoots	Roots	Shoots	Roots	Shoots	Roots
	----------mg P 100 g^{-1}----------					
Control	404a	346b	422a	306b	481a	388a
Lime	418a	450a	360b	362a	432b	378a
Si Slag	309b	246c	239c	211c	339c	239b

Using Duncan's multiple range test, values within a column followed by the same letter are not statistically different ($P<0.05$).

Table 3. Total content of P in shoots and roots of Bahiagrass after growing 3 months in a greenhouse.

Variant	Without P Fertilizers		50 kg P ha^{-1} as superphosphate		100 kg P ha^{-1} as superphosphate	
	Shoots	Roots	Shoots	Roots	Shoots	Roots
	----------mg P 100 $plants^{-1}$----------					
Control	2.30b	0.59b	3.57a	0.91b	4.28b	1.43b
Lime	1.97c	0.63b	2.12c	1.15b	3.98c	1.43b
Si Slag	3.48a	2.40a	2.73b	2.41a	5.03a	3.27a

Using Duncan's multiple range test, values within a column followed by the same letter are not statistically different ($P<0.05$).

Table 4. The concentration of water- and acid-extractable P in Entisol after growing Bahiagrass in greenhouse study.

Variant	Without P Fertilizers		50 kg P ha^{-1} as superphosphate		100 kg P ha^{-1} as superphosphate	
	Water-Extractable	Acid-Extractable	Water-Extractable	Acid-Extractable	Water-Extractable	Acid-Extractable
	----------mg P kg^{-1} of soil----------					
Original soil	6.9a	106a	-	-	-	-
Control	2.8b	63b	7.1b	95b	14.8a	123a
Lime	3.6b	51c	7.8b	85b	13.5b	114a
Si Slag	6.8a	64b	12.9a	115a	14.8a	128a

Using Duncan's multiple range test, values within a column followed by the same letter are not statistically different ($P<0.05$).

Figure 1. Effect of irrigation with distilled water on phosphorus concentration in a percolate solution from an Entisol treated with Si slag or limestone. Error bars indicate standard errors of the mean.

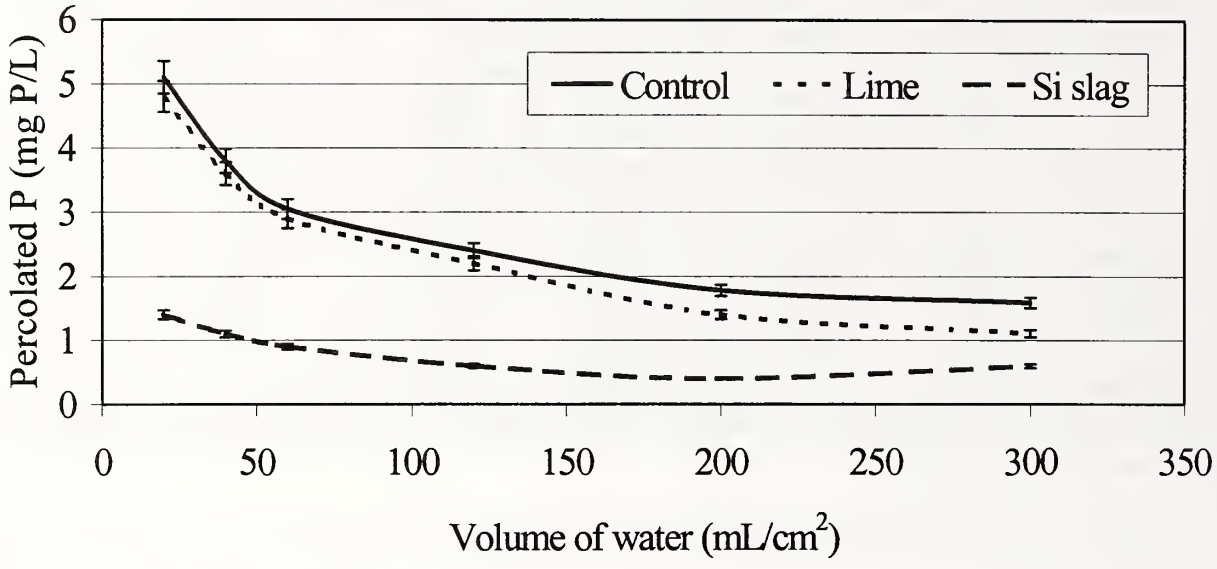


Figure 2. Effect of irrigation with a P-bearing solution on phosphorus concentration in a percolate solution from an Entisol treated with Si slag or limestone. Error bars indicate standard errors of the mean.

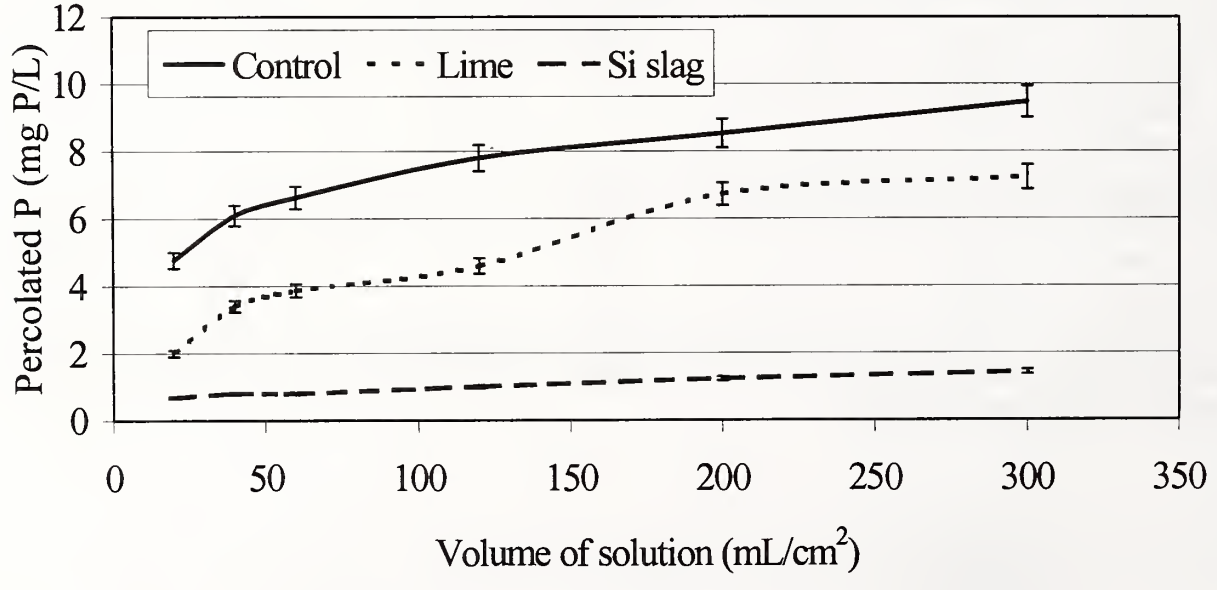


Figure 3. Effect of irrigation with distilled water on phosphorus concentration in a percolate solution from a Spodosol treated with Si slag or limestone. Error bars indicate standard errors of the mean.

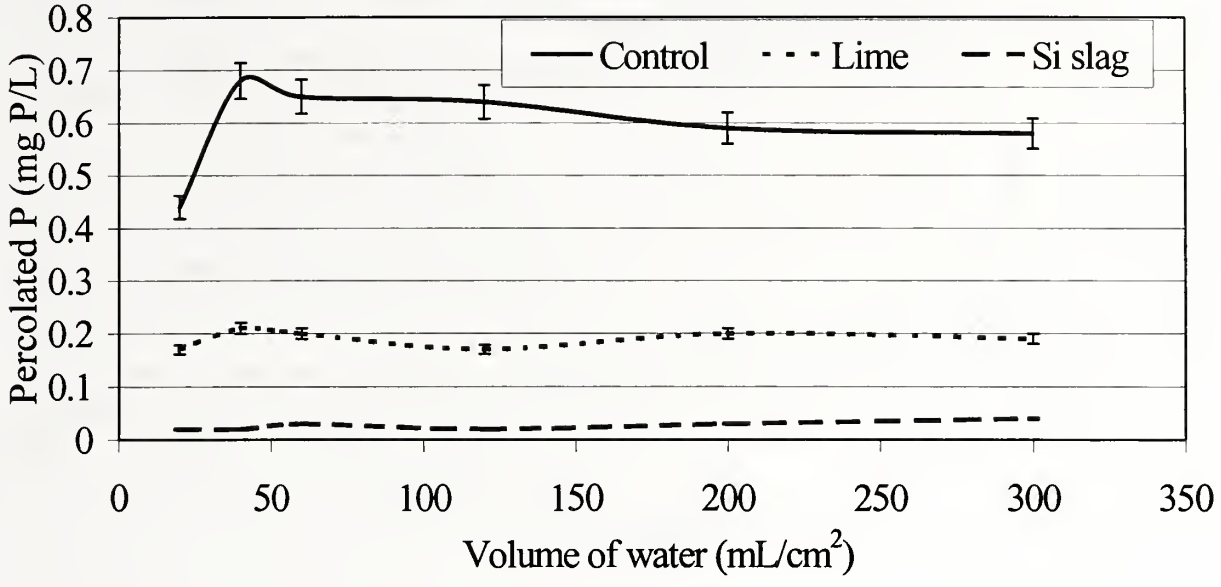


Figure 4. Effect of irrigation with a P-bearing solution on phosphorus concentration in a percolate solution from a Spodosol treated with Si slag or limestone. Error bars indicate standard errors of the mean.

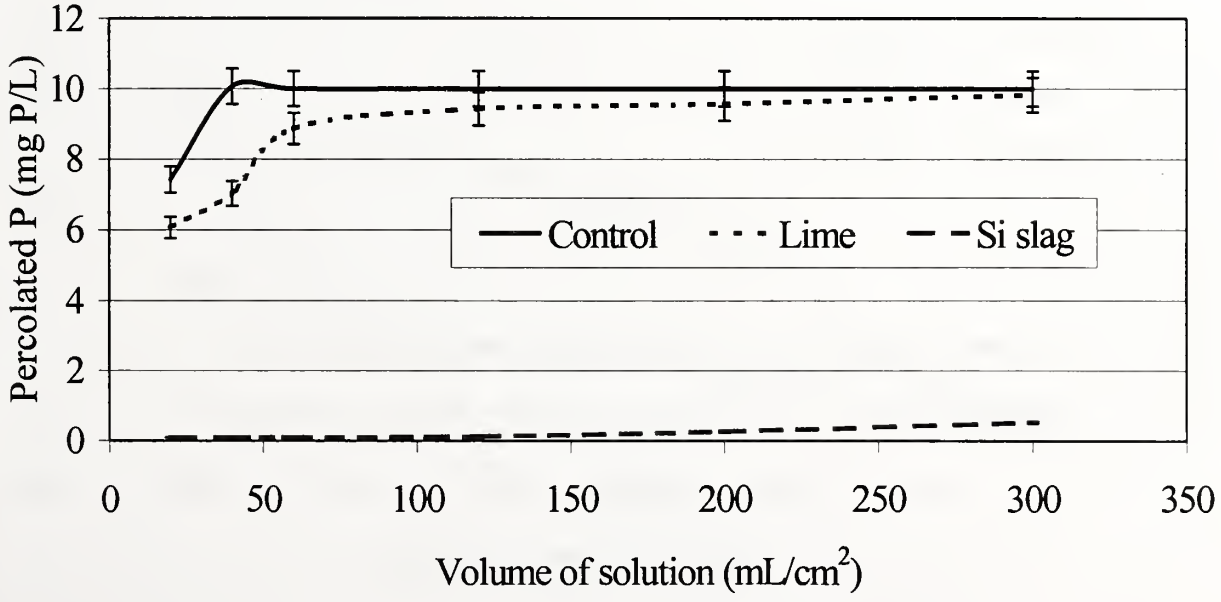


Figure 5. Effect of irrigation with distilled water on phosphorus concentration in a percolate from an Alfisol treated with Si slag or limestone. Error bars indicate standard error of the mean.

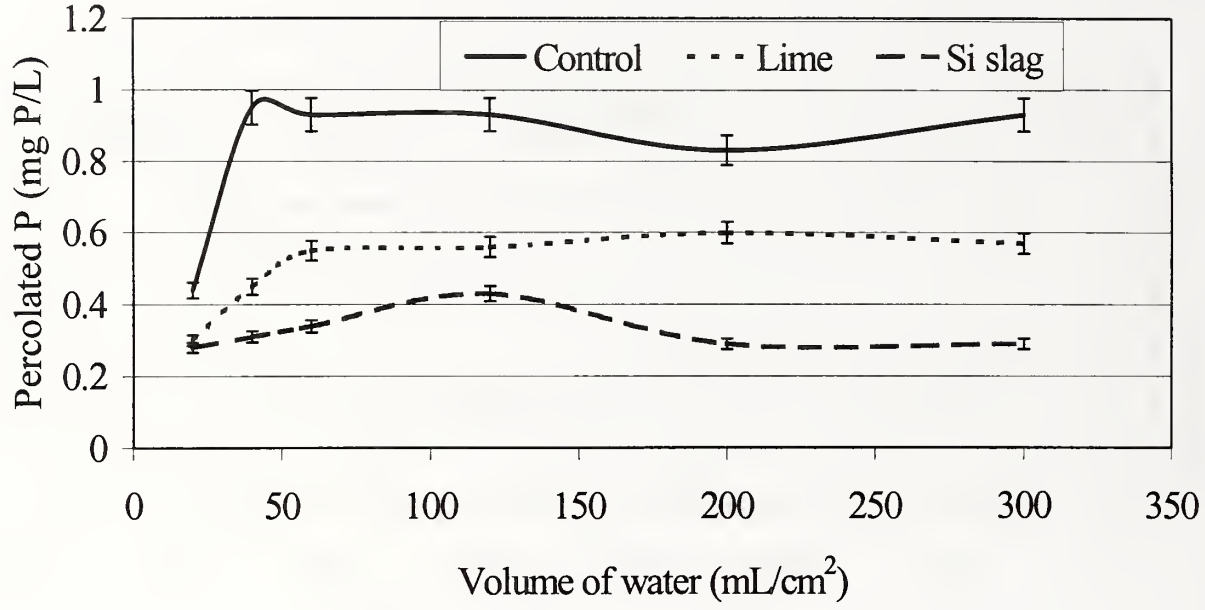


Figure 6. Effect of irrigation with a P-bearing solution on phosphorus concentration in a percolate solution from an Alfisol treated with Si slag or limestone. Error bars indicate standard errors of the mean.

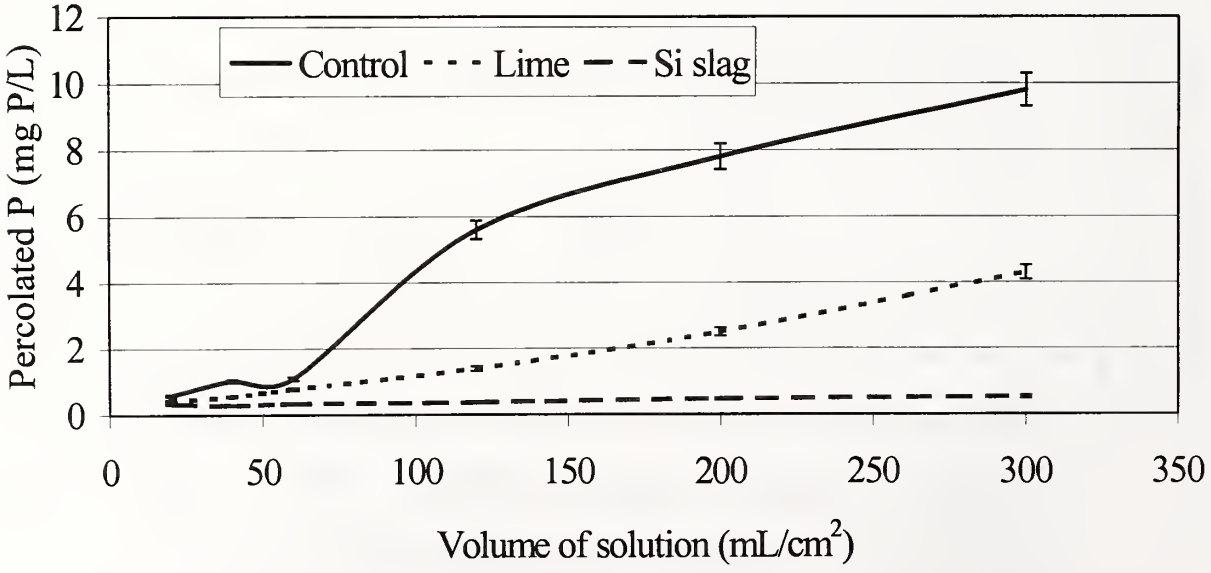


Figure 7. Phosphorus concentration in a percolate solution from the greenhouse experiment with an Entisol. Error bars indicate standard errors of the mean.

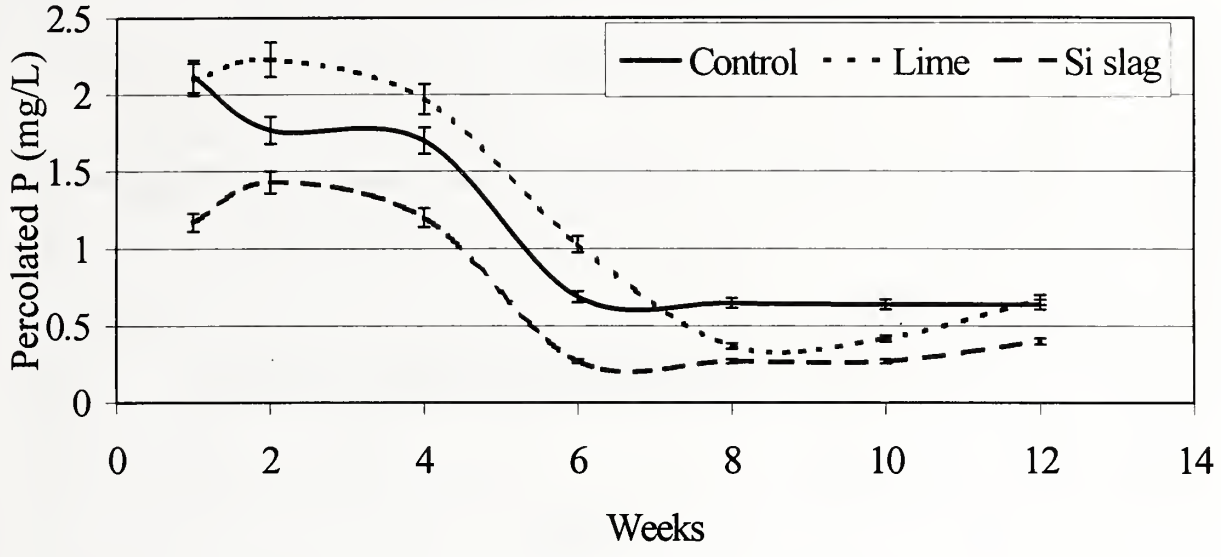


Figure 8. Phosphorus concentration in a percolate solution from the greenhouse experiment with an Entisol treated with P fertilizer (50 kg P/ha). Error bars indicate standard errors of the mean.

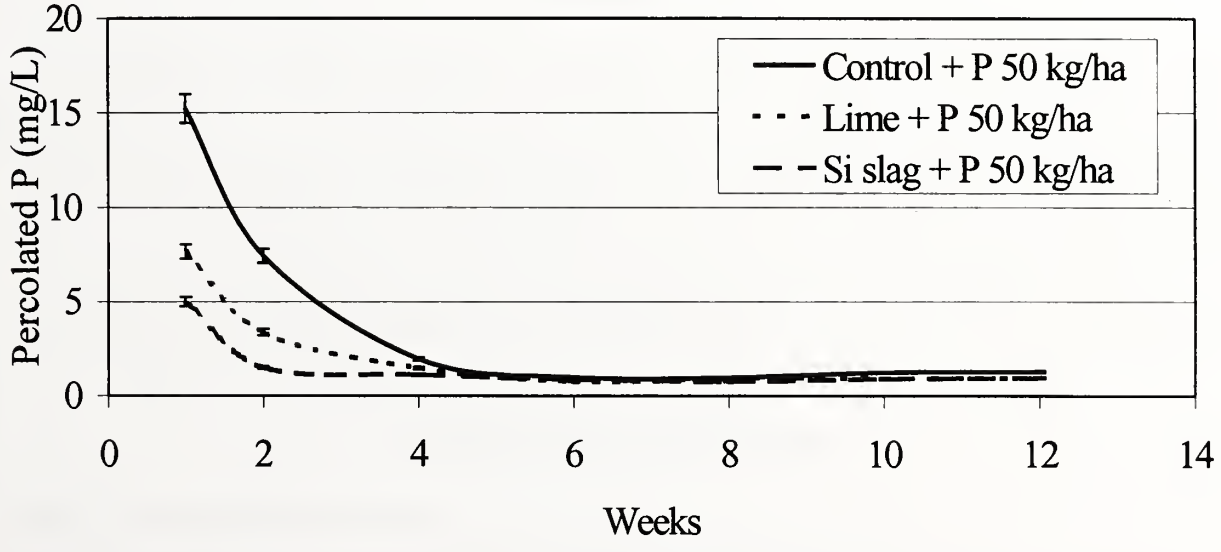
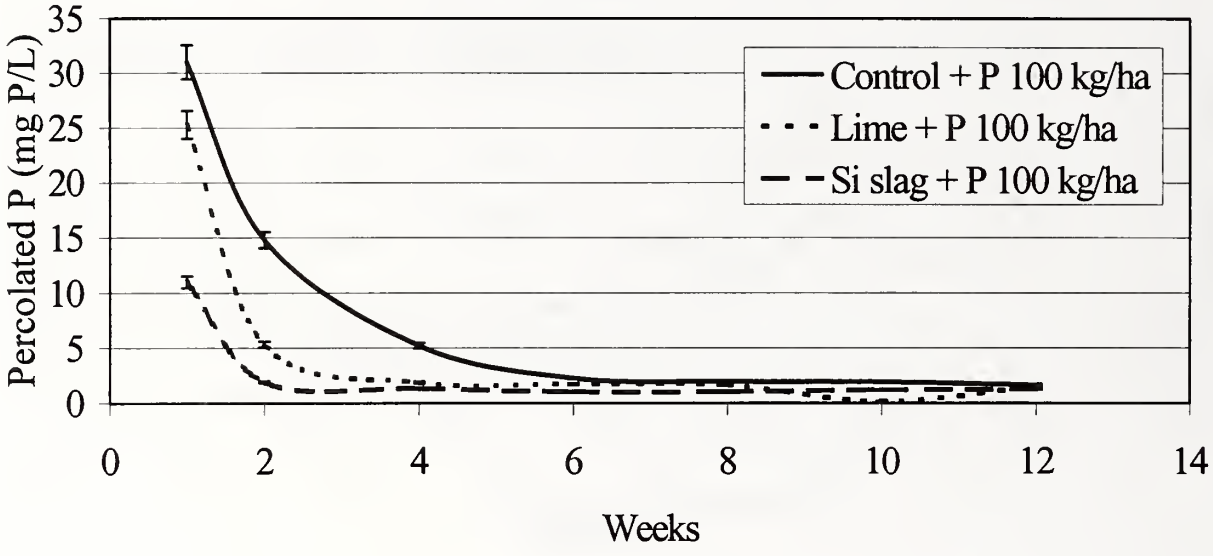


Figure 9. Phosphorus concentration in a percolate solution from the greenhouse experiment with an Entisol treated with P fertilizer (100 kg/ha). Error bars indicate standard errors of the mean.



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SILICON AS A BENEFICIAL ELEMENT FOR SUGARCANE

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ABSTRACT

A number of field and greenhouse studies have demonstrated that silicon (Si) is an important beneficial element for sugarcane (*Saccharum officinarum* L.). Effective management practices utilize Si fertilization on soils deficient in plant-available Si. Thus far, knowledge of the direct effects of Si fertilizers on sugarcane has not advanced as rapidly as for rice. Silica concentration in cultivated plants ranges from 0.3 to 8.4 %. A range of 210-224 million tons of Si or 70-800 kg ha^{-1} of plant-available Si is harvested with the sugarcane crop from arable soils annually. Crop removal of Si by sugarcane exceeds those of the macronutrients N, P, and K. Usually the concentration of Si in sugarcane leaves varies from 0.1 to 3.2%. Higher yield of sugarcane is associated with higher concentration of Si in the leaves. Field and greenhouse experiments conducted in the USA (Florida and Hawaii) and Mauritius demonstrated that application of Si fertilizers had a positive effect on the disease-, pest- and frost-resistance of sugarcane. It was shown that sugarcane productivity increased from 17 to 30 %, whereas production of sugar rose from 23 to 58% with increasing Si fertilization. One of the most important functions of Si was the stimulation of the plant's defense abilities against abiotic and biotic stresses. Literature data demonstrated that improved sugarcane nutrition brought about by fertilization with Si was shown to reinforce the plant's protection properties against leaf freckle, sugarcane rust, and sugarcane ringspot. In addition, Si fertilization has a more positive effect than liming on the chemical and physical properties of the soil.

INTRODUCTION

Beginning in 1840, numerous laboratory, greenhouse and field experiments showed sustainable benefits of Si fertilization for rice (*Oryza sativa* L.), barley (*Hordeum vulgare* L.), wheat (*Triticum vulgare* Vil), corn (*Zea mays* L.), sugarcane, cucumber (*Cucumus sativa* L), tomato (*Lycopersicon esculentum* Mill), citrus (*Citrus taitentis* Risso) and other crops (Epstein, 1999; Liebig, 1840; Matichenkov et al., 1999; Savant et al., 1997). Unfortunately, the present opinion about Si being an inert element is prevalent in plant physiology and agriculture despite the fact that Si is a biogeochemically active element and that Si fertilization has significant effects on crop production, soil fertility, and environmental quality (Epstein, 1999; Matichenkov and Bocharnikova, 2000; Voronkov et al., 1978).

RESULTS AND DISCUSSION

Silicon in the Soil-Plant System.

Silicon is the most abundant element in the earth's crust after oxygen: 200 to 350 g Si kg^{-1} in clay soils and 450 to 480 g Si kg^{-1} in sandy soils (Kovda, 1973). It is the current opinion that Si is an inert element and cannot play an important role in the biological and chemical processes. However many Si compounds are not inert. Silicon can form numerous compounds with high

chemical and biochemical activities. Four elements, carbon (C), aluminum (Al), phosphorus (P), and germanium (Ge) surround Si in the Periodic Table of Elements. The properties of Si are somewhat similar to those of the surrounding elements. Only Si can form stable polymers similar to C (Iler, 1979). Silicon is similar to Al in that it can act similarly in formatting minerals (Sokolova, 1985). Silicon can replace P in DNA (Voronkov et al., 1978). Also, Si has similar metallic properties to Ge (Iler, 1979). Usually plants absorb Si more than other elements (Savant et al., 1997). These properties in turn determine silicon's effect on soil fertility and plants.

Soils generally contain from 5 to 40% Si (Kovda, 1973). The main portions of soil Si-rich compounds are represented by quartz or crystalline silicates, which are inert. In many respects, these silicates form the skeleton of the soil. The physically and chemically active Si substances in the soil are represented by soluble and weakly adsorbed monosilicic acids, polysilicic acids, and organosilicon compounds (Matichenkov and Ammosova, 1996). These forms are interchangeable with each other as well as with other crystalline minerals and living organisms (soil microorganisms and plants). Monosilicic acid is the center of these interactions and transformations. Monosilicic acid is a product of Si-rich mineral dissolution (Lindsay, 1979). The soluble and weakly adsorbed monosilicic acids are absorbed by plants and microorganisms (Yoshida, 1975). They also control soil chemical and biological properties (P, Al, Fe, Mn and heavy metal mobility, microbial activity, stability of soil organic matter) and the formation of polysilicic acids and secondary minerals in the soil (Matichenkov et al., 1995; Sokolova, 1985). Plants and microorganisms can absorb only monosilicic acid (Yoshida, 1975). Polysilicic acid has a significant effect on soil texture, water holding capacity, adsorption capacity, and soil erosion stability (Matichenkov et al., 1995).

Using data from the literature on Si removal by different cultivated plants (Reimers, 1990; Bazilevish et. al., 1975) and from the FAO database on world crop production (FAO Internet Database, 1998), it was calculated that 210-224 million tons of plant-available Si is removed from arable soils annually. Harvesting cultivated plants usually results in Si removal from the soil. In most cases much more Si is removed than other elements (Savant et al., 1997). For example, potatoes remove 50 to 70 kg Si ha^{-1}. Various cereals remove 100 to 300 kg Si ha^{-1} (Bazilevich et al, 1975). Sugarcane removes more Si than other cultivated plants. Sugarcane removes 500 to 700 kg Si ha^{-1} (Anderson, 1991). At the same time sugarcane absorbs 40 to 80 kg P ha^{-1}, 100 to 300 kg K ha^{-1}, and 50 to 500 kg N ha^{-1} (Anderson, 1991).

Studies have shown that while other plant-available elements were restored by fertilization, Si was not. Soil fertility degradation started because the reduction of monosilicic acid concentration in the soil initiated decomposition of secondary minerals that control numerous soil properties (Karmin, 1986; Marsan and Torrent, 1989). A second negative effect of reduced monosilicic acid concentration in the soil is decreased plant disease and pest resistance (Epstein, 1999; Matichenkov et al., 1999; Savant et al., 1997).

In recent years we tested the concentration of monosilicic acid, polysilicic acids, and acid-extractable Si in Florida and Louisiana soils (Matichenkov and Snyder, 1996; Matichenkov et al., 1997; Matichenkov et al., 2000). The concentration of monosilicic and polysilicic acids in the soil can be analyzed only from fresh soil samples (Matichenkov et al., 1997). The concentration of acid-

extractable Si is positively correlated with biochemically active Si or sources of plant-available Si in the soil (Barsykova and Rochev, 1979).

Selected data on the concentration of monosilicic acid, polysilicic acid, and acid-extractable Si in Histosols, Spodosols, Entisols and Mollisols are presented in Table 1. The lowest concentrations of soluble and biochemically active Si substances are found in the sandy soil (Table 1). Cultivation can increase the concentration of monosilicic acids, probably because plant residuals (especially burned sugarcane leaves) are not removed from the soil. Even so, the concentration of soluble and biochemically active Si-rich compounds remains critically low.

The concentration of monosilicic acid in a native Histosol is usually characterized as being medium to high. The sources of plant-available Si are extremely critical (Table 1), and cultivation results in sharply reduced monosilicic acid levels in the soil. In commercial rice and sugarcane production in the Everglades Agricultural Area, growers usually use Si soil amendments for increased crop production and quality (Datnoff et al., 1997, Savant et al., 1997). Sugarcane usually is grown after rice. The application of Si fertilizer has beneficial effects on both rice and sugarcane (Savant et al., 1999). The concentration of monosilicic acid, polysilicic acid, and acid-extractable Si increased with cultivation (Table 1). The most dramatic increase was observed for acid-extractable Si. This parameter determines the amount of biogeochemically active Si and is a potential source for plant-available Si (Barsykova and Rochev 1979). Native Histosols have extremely low levels of biogeochemically active or plant-available Si. On the other hand cultivated Histosols have medium to high level of monosilicic acid or plant-available Si (Table 1).

The native soils from Louisiana were characterized by a high concentration of soluble and biochemically active Si (Table 1). High levels of biogeochemically active Si were found in accumulative alluvial soils (Kovda, 1973). Louisiana soils were collected in the Mississippi delta and were formed under alluvial accumulative processes. The long period of cultivation of these soils resulted in the decrease of monosilicic acid and acid-extractable Si (Table 1). Most likely this is a result of monosilicic acid absorption by cultivated plants rather than leaching, because monosilicic acid is characterized by a low capacity to move down the soil profile (Matichenkov and Snyder, 1996). However, the content of polysilicic acids increased, which is probably associated with degradation of soil minerals (Matichenkov et al., 1995; Iler, 1979). The decrease of acid-extractable Si supports this conclusion. As a result of agricultural activity, the concentration of plant-available Si was decreased and soil fertility was degraded.

These data demonstrate that Si fertilization is needed for all four soils under investigation to assure adequate Si nutrition of sugarcane and to optimize the fertility of these soils.

Effect of Si on Sugarcane

Silicon fertilizers influence plants in two ways: (1) the indirect influence on soil fertility, and (2) the direct effect on the plant. Most investigations of monosilicic acid effects on soil properties

concern their interaction with soil phosphates (Matichenkov and Ammosova, 1996). Silicon fertilizer applied into the soil initiates two processes. The first process involves increases in the concentration of monosilicic acids resulting in the transformation of slightly soluble phosphates into plant-available phosphates (Lindsay, 1979; Matichenkov, 1990). The equations for these reactions are as follows:

$$CaHPO_4 + Si(OH)_4 = CaSiO_3 + H_2O + H_3PO_4$$
$$2Al(H_2PO_4)_3 + 2Si(OH)_4 + 5H^+ = Al_2Si_2O_5 + 5H_3PO_4 + 5H_2O$$
$$2FePO_4 + Si(OH)_4 + 2H^+ = Fe_2SiO_4 + 2H_3PO_4$$

Secondly, Si fertilizer adsorbs P, thereby decreasing P leaching by 40-90 % (Matichenkov et al., 2000). It is noteworthy that adsorbed P is kept in a plant-available form.

Silicon fertilizers are usually neutral to slightly alkaline (Lindsay, 1979). Soluble Si reduces Al toxicity because monosilicic acid reacts with mobile Al and forms slightly soluble aluminosilicates (Lumsdon and Farmer, 1995). This means that Si amendments may be used for improving the chemical properties of acid soils. Numerous field experiments have demonstrated that Si fertilization has more influence on plant growth on acid soils than liming (Ayres, 1966; Fox et al., 1967). Silicon fertilizer can increase plant resistance to heavy metals (Epstein 1999) and toxic hydrocarbons (Bocharnikova et al., 1999). Both effects of Si fertilizer appear to occur through optimization of soil properties and the direct effect on soil microorganisms. Our earlier investigation demonstrated that soil treatment with Si-rich materials increased both water-holding capacity and soil adsorption capacity for ions (Matichenkov and Bocharnikova, 2000).

The direct effect of Si fertilizer on plants is primarily manifested in increasing disease and pest resistance. Data in the literature showed that Si fertilization increased the resistance of sugarcane to sugarcane rust (Dean and Todd, 1979), leaf freckle (Fox et al., 1967), sugarcane ringspot (Raid et al., 1991), leaf disorder (Clements, 1965), and stalk and stem borers (Edward et al., 1985; Meyer and Keeping, 1999). Except for biotic stresses such as pests and plant diseases, Si fertilization increased sugarcane resistance to abiotic stresses such as soil water shortage, cold temperature, UV-B radiation, and for Fe, Al and Mn toxicities (Savant et al., 1999).

The field experiments in Hawaii, Mauritius and Florida demonstrated high response of sugarcane to Si fertilizer (Table 2). It is important to note that Si fertilizer increased not only the productivity of cane but also the concentration of sugar in the plants as well (Table 2). It is probable that Si has a direct effect on biochemical processes in sugarcane that are similar to responses observed for sugar beet (Liebig, 1840).

CONCLUSIONS

Soils used for sugarcane in Florida and Louisiana usually have low concentrations of plant-available Si and biogeochemically active Si. The removal of Si by sugarcane initiated soil fertility

degradation. Cultivated plants tend to have Si deficiency. The application of Si in soil amendments is needed for both optimized soil fertility and improved plant nutrition. The field experiments in Florida, Hawaii, and Mauritius demonstrated the highly beneficial effects of Si fertilizers.

REFERENCES

1. Anderson, D.L.. 1991. Soil and leaf nutrient interactions following application of calcium silicate slag to sugarcane. Fertilizer Research 30:9-18.

2. Ayres, A.S.. 1966. Calcium silicate slag as a growth stimulator for sugarcane on low silicon soils. Soil Sci. 101(3):216-227.

3. Barsykova, A.G., and V.A. Rochev. 1979. The influence of silica-gel-rich fertilizers on mobile silicic acid in the soil and on available Si for plants. In The control and management of the content of the macro- and the microelements in media. Ural region, Proceedings of Sverdlovsky ACI 54:84-88.

4. Bazilevich, N.I., L.E. Rodin, and N.N Rozov. 1975. The biological productivity and cycle of chemical elements in plant associations. In: Bazilevich N.I. (Ed) Biosphere Resource, ser.1., Leningrad, pp.5-33.

5. Bocharnikova, E.A., V.V. Matichenkov and G.H. Snyder. 1999. A technology for restoration of hydrocarbon polluted soils. Proceed. 31st Mid-Atlantic Industrial and Hazardous Waste Conference, June, 1999:166-174.

6. Clements, H.F. 1965. Effects of silicate on the growth and freckle of sugarcane in Hawaii. Proc. Int. Soc. Sugar Cane Technol. 12:197-215.

7. Datnoff, E.L., C.W. Deren, and G.H. Snyder. 1997. Silicon fertilization for disease management of rice in Florida. Crop Protection 16(6):525-531.

8. Dean, J.L., and E.H. Todd. 1979. Sugarcane rust in Florida. Sugar Journal 42:10.

9. Edward, S.H., L.H. Allen, and G.J. Gascho. 1985. Influence of UV-B radiation and soluble silicates on the growth and nutrient concentration of sugarcane. Soil Crop Sci. Soc. Fla. 44:134-141.

10. Epstein, E. 1999. The discovery of the essential elements. Discoveries in plant biology, v.3. S.D.Kung and S.F. Yang (ed), World Scientific Publishing, Singapore.

11. FAO. 1998. World Agricultural Center, FAOSTAT agricultural statistic data-base gateway.

12. Fox, R.L., J.A. Silva, O.R. Younge, D.L. Plucknett, and G.D. Sherman. 1967. Soil and plant silicon and silicate response by sugar cane. Soil Sci. Soc. Amer. 31:775-779.

13. Iler, R.K. 1979. The chemistry of silica. Wiley, New York.

14. Karmin, Z. 1986. Formation of ferrihydrite by inhibition of grun rust structures in the presence of silicon. Soil Sci. Soc. Amer. J., 50(1):247-254.

15. Kovda, V.A. 1973. The bases of learning about soils. Moscow: Nayka, 2 v.

16. Liebig, J. Von. 1840. Organic chemistry in its application to agriculture and physiology. Ed.from the manuscript of the author by Lyon Playfair. Taylor and Walton, London.

17. Lindsay, W.L. 1979. Chemical equilibria in soil. John Wiley & Sons, New York

18. Lumsdon, D.G., and V.C. Farmer. 1995. Solubility characteristics of proto-imogolite sols: how silicic acid can detoxify aluminium solutions. European Soil Sci., 46:179-186.

19. Marsan, F.A., and J. Torrent. 1989. Fragipan bonding by silica and iron oxides in a soil from northwestren Italy. Soil Sci. Soc. Amer. J., 53(4):1140-1145.

20. Matichenkov, V.V. 1990. Amorphous oxide of silicon in soddy podzolic soil and its influence on plants. Author reference of Can. Diss., Moscow State University.

21. Matichenkov, V.V., D.L. Pinsky, and E.A. Bocharnikova. 1995. Influence of mechanical compaction of soils on the state and form of available silicon. Eurasian Soil Science 27(12):58-67.

22. Matichenkov, V.V., and J.M. Ammosova. 1996. Effect of amorphous silica on soil properties of a sod-podzolic soil. Eurasian Soil Science 28(10):87-99.

23. Matichenkov, V.V. and G.H. Snyder. 1996. The mobile silicon compounds in some South Florida soils. Eurasian Soil Science 12:1165-1173.

24. Matichenkov, V.V., Ya. M. Ammosova, and E.A. Bocharnikova. 1997. The method for determination of plant available silica in soil. Agrochemistry 1:76-84.

25. Matichenkov, V.V., D.V. Calvert, and G.H. Snyder. 1999. Silicon fertilizers for citrus in Florida. Proc. Fla. State Hort. Soc. 112:5-8.

26. Matichenkov, V.V., E. A. Bocharnikova, D.V. Calvert, and G.H. Snyder. 2000. Comparison study of soil silicon status in sandy soils of south Florida. Soil Crop Sci. Florida Proc. 59:132-137.

27. Matichenkov, V.V., D.V. Calvert, G.H. Snyder, B. Whalen, and Y. Wan. 2000. Nutrients leaching reduction by Si-rich substances in the model experiments. In Proc. 7th Inter. conf. wetland systems for water pollution control, Lake Buena Vista, Florida, Nov. 11-16, 2000, 583-592.

28. Matichenkov, V.V. and E.A. Bocharnikova. 2000. The relationship of silicon to soil physical and chemical properties. Proc. Inter. Conf. Silicon in agriculture, in press.

29. Meyer, J. H. and M. Keeping. 1999. Past, present and future silicon research in the South African sugar industry. *In* Silicon in agriculture, Program agenda and abstracts, Sept. 26-30, 1999, Fort Lauderdale, Florida, USA, 10.

30. Raid, R.N., D.L. Anderson, and M.F. Ulloa. 1991. Influence of cultivar and soil amendment with calcium silicate slag on foliar disease development and yield of sugarcane. Florida Agricultural Experimental Station Journal Ser. N R-01689.

31. Reimers, N.F.. 1990. Natural uses. Dictionary-reference book, Moscow, Misl.

32. Savant, N.K., G.H. Snyder, and L.E. Datnoff. 1997. Silicon management and sustainable rice production. Advances in Agronomy 58:151-199.

33. Savant, N.K., G.H. Korndorfer, L.E.Datnoff, and G.H. Snyder. 1999. Silicon nutrition and sugarcane production: a review. J. Plant Nutr. 22(12):1853-1903.

34. Silva, J.A. 1969. The role of research in sugar production. Hawaiian Sugar Technologists Association: 1969 Report.

35. Sokolova, T.A.. 1985. The clay minerals in the humid regions of USSR. Novosibirsk, Nayka.

36. Voronkov, M.G., G.I. Zelchan, and A.Y. Lykevic. 1978. Silicon and life. Riga, Zinatne.

37. Yoshida, S., 1975. The physiology of silicon in rice. Tech. Bull. n.25., Food Fert. Tech. Centr., Taipei, Taiwan.

Table 1. Concentrations of monosilicic acid, polysilicic acid and acid-extractable Si in Histosols, Spodosols, Entisols, and Mollisols (mg Si kg^{-1} of soil).

Soil	Soluble silicon		Acid-extractable silicon
	Monosilicic acid	Polysilicic acid	
Histosol (Florida, Lauderhill series)			
Native	24.3-46.5	0-0.8	15-45
Cultivated without silica fertilizers	13.4-32.4	1.5-2.7	97-127
Cultivated with silica fertilizers	15.3-96.2	1.5-23.4	93-548
Spodosol (Florida,Ancona series)			
Native	1.4-2.3	2.4-12.7	45-75
Cultivated	2.3-6.1	1.7-2.4	42-57
Entisol (Louisiana, Mhoon series)			
Native	19.1-20.3	27.3-29.8	319-325
Cultivated	11.5-14.2	88.9-117.5	279-319
Mollisol (Louisiana, Iberia series)			
Native	23.2-23.8	40.0-58.2	294-415
Cultivated	12.3-19.5	56.3-116.5	171-298

Table 2. The effect of location, soil type, source and rate of fertilizer application on yield of sugarcane and sugar.

Soil	Si fertilizer	Rate, ton/ha	Limestone or fertilizer	Sugar		Cane		Reference
				t/ha	%	t/ha	%	
Aluminos humic Latosol, Mauritius	Electric furnace slag	0	NPK	27.4	100	266.7	100	Ayres, 1966
		0	NPK + lime 4.94t/ha	26.7	97.4	256.8	96.3	
		6.177	NPK	33.8	123.4	313.7	117.6	
Humic Latosol, Hawaii	TVA slag	0	P 0.28t/ha	23.4	100	253	100	Fox et al., 1967
		0	Lime 4.5 t/ha + P 1.112t/ha	20.7	88.5	262	103.5	
		4.5	P 0.28t/ha	31.6	135.0	327	129.2	
		4.5	P 1.112t/ha	32.7	139.7	338	133.5	
Humic Latosol, Hawaii	Calcium silicate	0	-	-	-	131	100	Silva, 1969
		0.83	-	-	-	151	115.3	
		1.66	-	-	-	166	126.7	
Histosol, Florida	Calcium silicate slag	0	-	12.5	100	126	100	Raid et al., 1991
		0	P	18.1	144.8	150	119.0	
		6.7	-	15.8	126.4	156	123.8	
		6.7	P	23.8	190.4	194	153.9	

MAXIMIZING ECONOMIC RETURNS FROM SUGARCANE PRODUCTION THROUGH OPTIMAL HARVEST SCHEDULING

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ABSTRACT

The long-term viability of the sugar industry depends upon finding ways to produce sugar more economically through production management decisions which can reduce production costs or increase returns. Harvest scheduling is one such practice which has a direct impact on net farm returns. Sugarcane cultivars have distinct sucrose maturation curves, which may vary up or down from year to year depending upon weather and other factors. A study was conducted on a commercial sugarcane farm to predict sugar per acre across the harvest season and to develop a programming model which could determine the order of harvest of fields on the farm which would maximize total sugar produced and net returns above harvest costs. Optimal adjustment of harvest of individual fields resulted in increased sugar yield per acre and total farm net returns.

INTRODUCTION

As a sugarcane plant matures throughout the growing season, the amount of sucrose in the cane increases. Most of this sucrose production occurs when the plant is fully mature and begins to ripen. Several studies have developed models to predict the sucrose level in sugarcane. Crane et al. (1982) developed a stubble replacement decision model for Florida sugarcane producers. They reported that sugar accumulation is a function of both sucrose accumulation and vegetative growth. The study suggested that the accumulation of sugar may be approximated as a quadratic function of time. Chang (1995), in research on Taiwanese sugarcane cultivars, suggested that individual cultivars have distinct sucrose maturation curves with different peak levels. The study concluded that the sugar content of a cultivar could be predicted as a function of time with reasonable accuracy and that the within-season trend of sucrose accumulation follows a second order curve.

During the harvest season, second stubble and older stubble fields are usually harvested first, followed by more recently planted fields, first stubble and then plantcane. Within this general order of crop harvest, producers attempt to estimate the sugar content of cane in the field in order to

harvest fields at a point where the sugar content in the cane is at or near a maximum. If individual sugarcane cultivars have distinct sucrose maturation curves, which may vary up or down from year to year depending upon weather and other factors, then the sugar content of individual fields could be incorporated into a model which would determine an optimal order of harvest for all fields on a particular farm, which would maximize total sugar produced (or total net returns received) on the farm.

Applications of crop harvest scheduling models utilizing some type of operations research procedure are most common in the timber industry. Most of these applications involve the use of either linear programming or simulation models. Recent studies have investigated the use of Monte Carlo integer programming (Nelson et al., 1991; Daust and Nelson, 1993), bayesian concepts (Van Deusen, 1996), and tabu search procedures (Brumelle et al., 1998). Several studies have developed crop growth models to predict the harvest date of agricultural crops (Lass et al.,1993; Malezieux, 1994; Wolf, 1986). However, most of these studies utilize optimal harvest decision rules based upon agronomic characteristics of the crop rather than economic principles.

Several studies have addressed various aspects of sugarcane productivity and harvest operations. Two studies have evaluated the economics of sugarcane stubble crop replacement in Florida (Crane et al., 1982) and Louisiana (Salassi and Milligan, 1997). These studies evaluated the optimal crop cycle length by comparing annualized future net returns from replanting to estimated returns from extending the current crop cycle for another year. Semenzato (1995) developed a simulation algorithm for scheduling sugarcane harvest operations at the individual farm level in such a way that the lapse of time between the end of burning and processing is minimized. The model calculated the maximum size of a field which could be harvested and have all of its cane processed within a specified period of time. This study focused on farm size and equipment availability in order to efficiently utilize limited resources in a timely manner. A recent study in Australia did determine optimal sugarcane harvest schedules which maximized net returns using mathematical programming procedures (Higgins et al., 1998; Muchow et al, 1998). However, the modeling framework in this study encompassed many farms within a production region over a multi-year harvest period. Furthermore, the smallest unit of time within the harvest scheduling model was one month.

The purpose of this study was to develop a methodology for the incorporation of within-season sucrose accumulation in sugarcane into an optimal single-season, daily harvest scheduling model at the individual farm level. The objective of the general modeling procedure was to capture the dynamic effect of sucrose accumulation during the growing season and to utilize this information, within a mathematical program modeling framework, in determining when specific sugarcane fields should be harvested in order to maximize total farm net returns. Data for this analysis were obtained from Agricultural Research Service, USDA experimental research tests conducted in Louisiana over several years. Sucrose levels were estimated as a function of time for major cultivars currently produced commercially in the state. These data were then incorporated into a mathematical programming model which determined an optimal harvest schedule which maximizes whole farm net returns for a given farm situation. Production and harvest data collected from a commercial sugarcane farm in Louisiana in 1996 were used to evaluate the ability of the modeling procedure to improve farm returns through adjustment of the actual harvest schedule.

MATERIALS AND METHODS

Sugar Prediction Models

The amount of raw sugar in a field of sugarcane is a function of several variables. Two important measures of sugarcane yield include tons of sugarcane per acre and pounds of raw sugar produced per acre. The relationship between sugar per acre and factors which influence it can be stated simply as follows:

$$(1) \qquad S_A = TRS \times TONS = TRS \times POP \times STWT$$

where S_A is total pounds of raw sugar per acre, TRS is theoretical recoverable sugar in pounds of sugar per ton of cane, TONS is the tons of sugarcane produced per acre, POP is the per acre population of sugarcane stalks in the field, and STWT is the stalk weight. Although the population of sugarcane stalks within a field can be assumed to be constant throughout the harvest season, the same assumption cannot be made for the other factors in the relationship. Theoretical recoverable sugar and stalk weight both increase as the harvest season progresses. In order to incorporate this yield increase within a whole-farm mathematical programming harvest scheduling model, estimates must be obtained for the predicted levels of each of these factors for each variety of sugarcane produced on the farm for every day of the harvest season.

Sucrose maturity data developed at the ARS, USDA Sugar Cane Research Unit in Houma, Louisiana, were used in the analysis. Stalk weight and sugar content of the commercial sugarcane cultivars grown in Louisiana were sampled at intervals during the harvest season from 1981 to 1996. The data included measurements of theoretical recoverable sugar, sugar per stalk and stalk weight by julian date for 3 to16 years, depending upon variety. The harvest season for sugarcane in Louisiana has historically run from the first of October through the end of December. Observations for each commercial cultivar ranged from julian date 255 to 346 or approximately the middle of September through the middle of December. The age of the crop (plantcane or stubble) was also included.

Models were estimated for stalk weight and sugar per stalk in order to predict the amount of sugarcane and raw sugar in the field for each day of the harvest season. Previous research suggests that a quadratic model can be used to model sugar accumulation (Crane et al., 1982). Graphical analysis of both the stalk weight as well as the sugar per stalk data suggested that these variables could be estimated using a semi-log functional form. Biological response functions of stalk weight and sugar per stalk were estimated for each cultivar as follows:

$$(2) \qquad STWT_{ct} = \beta_0 + \beta_1 LNJD + \beta_2 CROP + \sum_{i=81}^{95} \beta_i YEAR_i + \epsilon$$

$$(3) \qquad SPS_{ct} = \alpha_0 + \alpha_1 LNJD + \alpha_2 CROP + \sum_{i=81}^{95} \alpha_i YEAR_i + \epsilon$$

where $STWT_{ct}$ represents stalk weight in pounds per stalk of cultivar *c* on day *t*, SPS_{ct} represents sugar per stalk in pounds of cultivar *c* on day *t*, LNJD is the natural log of julian date (numeric day of the year), CROP is a (0,1) indicator variable representing crop age as either plantcane or stubble crop, and $YEAR_i$ represents discrete indicator variables for different years. Only two categories of the indicator variable CROP were included in the model as stubble crops for a given variety generally have similar sucrose accumulation levels regardless of crop age. These stubble crop sucrose levels, however, are significantly different than plant cane sucrose levels. The annual indicator variables for year were included to capture the relationship that sugarcane cultivars have distinct sugar accumulation curves which shift vertically from year to year depending upon weather and other factors. The base year for comparison in this estimation was 1996 and the indicator variables served the purpose of adjusting the sugar accumulation curve to factors in a given year by shifting the intercept of the prediction equation. All models were estimated using SAS (SAS Institute, version 6.12). The estimates of stalk weight and sugar per stalk were combined with stalk populations to estimate cane and sugar yield for each field.

Estimated models of stalk weight and sugar per stalk for each sugarcane cultivar are shown in Tables 1 and 2. Julian date (LNJD) and crop age (CROP) were found to be highly significant in the stalk weight prediction models (Table 1). Positive signs on the julian date variable indicate that stalk weight increases throughout the harvest season. The signs on the significant crop age variables were negative, as expected, indicating that stalk weight tends to be greater for plantcane crops than for older stubble crops. Coefficients of determination for specific variety models ranged from 0.36 to 0.81. In several of the estimated equations, indicator variables for years were significant, which implies that the stalk weight growth curves vary from year to year depending upon weather and other factors. Similar results were found for the sugar per stalk prediction models (Table 2). Julian date was highly significant with positive coefficients indicating sugar accumulation increases during the harvest season and crop age was found to be significant in six of the seven equations estimated. The sign on the estimated coefficient for crop age was negative in each of the six equations in which it was significant. Coefficients of determination were very high in the sugar per stalk models ranging from 0.86 to 0.90. Durbin-Watson tests for autocorrelation either failed to reject the hypothesis of no autocorrelation or were inconclusive, indicating that the error terms from the model predictions were not serially correlated. The White test for heteroskedasticity (White, 1980) failed to reject the hypothesis of homoskedasticity for each cultivar tested, indicating that error terms from the model predictions have a constant variance. The absence of autocorrelation and heteroskedasticity indicated that the estimated parameters in the prediction models were efficient (minimum variance) estimators.

Farm Level Production Estimates

A sample data set was developed from information collected from a commercial sugarcane farm in Louisiana for the 1996 harvest season. Characteristics of the farm are presented in Table 3. Stalk number estimates were collected on September 18-19 and October 2, 1996 from each of the fields on the farm. The number of samples taken per field depended upon the size of the field, but a target of one count was taken for every one and half acres. In a randomly selected area of the field, a twenty-five foot distance was measured between the middle of two rows. Then, the number of millable stalks within that distance was counted and then converted to an estimate of stalk population number per acre and field. Sample stalk counts for each field were then averaged to estimate a mean

stalk population per field. Ten-stalk samples were cut from randomly selected locations in each field on October 7 and 9, 1996. Each stalk sample was weighed and milled to obtain a juice sample for analysis. The average stalk weight and estimated theoretical recoverable sugar from the juice analysis were combined with field information to develop stalk weight and sugar per stalk measurements by field.

Prediction models of stalk weight and sugar per stalk were then adjusted to the 1996 crop year. This adjustment was incorporated into each prediction model as a parallel shift in the intercept. Stalk weight and sugar per stalk were then estimated for each day of the harvest season using the estimated prediction models with adjusted intercepts.

Estimates of tons of sugarcane per acre and pounds of raw sugar per acre were calculated by multiplying stalk weight and sugar per stalk by stalk population as follows:

$$(4) \qquad CANE_{ft} = POP_f \times STWT_{ct} \; / \; 2000$$

$$(5) \qquad SUGAR_{ft} = POP_f \times SPS_{ct}$$

where $CANE_{ft}$ is the estimated tons of sugarcane per acre in field *f* on julian date *t*, POP_f is the estimated stalk population per acre in field *f*, $STWT_{ct}$ is the estimated stalk weight in pounds for cultivar *c* on julian date *t*, $SUGAR_{ft}$ is the estimated pounds of raw sugar per acre in field *f* on julian date *t*, and SPS_{ct} is the estimated sugar per stalk in pounds for cultivar *c* on julian date *t*. Estimated yields per field were then adjusted for field conditions (recovery and trash) and differences between theoretical recoverable sugar and commercial recoverable sugar as follows:

$$(6) \qquad ADJCANE_{ft} = CANE_{ft} \times (1 + TRASH_f) \times FIELDRECOVERY_f$$

$$(7) \qquad ADJSUGAR_{ft} = SUGAR_{ft} \times 0.8345 \times SCALEFACTOR$$

$ADJCANE_{ft}$ represents the tons of sugarcane actually harvested from the field and delivered to the mill for processing. $TRASH_f$ is a percentage estimate of leaf matter and other trash in the harvested cane, and $FIELDRECOVERY_f$ is a percentage estimate the amount of sugarcane in the field actually recovered by harvest operations. Estimated levels of trash and field recovery were determined on an individual field basis from producer information. $ADJSUGAR_{ft}$ represents the actual pounds of raw sugar recovered from the processed cane. The estimated sugar yield is multiplied by a standard factor (0.8345) to convert theoretical recoverable sugar into commercially recoverable sugar. This standard is used by sugar mills to estimate recovery since the actual liquidation factor will not be known until the end of season. Accounting for differences from the laboratory analysis to the fields, the estimated sugar per field is reduced by a scale factor. The assumed scale factor is 92%.

Mathematical Programming Formulation

The determination of a harvest schedule was formulated as a linear mathematical programming model which maximized producer net returns above harvest costs over total farm acreage. Farm returns were derived from the sale of sugar and molasses less a percentage of the total production as a "payment-in-kind" to the factory for processing and a percentage of the producer's

share paid to the land owner as rent. Since preharvest production costs were assumed to be independent of harvest operations, only harvest costs were included in the model. Harvest costs were assumed to be a function of the total tonnage of sugarcane harvested. The objective function for the model was defined as follows:

$$(8) \qquad Z = (P_s \times S_p) + (P_m \times M_p) - (C_h \times T_t)$$

where Z represents total farm level producer net returns from sugar and molasses production above harvesting costs, P_s represents the price received per pound of sugar (cents per pound), S_p is the producer's share of sugar produced (pounds), P_m is the price of molasses (dollars per gallon), M_p is the producer's share of molasses (gallons), C_h is the cost of harvesting sugarcane (dollars per ton), and T_t is the total tons of sugarcane harvested.

The functional constraints in the model consist of two sets of binding constraints and several transfer rows. The first three functional constraints are transfer rows that accumulate the total pounds of sugar produced, tons of sugarcane harvested, and gallons of molasses recovered, respectively. The first set of binding constraints forces the model to choose each field exactly once during the harvest season. The model can harvest any percentage of a field on any available day. Harvest of individual fields were restricted to certain defined periods, based upon crop age, by including estimated daily sugar accumulation for only the days during which harvest of the field is permitted. The second set of binding constraints creates a daily limit on the tons of sugarcane that may be harvested in one day. Each day has a constraint row that limits the tons of cane harvested to less than a specified daily quota amount. The model can be expanded to handle any number of fields, and the days available for harvest can be customized to any particular harvest season length.

RESULTS AND DISCUSSION

Two different harvest scenarios were solved by the harvest scheduling model. The solution results for each of these two scenarios are shown in Table 4. The first solution represents results from simulating the producer's actual daily harvest schedule. After the 1996 harvest season ended, the producer provided information on the specific day each field was harvested as well as actual sugar yields obtained. The actual harvest schedule solution in Table 4 is based on the date of actual harvest by field and the predicted sugarcane and sugar yields from the estimated prediction models. Sugarcane (tons) and sugar (pounds) yields per acre achieved by the producer closely matched predicted yields from the estimated models. Predicted total sugarcane production was 16,964 tons of sugarcane compared to the actual production of 16,639 tons reported by the producer. Estimated producer returns above harvest costs for the actual harvest schedule were $326,771. Average sugarcane yield over the whole farm was 30.5 tons per acre, resulting in an average sugar yield of 5,573 pounds per acre.

A second harvest scheduling model was solved for a solution in which harvest dates for individual fields were constrained to specified intervals. In Louisiana, sugarcane harvest begins with fields which contain the oldest stubble crops (second-stubble and older), then proceeds to younger, first stubble crops. All stubble crop fields are usually harvested first. Within each stubble group, varieties are usually harvested in order of maturity class: very early, early, and mid-season (Faw, 1998). Finally, fields containing plantcane which are being harvested for the first time are harvested

at the end of the harvest season in order to avoid damage of future stubble crops from early harvest. Plantcane fields are usually harvested beginning with varieties that deteriorate rapidly after a freeze and end with harvest of varieties that deteriorate at a slower rate after a freeze (more freeze tolerant). An additional consideration which impacts the harvest schedule is soil type. Extended periods of rain during the harvest season makes harvest of sugarcane on heavy textured clay soils difficult. Harvest operations on excessively wet fields containing clay soils can severely rut a field and possibly damage the stubble crop which would be harvested the following year. As a result, fields containing heavy textured clay soils would generally be harvested before fields containing lighter textured sandy soils.

In the constrained harvest model, possible harvest dates were specified for each field in the sample data set which conformed to traditional harvesting practices. Generally stated, these harvest date ranges began with second-stubble harvest beginning on October 1st and continuing into November, first-stubble harvest beginning in late October and continuing through November, and plantcane harvest beginning in late November and continuing through the end of December. Harvesting periods by crop age in the constrained harvest model were also adjusted for soil type. The resulting defined harvest periods included in the model were as follows: (a.) October 1-November1: second-stubble and older crops, all soil types; (b.) October 20 - November 15: first-stubble crops, heavy soil; (c.) October 25 - November 25: first-stubble crops, mixed soil; (d.) November 1 - December 31: first-stubble crops, light soil; (e.) November 25 - December 31: plantcane crops, heavy soil; (f.) December 1 - December 31: plantcane crops, mixed soil; and (g.) December 10 - December 31: plantcane crops, light soil. These defined harvest periods were based on the distribution of soil types on the particular farm being analyzed. A farm with a different distribution of soil types would probably have had a slightly different set of defined harvest periods. Solution results from this model indicated that sugar production and net returns could be increased with relatively minor adjustments to the actual harvest schedule. Optimal adjustment of harvest of individual fields resulted in a projected increase in total farm net returns of $17,360, or approximately $31 per harvested acre. Average harvested yield of sugarcane increased by 0.7 tons per acre resulting in an increase in average sugar yield per acre of 263 pounds. Analysis of individual field results indicated that the optimal harvest date changed an average of 13 days from the actual harvest date with some fields being harvested earlier and other fields harvested later in the season.

One factor which would have an effect on optimal harvest schedule determination to maximize net returns would be related to harvest travel costs. Harvest travel cost, i.e., the cost of moving sugarcane harvesting equipment from one field to another on the farm during the harvest season, would significantly impact net returns above harvest costs for farms on which individual fields are located at considerable distances from one another. Although harvest travel costs were not included in the analysis presented here, they should be considered when comparing alternative harvest schedules with the purpose of maximizing net returns. The relevant cost measure to consider in this decision analysis would be the change in travel costs among different schedules. For a specific change from one harvest schedule to another, this change in travel cost could be positive or negative. Inclusion of travel costs in the analysis should be considered in a whole farm basis. Whole farm harvest travel costs can be minimized by restricting harvest of fields within close proximity to each other to one defined harvest period and restricting fields in another locality to a different harvest period.

CONCLUSIONS

The long- term viability of the sugar industry will depend upon finding ways to produce sugar more economically through reduction of production costs and efficient management of available resources. Maximizing net returns for a whole farm, rather than trying to produce the maximum amount of sugar per field, should be the primary goal of producers. The purpose of this study was to develop a methodology to assist in scheduling the sequence in which sugarcane fields are harvested to maximize producers' economic returns. Models which predicted stalk weight and sugar per stalk by cultivar were estimated as a function of julian date and crop age as well as indicator variables representing years of production with different growing conditions. These models were then used to predict sugar yields by cultivar and field for a sample farm. The optimization linear programming model used the estimated accumulation of stalk weight and sugar per stalk with field information to generate yield predictions. The predicted yields were used to select a harvest schedule subject to constraints that maximized producer net returns above harvest cost.

The ability to predict sugarcane tonnage and raw sugar yields allows producers and mill personnel to more effectively plan the harvest of a sugarcane crop based on the current status of that crop. The type of harvest scheduling model developed here, although somewhat complex, could be standardized to allow for easy imputation of sucrose and tonnage accumulation data as well as individual farm data. A producer, or crop consultant, could potentially analyze the yield of each cultivar of sugarcane in the farm's crop mix and make decisions concerning harvest as well as future plantings. Optimization of harvest schedules could potentially recover more sugar from the fields, which directly increases the sugar recovered by the mills. Knowledge of the size and maturity stage of the crop could allow mills to more effectively assign delivery quotas among producers and plan the harvest schedule to maximize sugar production. Interest in site specific farming using global positioning satellites (GPS) and global information system (GIS) is growing among sugarcane producers, but the limiting factor is the ability to attribute yield to location. The model developed in this study allows for the possibility of predicting sugar yield for individual fields. This information can be useful in designing fertility programs, weed control programs and in making crop replacement decisions on an individual field basis.

REFERENCES

1. Brumelle, Shelby, Daniel Granot, Merja Halme, and Ilan Vertinsky. 1998. A tabu search algorithm for finding good forest harvest schedules satisfying green-up constraints. European Journal of Operational Research. 106:408-424.

2. Chang, Y. S. 1995. The trend of sucrose accumulation during maturation of sugarcane with special reference to the maturity of sugarcane cultivars. Report of the Taiwan Sugar Research Institute. 148:1-9.

3. Crane, Donald R., T. H. Spreen, J Alvarez and G. Kidder. 1982. An analysis of the stubble replacement decision for Florida sugarcane growers, Agricultural Experiment Station, Institute of Food and Agricultural Sciences, University of Florida. Bulletin 822.

4. Daust, David K., and John D. Nelson. 1993. Spatial reduction factors for strata-based harvest schedules. Forest Science. 39:152-165.

5. Faw, Wade F. 1998 Sugarcane Harvesting Schedule. Sugarcane Circular Letter No. 11-98, Louisiana Cooperative Extension Service, Louisiana State University Agricultural Center.

6. Higgins, A. J., R. C. Muchow, A. V. Rudd, and A. W. Ford. 1998. Optimising harvest date in sugar production: a case study for the Mossman mill region in Australia - I. Development of operations research model and solution. Field Crops Research. 57:153-162.

7. Lass, L. W., R. H. Callihan, and D. O. Everson. 1993. Forecasting the harvest date and yield of sweet corn by complex regression models. Journal of the American Society for Horticultural Science. 118:450-455.

8. Malezieux, E. 1994. Predicting pineapple harvest date in different environments using a computer simulation model. Agronomy Journal. 86:609-617.

9. Muchow, R. C., A. J. Higgins, A. V. Rudd, and A. W. Ford. 1998. Optimising harvest date in sugar production: a case study for the Mossman mill region in Australia - I. Sensitivity to crop age and crop class distribution. Field Crops Research. 57:243-251.

10. Nelson, John, J. Douglas Brodie, and John Sessions. 1991. Integrating short-term, area-based logging plans with long-term harvest schedules. Forest Science. 37:101-122.

11. Salassi, M. E., and S. B. Milligan. 1997. Economic analysis of sugarcane variety selection, crop yield patterns, and ratoon crop plow out decisions. Journal of Production Agriculture. 10:539-545.

12. SAS Institute. 1989. SAS/OR User's Guide, Version 6, 1st edition. SAS Institute, Cary, NC.

13. Semenzato, R. 1995. A simulation study of sugar cane harvesting. Agricultural Systems. 47:427-437.

14. Van Deusen, Paul C. 1996. Habitat and harvest scheduling using Bayesian statistical concepts. Canadian Journal of Forest Research. 26:1375-1383.

15. White, H. 1980. A heteroskedasticity-consistent covariance matrix estimator and a direct test of heteroskedasticity. Econometrica. 48:817-838.

16. Wolf, S. 1986. Predicting harvesting date of processing tomatoes by a simulation model. Journal of the American Society for Horticultural Science. 111:11-16.

Table 1. Parameter Estimates for Stalk Weight Prediction Models

	Sugarcane Varieties						
VAR	LCP 82-89	LHo 83-153	CP 79-318	CP 70-321	CP 65-357	CP 72-370	LCP 85-384
INT	-7.717**	-6.747**	-8.868**	-6.672**	-6.884**	-5.550**	-9.192**
	(-5.10)	(-4.68)	(-6.51)	(-6.92)	(-6.92)	(-6.34)	(-3.53)
LNJD	1.805**	1.621**	2.040**	1.652**	1.718**	1.441**	1.988**
	(6.81)	(6.41)	(8.57)	(9.82)	(9.89)	(9.40)	(4.35)
CROP	-0.373**	-0.312**	-0.295**	-0.330**	-0.352**	-0.389**	-0.158*
	(-7.46)	(-6.56)	(-6.50)	(-10.27)	(-10.53)	(-13.44)	(-1.88)
1981	-	-	-	0.190**	0.097	0.107	-
				(2.56)	(1.32)	(1.47)	
1982	-	-	-	0.091	-0.294**	0.013	-
				(1.19)	(-3.85)	(0.17)	
1983	-	-	-	-0.154**	-0.372**	-0.109	-
				(-2.02)	(-4.86)	(-1.46)	
1984	-	-	-	-0.233**	-0.474**	-0.090	-
				(-3.13)	(-6.39)	(-1.22)	
1985	-	-	-	-0.215**	-0.610**	-0.152**	-
				(-2.90)	(-8.27)	(-2.09)	
1986	-	-	-	-0.227**	-0.397**	-0.144*	-
				(-3.06)	(-5.37)	(-1.98)	
1987	-	-	-0.347**	-0.483**	-0.509**	-0.392**	-
			(-3.53)	(-5.80)	(-6.07)	(-4.88)	
1988	-	-	-0.055	0.001	-0.181**	-0.138*	-
			(-0.64)	(0.01)	(-2.46)	(-1.89)	
1989	-	-	-0.101	0.092	-0.037	0.016	-
			(-1.13)	(1.20)	(-0.48)	(0.21)	
1990	0.214**	-	0.187**	0.259**	0.034	0.212**	-
	(2.55)		(2.15)	(3.50)	(0.41)	(2.91)	
1991	-0.862**	-0.813**	-0.637**	-0.981**	-0.985**	-0.805**	-
	(-9.99)	(-10.65)	(-7.11)	(-12.79)	(-12.87)	(-10.77)	
1992	-0.459**	-0.372**	-0.317**	-0.483**	-0.572**	-0.364**	-
	(-5.47)	(-5.02)	(-3.64)	(-6.52)	(-7.75)	(-5.00)	
1993	-0.374**	-0.400**	-0.375**	-0.280**	-0.359**	-0.293**	-
	(-4.46)	(-5.40)	(-4.31)	(-3.77)	(-4.87)	(-4.03)	
1994	-0.009	-0.160**	-0.025	-0.098	-0.287**	-0.109	-0.061
	(-0.11)	(-2.15)	(-0.29)	(-1.32)	(-3.89)	(-1.49)	(-0.62)
1995	-0.161*	-0.130*	-0.081	-0.000	-0.222**	-0.116	0.061
	(-1.92)	(-1.75)	(-0.93)	(-0.01)	(-3.01)	(-1.59)	(0.62)
Adj. R^2	0.81	0.79	0.73	0.80	0.78	0.80	0.36
n	72	62	98	158	158	153	36
DW	1.77	2.03	1.89	1.94	2.25	1.84	2.42
White prb	0.34	0.89	0.74	0.41	0.34	0.87	0.36

Notes: Numbers in parentheses are *t*-values. Single and double asterisks (*) denote statistical significance at the 10% and 5% levels, respectively, *n* is the sample size, *DW* is the Durbin-Watson statistic, and *White prb* is the probability level of the White test for heteroskedasticity.

Table 2. Parameter Estimates for Sugar per Stalk Prediction Models

	Sugarcane Varieties						
VAR	LCP 82-89	LHo 83-153	CP 79-318	CP 70-321	CP 65-357	CP 72-370	LCP 85-384
INT	-3.511**	-3.296**	-4.064**	-3.470**	-3.932**	-2.442**	-4.081**
	(-18.62)	(-14.40)	(-24.19)	(-25.99)	(-29.80)	(-19.95)	(-15.74)
LNJD	0.664**	0.626**	0.764**	0.663**	0.741**	0.486**	0.757**
	(20.08)	(15.58)	(26.05)	(28.49)	(32.17)	(22.68)	(16.64)
CROP	-0.024**	-0.014*	-0.017**	-0.029**	-0.027**	-0.041**	0.004
	(-3.86)	(-1.86)	(-2.96)	(-6.54)	(-6.11)	(-10.07)	(0.43)
1981	-	-	-	0.018*	0.027**	0.010	-
				(1.77)	(2.71)	(0.96)	
1982	-	-	-	-0.011	-0.037**	-0.009	-
				(-1.00)	(-3.60)	(-0.86)	
1983	-	-	-	-0.028**	-0.022**	-0.035**	-
				(-2.62)	(-2.17)	(-3.37)	
1984	-	-	-	-0.041**	-0.042**	-0.021**	-
				(-3.93)	(-4.31)	(-2.04)	
1985	-	-	-	-0.037**	-0.052**	-0.034**	-
				(-3.65)	(-5.29)	(-3.35)	
1986	-	-	-	-0.032**	-0.003	-0.022**	-
				(-3.09)	(-0.32)	(2.15)	
1987	-	-	-0.005	-0.033**	-0.008	-0.038**	-
			(-0.44)	(-2.87)	(-0.68)	(-3.40)	
1988	-	-	-0.004	-0.006	-0.004	-0.022**	-
			(-0.35)	(-0.56)	(-0.44)	(-2.20)	
1989	-	-	0.001	0.003	0.028**	-0.014	-
			(0.12)	(0.26)	(2.81)	(-1.34)	
1990	0.011	-	0.005	0.006	0.009	0.003	-
	(1.06)		(0.46)	(0.58)	(0.80)	(0.33)	
1991	-0.097**	-0.113**	-0.070**	-0.147**	-0.079**	-0.108**	-
	(-9.02)	(-9.36)	(-6.32)	(-13.85)	(-7.76)	(-10.34)	
1992	-0.034**	-0.044**	-0.017	-0.047**	-0.014	-0.047**	-
	(-3.27)	(-3.74)	(-1.58)	(-4.54)	(-1.43)	(-4.58)	
1993	-0.047**	-0.064**	-0.039**	-0.049**	-0.012	-0.033**	-
	(-4.54)	(-5.42)	(-3.68)	(-4.79)	(1.20)	(-3.29)	
1994	0.004	-0.020	0.012	-0.021**	-0.008	-0.011	-0.008
	(0.35)	(-1.66)	(1.11)	(-2.05)	(-0.78)	(-1.04)	(-0.84)
1995	-0.019*	-0.017	-0.008	0.005	-0.015	-0.014	-0.005
	(-1.79)	(-1.43)	(-0.76)	(0.49)	(1.50)	(-1.41)	(-0.46)
Adj. R^2	0.89	0.86	0.90	0.89	0.89	0.86	0.89
n	72	62	98	158	158	153	36
DW	2.01	2.44	2.13	1.99	2.23	1.88	2.74
White prb	0.37	0.39	0.86	0.20	0.82	0.74	0.14

Notes: Numbers in parentheses are *t*-values. Single and double asterisks (*) denote statistical significance at the 10% and 5% levels, respectively, *n* is the sample size, *DW* is the Durbin-Watson statistic, and *White prb* is the probability level of the White test for heteroskedasticity.

Table 3. Sample Farm Acreage and Production Characteristics

Farm data:			
Farm size (harvested acreage)		556.9	
Number of fields		112	
Smallest field (acres)		0.3	
Largest field (acres)		19.6	
Variety data:			
LCP 82-89	plantcane	1 field	1.3 acres
LCP 82-89	stubble crop	13 fields	44.0 acres
LHo 83-153	plantcane	2 fields	6.7 acres
LHo 83-153	stubble crop	6 fields	31.8 acres
CP 79-318	stubble crop	4 fields	14.2 acres
CP 70-321	plantcane	12 fields	74.2 acres
CP 70-321	stubble crop	43 fields	228.9 acres
CP 65-357	stubble crop	7 fields	38.0 acres
CP 72-370	plantcane	3 fields	13.6 acres
CP 72-370	stubble crop	14 fields	61.7 acres
LCP 85-384	plantcane	5 fields	37.3 acres
LCP 85-384	stubble crop	2 fields	5.2 acres

Table 4. Comparison of actual harvest schedule with optimal harvest schedules

Solution Summary	Actual harvest schedule[1]	Constrained optimal harvest schedule
Returns above harvest costs	$326,771	$344,131
Returns above harvest costs per acre	$587	$618
Total sugar (pounds)	3,103,709	3,250,056
Total cane (tons)	16,964	17,373
Total molasses (gallons)	90,008	94,252
Acres	556.9	556.9
Average CRS (pounds sugar/ton)	183.0	187.1
Sugar per acre (pounds)	5,573	5,836
Cane per acre (tons)	30.5	31.2

[1] Producer's actual harvest schedule with total sugar and cane production estimated from prediction models. Producer records report actual production of 16,639 tons of sugarcane and 2,961,500 pounds of sugar.

CULTIVAR AND CROP EFFECTS OF SUGARCANE BULL SHOOTS ON SUGARCANE YIELD IN LOUISIANA

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ABSTRACT

Bull shoots are late-sprouting, large-diameter tillers that often appear late in the season in sugarcane (*Saccharum* spp.) grown in south Louisiana. The effect of bull shoots on sugarcane yield has not been assessed in Louisiana. The objectives of this study were to evaluate the cultivar and crop effects of bull shoots on sugarcane yield and yield components. Cultivar effects of bull shoots were evaluated during 1998 and 1999 at the USDA-ARS Ardoyne Farm at Chacahoula, LA. Crop effects of bull shoots were evaluated during 1998 at a test conducted on Joel Landry's farm near Paincourtville, LA. Sugarcane cultivars produced significantly different amounts of bull shoots. Sugarcane cultivars LHo 83-153 and LCP 85-384 produced the least amount of cane yield derived from bull shoots, averaging 3.2 and 4.4 percent of the total cane yield for the two years, respectively. Sugarcane cultivar HoCP 85-845 produced the greatest cane yield derived from bull shoots, 16.1 percent of the total cane yield for the two years. For all cultivars, both sucrose concentration and fiber content were lower for the bull shoots than for the whole stalks. For the test conducted at the Joel Landry Farm, the plantcane crop derived 16.6 percent of its total cane yield from bull shoots, whereas the first-ratoon crop derived 11.8 percent of its total cane yield from bull shoots. For both tests, the overall effect of bull shoots was positive because of the net increase in sucrose yield per unit area. However, bull shoots may have an adverse effect on processing because of added polysaccharides, starch, and color precursors. With the additional costs of transportation and processing and the negative effects on sugar quality, bull shoots may likely have an overall negative effect on overall sugar production.

INTRODUCTION

Bull shoots are late-sprouting, large-diameter tillers that often appear late in the growing season in sugarcane grown in south Louisiana. Bull shoots are also referred to as suckers or water sprouts. Some sugarcane cultivars tend to produce more bull shoots than others, and the problem is more pronounced in some years. Bull shoots are considered to produce additional weight with minimal sucrose concentration adding significant transportation and milling costs.

Sugarcane is clonally propagated for commercial production. In Louisiana, whole stalks and, to a lesser extent, smaller billet pieces are planted in the soil during August and September to begin a cycle of crops. Usually, a plantcane crop and two to three ratoon crops are harvested from a single planting. Because of Louisiana's temperate climate, the crop remains dormant in the winter months following harvest. In the spring, new shoots emerge to begin the subsequent crop. Once a sugarcane crop is harvested, the roots are physiologically active for only a short while (Baver et al., 1962). The roots cease to function and quickly die. For each new ratoon, a shoot that develops from an

underground overwintering bud quickly develops its own root system. Like many grasses, sugarcane relies on tillering to attain a desired plant population. In Louisiana, the tillering period usually ranges from late April through early June. Maximum tillering occurs approximately 500°C d after regrowth (Inman-Bamber, 1994). More tillers are produced than can normally become mature millable stalks. Tiller senescence occurs after the canopy closes beyond 70% interception of photosynthetically active radiation (Inman-Bamber, 1994).

Suckering, or the formation of bull shoots, begins in fields that are six to seven months of age (Hess, 1954). The formation of bull shoots begins in fields where sunlight is able to penetrate to the soil surface. It is common to observe a flush of bull shoots produced after sugarcane has lodged. In Hawaii, this flush of tillers is important to the overall contribution of cane yield. In Mauritius, bull shoots are not cut during hand harvesting and serve as an important beginning toward the next crop cycle. In Louisiana, some cultivars, like HoCP 85-845, can produce bull shoots even when the crop remains erect with a dense canopy. The cultivar CP 72-370 also has a tendency to produce bull shoots in Louisiana. However, the leaf angle of CP 72-370 is extremely erect and may allow enough sunlight to penetrate the canopy, thus allowing bull shoots to form late in the growing season. Salter and Bonnet (2000) indicated that high soil nitrogen level was one of several factors that may contribute to late season sucker production.

The effects of sugarcane bull shoots on sugarcane yield parameters have not been quantified for different cultivars or for different sugarcane crops (plantcane vs first ratoon). Therefore, our objectives were to assess cultivar and crop effects of sugarcane bull shoots on sugarcane yield and yield components.

MATERIALS & METHODS

Tests were conducted in 1998 and 1999 to determine the effect of bull shoots on different sugarcane cultivars at the USDA-ARS Sugarcane Research Unit's Ardoyne Farm at Chacahoula, LA. Data were collected each year from the plantcane crop of the second line trials of the USDA-ARS sugarcane breeding program. Cultivars used as controls in the second line trials (CP 70-321, LHo 83-153, LCP 85-384, and HoCP 85-845) were replicated five times throughout the trials and were harvested from this test for analyses. Each plot was a single row 4.9 m long and 1.8 m wide. The control cultivars in the second line trials were arranged as a randomized complete block design. The soil type was a Commerce silt loam.

In 1998, a test was conducted on Joel Landry Farms in Paincourtville, LA to determine the effect of sugarcane bull shoots on different sugarcane crops (plantcane vs first ratoon). The soil type for this test was also a Commerce silt loam. The cultivar tested was HoCP 85-845 in adjacent fields of a plantcane and first-ratoon crop. The experimental design at this location was a randomized complete block with a split-plot arrangement of treatments. Whole plots were crop, and sub plots were whole stalk and bull shoot treatments. Each plot was a single row 4.9 m long and 1.8 m wide.

The tests conducted at the Ardoyne Farm were harvested on December 17, 1998 and November 23, 1999. The test conducted at the Joel Landry Farm was harvested on December 18, 1998. Just prior to harvest, all stalk types were counted in each plot. For the Ardoyne Farm tests, whole stalks were counted as well as bull shoots, which were divided into two categories: those stalks greater than one meter and those stalks less than one meter in height. Hand-cut stalk samples

of five stalks of each stalk type were harvested and sent to the sucrose laboratory for quality analyses. In some instances, less than five stalks were harvested when stalk type counts were less than five. In the Joel Landry Farm test, stalk counts were done similarly except that the bull shoots were not categorized by height. Ten hand-cut stalks of each stalk type were harvested for analyses in the sucrose laboratory. All samples were cut level with the ground, topped through the apical bud, stripped of leaf material, bundled, and tagged. Bundle weight was recorded upon entry into the sucrose laboratories.

The samples from the Joel Landry farm were processed at the LSU Sugar Research Station sucrose laboratory at St. Gabriel, LA. Fiber content (g/kg) was determined by chopping six stalks with a Jeffco cutter-grinder (Jeffress Brothers Ltd., Brisbane Queensland, Australia), mixing, and taking a 600-g sub-sample for fiber analysis (Tanimoto, 1964). Each sample was pressed with a hydraulic press at 10.35 MPa pressure for one minute to separate the juice from the residue (bagasse). The residue was weighed and then oven-dried for three days at a temperature of 40.5°C. The weight of the dry plug was then recorded. A portion of the crusher juice was analyzed for Brix (percent soluble solids w/w) by refractometer (Chen and Chou, 1993). Pol of the clarified juice was obtained with an automated saccharimeter. Fiber content and sucrose concentration were estimated as described by Gravois and Milligan (1992).

Samples from the Ardoyne Farm were analyzed each year at the USDA-ARS Sugarcane Research Unit's sucrose laboratory at the Ardoyne Farm. Samples were prepared with a prebreaker (Legendre, 1992). For quality analysis, 1000-g samples were pressed with 2.01 MPa pressure for seventy-five seconds. The remaining sample plug was oven-dried for three days at a temperature of 40.5°C. Sucrose concentration (g/kg) was obtained using Brix, pol, and fiber percent cane along with recent modifications to the formula (Legendre, 1992). Using the fibraque correction, New Fiber content = Fiber * 1.3; New Pol = Pol * (100 - New Fiber)/(100 - Fiber); New Brix = Brix * (100-New Fiber)/(100-Fiber) * Z, where Z = 1.15 - 0.0018((1000 - Corrected Residue Weight)/10). The factor Z further corrects the Brix to reflect the lower purity of the juice remaining in the pressed core sample. Thus, the Winter-Carp formula is calculated as follows:

Sucrose concentration = 0.5 * ((0.28 * New Pol - 0.08 * New Brix) * (100 - (56.67 * New Fiber)/(100 - New Fiber)))

These modifications in the sucrose concentration formula result in lower values and more closely reflect the yield of commercially recoverable sugar as reported by the mills.

Cane yield (Mg/ha) was estimated as the product of stalk number per unit area (no. per m^2) and mean stalk weight (kg). Sucrose yield (Mg/ha) was the product of cane yield and sucrose concentration divided by 10.

Data for the USDA Ardoyne Farm experiment were analyzed with the following mixed model:

$$T_{ijkl} = \mu + Y_i + R_{j(i)} + V_k + S_l + YV_{ik} + YS_{il} + VS_{kl} + YVS_{ikl} + E_{ijkl}$$

where μ was the overall mean; Y_i was year i; $R_{j(i)}$ was replication j within Year i; V_k was Cultivar k;

S_l was stalk type l. YV_{ik}, YS_{il}, VS_{kl}, and YVS_{ikl} were the interactions, and E_{ijk} was the residual. Crop and stalk type and their interaction were considered fixed effects, with the remaining effects considered as random effects in the model.

Data for the Joel Landry Farm experiment were analyzed with the following mixed model:

$$T_{ijk} = \mu + C_i + R_{j(i)} + S_k + CS_{ik} + E_{ijk}$$

where T_{ijk} is observation j in crop i, of stalk type k; μ is the overall mean; C_i is crop i; S_k is stalk type k; CS_{ik} is stalk type by crop interaction; and E_{ijk} is the residual. Replication was considered a random effect, and crop and stalk type were considered fixed effects in the model. Means separation techniques were based on LSD (P=0.05).

A separate experiment was conducted in 1986 to determine the effect of date of sampling and sucrose concentration on stalk density. Five experimental clones from the L84 assignment series and the control cultivar CP 65-357 were sampled from the infield tests at the St. Gabriel Research Station. Stalk density and sucrose concentration were evaluated for each cultivar on August 13, 1986; October 2, 1986; and December 1, 1986. Stalk density (g/cm^3) was estimated based on stalk height (cm), stalk diameter (cm), and stalk weight (g) measurements from five stalks. Stalk volume was estimated as: $\pi * \text{stalk height} * (\text{radius})^2$. Stalk density was estimated as stalk weight/stalk volume. Sucrose concentration was estimated as described by Gravois and Milligan (1992). Partial correlation coefficients among the traits were obtained after adjusting for date and replication effects in the model.

RESULTS & DISCUSSION

For the tests conducted at the Ardoyne Farm, both sugarcane cultivars and stalk types differed significantly for all traits (Table1). Based on cane yield in 1998, the cultivar HoCP 85-845's total bull shoot cane yield was 26.0 Mg/ha, which was 21.5 percent of the total cane yield for that cultivar (Table 2). In contrast, only 2.3 Mg/ha or 2.1 percent of the total cane yield of the cultivar LHo 83-153 was attributed to bull shoots. LCP 85-384 is the most widely grown cultivar in Louisiana, harvested on 71 percent of the state's 2000 acreage (Louisiana Cooperative Extension Service Census 2000). The effect of bull shoots on LCP 85-384 was minimal. Only 6.6 and 2.1 percent, in 1998 and 1999, respectively, of LCP 85-384's total cane yield was contributed by bull shoots, with the majority of bull shoots being under one meter in 1998. In 1999, LCP 85-384 was the cultivar with the least amount of cane yield derived from bull shoots.

The effect of crop on bull shoot production was evaluated in the 1998 test conducted at the Joel Landry Farm. HoCP 85-845 stalk type (whole stalks, bull shoots, and total stalks) was significantly different for all sugarcane traits (Table 3). Crop (plantcane vs. first ratoon) effects were significant for sucrose yield, sucrose concentration, stalk number, stalk weight, and fiber content. Sucrose yield, sucrose concentration, and stalk weight means of the bull shoots were significantly higher for the plantcane crop than for the first-ratoon crop (Table 4). Conversely, fiber content of the bull shoots was significantly lower for the plantcane crop than for the first-ratoon crop. Similar to the results of the Ardoyne Farm test, the bull shoots had a lower sucrose concentration and fiber content compared to the whole stalks. In the Joel Landry Farm test, bull shoots accounted for 16.6

and 11.8 percent of the total cane yield in the plantcane and first-ratoon crops, respectively. The overall effect of bull shoots on sugarcane production was positive when assessed by sucrose yield for both plantcane and first-ratoon crops.

The production of sugarcane is measured by the field cane yield produced per unit area. The quality of that cane yield is measured by the sucrose concentration. In sugarcane produced in Louisiana, the tops and side leaves of the stalks are removed either by controlled agricultural burns or mechanically by extractor fans in combine harvesting systems. Tops and side leaves can decrease sugarcane quality if processed with whole stalks of sugarcane (Ivin and Doyle, 1989).

In a combine harvesting system, short bull shoots would likely be easily extracted with the tops and side leaves through the extractor fan systems. Some portion of the tall bull shoots would likely have a greater chance of being discarded through the extractor fans because of their lower sucrose concentration, which makes these stalk portions less dense than the whole stalks. This premise is supported by the data collected in the 1986 stalk density study. As expected, sucrose concentration significantly increased for each sampling date (August through December). Likewise, stalk density significantly increased for each sampling date: 0.95 g/cm^3 in August, 1.06 g/cm^3 in October, and 1.13 g/cm^3 in December. As the sucrose concentration of the stalks increased, stalk density increased. There was no variety x date interaction, indicating that all varieties followed this pattern. The lower stalk density of the bull shoots would make separation of the bull shoots from the whole stalks more achievable through an air flow fan extractor system. However, as noted in these studies, the bull shoots had larger stalk diameters. Bull shoot billet pieces would likely weigh more than whole stalk billet pieces of similar length, which would tend to offset the stalk density differential between the two stalk types.

In a whole stalk harvesting system, both short and tall bull shoots would be harvested and sent to the factory, although some of the shorter bull shoots would not carry over to the heap. Since bull shoots are living green shoots, burning would have a minimal effect on reducing the cane yield derived from bull shoots. The increase in cane yield is offset by a lower sucrose concentration for the bull shoots. However, the overall effect of bull shoots as measured by sucrose yield was positive in the Ardoyne Farm test for each cultivar in both 1998 and 1999 and in the Joel Landry Farm test in 1998. Other economic factors would tend to diminish the positive effect of bull shoots on sucrose yield. First, both the factory and grower are incurring transportation costs to what is essentially poor quality cane. The overall effect of bull shoots at the factory would be to lower both sucrose concentration, a negative aspect, and fiber content, a positive aspect. While the overall effect of bull shoots on sucrose yield in the field is positive, bull shoots may have an adverse effect on processing because of added polysaccharides, starch, and color precursors. With the additional costs of transportation and processing and the negative effects on sugar concentration, bull shoots may likely have a negative effect on overall sugar production.

REFERENCES

1. Baver, L.D., H.W. Brodie, T. Tanimoto, and A.C. Trouse. 1962. New approaches to the study of cane root systems. Proc. Int. Soc. Sugar Cane Technol. Congr. 11:248-252.

2. Chen, J.C.P. and C.C. Chou. 1993. Meade-Chen Cane Sugar Handbook, 12th ed. John Wiley and Sons, Inc.

3. Gravois, K.A. and S.B. Milligan. 1992. Genetic relationships between fiber and sugarcane yield components. Crop Sci. 32:62-67.

4. Hess, J.W. 1954. The influence of suckers on the yield of sugarcane. Sugar Journal 16:25-31.

5. Inman-Bamber, N.G. 1994. Temperature and seasonal effects of canopy development and light interception of sugarcane. Field Crops Res. 36:41-51.

6. Ivin, P.C. and C.D. Doyle. 1989. Some measurements of the effect of tops and trash on cane quality. Proc. Australian Soc. Sugar Cane Technol. 11:1-7.

7. Legendre, B.L. 1992. The core/press method of predicting the sugar yield from cane for use in payment. Sugar J. 54(9):2-7.

8. Salter, B. and G.D. Bonnett. 2000. High soil nitrate concentrations during autumn and winter increase suckering. Proc. Australian Soc. Sugar Cane Technol. 22:322-327.

9. Tanimoto, T. 1964. The press method of cane analysis. Hawaii, Plant. Rec. 57(2):133-150.

Table 1. Mean squares from the analysis of variance conducted on experiments at the USDA Ardoyne Farm during 1998 - 1999.

Source	df	Sucrose yield	Cane yield	Sucrose concentration	Stalk number	Stalk weight	Fiber content
		$(Mg/ha)^2$	$(Mg/ha)^2$	$(g/kg)^2$	$(No./ha)^2$	$(kg)^2$	$(g/kg)^2$
Year	1	5.1	2210.2*	3653.7*	11628333.5	1.81	11744.5
Rep(Year)	8	1.5	318.0**	393.7**	100162708.8	0.45**	5142.9**
Cultivar	4	6.3**	762.7**	602.4**	569034650.2**	0.90**	13931.3**
Stalk Type	3	1682.1**	91995.8**	139204.9**	42818341556.0**	8.83**	16575.4**
Year*Cultivar	3	1.3	69.2	1014.0**	1880417458.9	0.93**	14762.6**
Year*Stalk Type	3	2.5*	340.9**	26.6	5095687.6	0.01	958.9
Stalk Type*Cultivar	12	7.7**	511.2**	416.1**	675754568.8**	0.13**	2738.9**
Year*Stalk Type*Cultivar	9	2.0*	245.6**	230.1**	124110538.6	0.35**	5669.8**
Pooled error	181	0.9	85.8	51.3	67399867.3	0.05	1072.0

Table 2. Trait means by year and cultivar for the 1998-1999 USDA Ardoyne Farm tests

Cultivar	Sucrose yield (Mg/ha)	Cane yield (Mg/ha)	Sucrose concentration (g/kg)	Stalk number (No./ha)	Stalk weight (kg)	Fiber content (g/kg)
			1998			
Bull Shoots (Short)[1]						
CP 70-321	0.095	4.9	19.3	9639	0.46	164.8
CP 72-370	0.003	4.4	0.7	11432	0.39	168.8
LHo 83-153	-0.006	1.1	-5.7	4707	0.26	156.8
LCP 85-384	-0.001	4.6	-0.2	12328	0.42	152.6
HoCP 85-845	-0.019	6.9	-2.8	15018	0.46	146.5
LSD(0.05)	NS	NS	2.3	NS	NS	10.0
Bull Shoots (Tall)[1]						
CP 70-321	0.183	5.8	31.6	6052	0.92	163.3
CP 72-370	0.560	14.8	40.4	9863	1.29	164.5
LHo 83-153	0.007	1.2	5.9	1121	0.21	134.5
LCP 85-384	0.073	3.7	19.8	4483	0.66	130.9
HoCP 85-845	0.701	19.1	36.7	13225	1.46	165.3
LSD(0.05)	0.500	12.9	10.6	NS	0.35	62.9
Bull Shoots (Total)						
CP 70-321	0.278	10.7	26.0	15691	0.74	163.7
CP 72-370	0.447	19.2	23.3	21295	0.96	165.6
LHo 83-153	0.008	2.3	3.6	2690	0.17	133.8
LCP 85-384	0.082	8.3	9.9	15916	0.49	125.8
HoCP 85-845	0.697	26.0	26.8	28244	1.21	160.3
LSD(0.05)	NS	NS	8.4	NS	NS	60.8
Whole Stalks						
CP 70-321	11.276	93.5	120.6	59625	1.56	173.1
CP 72-370	12.354	103.9	118.9	71505	1.46	178.1
LHo 83-153	13.983	109.5	127.7	81367	1.36	164.0
LCP 85-384	14.850	116.2	127.8	85178	1.37	159.9
HoCP 85-845	11.120	94.8	117.3	66349	1.43	191.8
LSD(0.05)	NS	20.5	5.3	16206	0.14	9.1
Total Stalks						
CP 70-321	11.545	104.2	110.8	75316	1.48	172.1
CP 72-370	12.801	123.1	104.0	92800	1.38	176.2
LHo 83-153	14.064	111.8	125.8	84057	1.34	162.0
LCP 85-384	14.977	124.5	120.3	101094	1.29	157.7
HoCP 85-845	11.814	120.8	97.8	94593	1.38	185.0
LSD (0.05)	NS	19.4	4.8	15191	0.11	8.6

Table 2. cont'd.

Cultivar	Sucrose yield (Mg/ha)	Cane yield (Mg/ha)	Sucrose concentration (g/kg)	Stalk number (No./ha)	Stalk weight (kg)	Fiber content (g/kg)
	1999					
Bull Shoots (Short)[1]						
CP 70-321	0.053	2.3	23.0	12553	0.20	136.5
LHo 83-153	0.016	1.8	8.9	13001	0.12	137.3
LCP 85-384	0.013	1.1	11.7	8966	0.13	127.3
HoCP 85-845	0.012	3.4	3.6	12777	0.29	133.2
LSD(0.05)	0.015	1.2	5.4	NS	0.10	6.8
Bull Shoots (Tall)[1]						
CP 70-321	0.069	2.2	31.3	4707	0.57	112.6
LHo 83-153	0.083	1.9	43.8	2017	0.95	131.8
LCP 85-384	0.032	1.2	26.5	1569	0.48	73.1
HoCP 85-845	0.246	8.3	29.6	16139	0.59	136.6
LSD(0.05)	0.095	2.2	NS	6158	NS	NS
Bull Shoots (Total)						
CP 70-321	0.114	4.5	25.3	14571	0.36	110.6
LHo 83-153	0.106	3.7	28.7	15019	0.62	134.8
LCP 85-384	0.042	2.3	18.4	6950	0.30	73.3
HoCP 85-845	0.260	11.7	22.2	28917	0.52	135.5
LSD(0.05)	0.106	3.4	13.6	10485	NS	56.7
Whole Stalks						
CP 70-321	8.823	64.4	137.0	55814	1.15	145.6
LHo 83-153	11.846	85.1	139.2	75539	1.13	133.6
LCP 85-384	14.058	105.3	133.5	91678	1.16	151.8
HoCP 85-845	12.228	97.9	124.9	69487	1.40	157.0
LSD(0.05)	3.390	26.1	1.9	14738	NS	NS
Total Stalks						
CP 70-321	8.991	68.9	130.5	70385	1.10	143.6
LHo 83-153	11.935	88.8	134.4	90558	1.11	133.5
LCP 85-384	14.117	107.6	131.2	98628	1.14	150.2
HoCP 85-845	12.483	109.6	113.9	98404	1.31	154.7
LSD(0.05)	3.140	27.3	2.2	13001	NS	NS

[1] Length of short bull shoots was under one meter, and the length of tall bull shoots was over one meter.

Table 3. Mean squares from the analysis of variance conducted on plantcane and first ratoon crop experiments at the Joel Landry Farm test during 1998.

Source	df	Sucrose yield	Cane yield	Sucrose concentration	Stalk number	Stalk weight	Fiber content
		$(Mg/ha)^2$	$(Mg/ha)^2$	$(g/kg)^2$	$(No./ha)^2$	$(kg)^2$	$(g/kg)^2$
Crop	1	9.6	59.0	924.5**	939062230.0**	0.10**	226.8*
Rep(Crop)	4	2.3*	300.3**	43.8	140123014.0**	0.01**	70.8
Stalk Type	2	192.8**	13142.1**	10361.7**	11801044408.0**	0.34**	3793.4**
Crop*Stalk Type	2	2.2*	73.4	3.5	151015272.0**	0.01	101.0
Pooled error	8	0.4	32.1	53.0	14515518.0	0.001	34.1

Table 4. Trait means by crop for the Joel Landry Farm test conducted during 1998[1].

Stalk Type	Sucrose yield	Cane yield	Sucrose concentration	Stalk number	Stalk weight	Fiber content
	(Mg/ha)	(Mg/ha)	(g/kg)	(No./ha)	(kg)	(g/kg)
Plantcane						
Whole stalk	9.35	82.5	113.3	76959	1.06	194.5
Bull shoots	1.55	16.4	94.7	23909	0.68	138.6
Total	10.90	98.9	110.2	100868	0.97	181.5
LSD (0.05)	1.83	16.9	18.3	8490	0.09	5.1
First ratoon						
Whole stalk	11.59	92.0	126.0	95639	0.96	195.1
Bull shoots	0.59	12.3	48.3	26898	0.44	154.9
Total	12.18	104.3	116.8	122537	0.85	186.0
LSD (0.05)	0.52	6.7	14.5	8781	0.09	18.0

[1]LSD values to compare two main-plot (crop) means at the same or different sub-plot (stalk type) treatments are 1.77 Mg/ha for sucrose yield, 5.7 g/kg for sucrose concentration, 7179 No./ha for stalk number, 0.06 kg for stalk weight, and 5.9 g/kg for fiber content.

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ECONOMICALLY OPTIMAL CROP CYCLE LENGTH FOR MAJOR SUGARCANE VARIETIES IN LOUISIANA

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ABSTRACT

The widespread adoption of the high-yielding variety LCP85-384 has resulted in two significant changes in the production sector of the Louisiana sugarcane industry. Plant characteristics of this variety make it very suitable for combine harvesting and have helped promote the conversion from wholestalk harvesting to combine harvesting in the state. Secondly, the variety is also an excellent stubbling variety, resulting in the expansion of standard sugarcane crop cycles beyond harvest of second stubble. Outfield trial yield data over the 1996-2000 period for major sugarcane varieties produced in Louisiana were used to determine the optimal crop cycle length which would maximize the net present value of producer returns. Cane yield and sugar per ton data for plantcane through third stubble were used to estimate the annualized net return of crop cycles through harvest of second and third stubble and to determine the breakeven level of fourth stubble yields which would justify production and harvest. Analysis of yield and net return data for the varieties CP 70-321, LCP 85-384, and HoCP 85-845 indicated that minimum yield levels necessary to keep older stubble in production for harvest depend directly upon the yields of the prior crop cycle phases and differ significantly across varieties.

INTRODUCTION

The production sector of the Louisiana sugarcane industry has undergone tremendous change over the past few years. Many sugarcane producers have switched from the use of wholestalk harvesters to combine harvesters. The performance rate difference between these two harvesters, coupled with the relatively more perishable billeted sugarcane, has caused producers and mills to look more closely at the timing and scheduling of sugarcane harvesting, transport, and milling operations. The release of the variety LCP 85-384 in 1993 has resulted in substantial changes in the sugarcane varieties grown in Louisiana. This variety is a high yielding variety with excellent stubbling ability (Legendre, 2000). In 1995, the leading sugarcane variety grown in Louisiana was CP 70-321, accounting for 49 percent of total acreage (Gravois, 1999). Other leading varieties produced included CP 65-357 and LCP 82-89, representing 15 percent and 13 percent of total state acreage, respectively. Acreage of LCP 85-384 only accounted for 3 percent of total sugarcane acreage in 1995. By 2000, acreage of LCP 85-384 had increased to 71 percent of total state sugarcane acreage. CP 70-321 and HoCP 85-845 were the second and third leading varieties produced in 2000 with only 14 percent and 8 percent of total acreage, respectively. Partly due to the widespread adoption of LCP 85-384 as well as the expansion of sugarcane into new production areas, total sugarcane acreage in Louisiana has increased from 370,000 acres in 1996 to 490,000 acres in 2000 (USDA, 2001). Total sugar production over the four-year period increased by 57 percent to 1.65 million tons of sugar, raw value.

The widespread adoption of the variety LCP 85-384 has caused producers to reevaluate the number of stubble crops to keep in production before plowing out and replanting. Traditionally, most sugarcane producers in Louisiana would harvest a plantcane crop and two stubble crops and then plow

out the stubble after harvest of the second stubble crop. As a result of the excellent stubbling ability of LCP 85-384, producers are now considering such production decisions as how long should stubble crops be kept in production before plowing out or whether a stubble crop should be kept in production if a net profit could be made from its harvest. Although these questions are currently related to the production of LCP 85-384 in Louisiana, this basic production decision is relevant to the production of any sugarcane variety in any region or location.

Crane et al. (1980, 1982) developed a conceptual model of the stubble replacement decision for sugarcane production in Florida. Yield prediction equations (Alvarez et al., 1982) were estimated and integrated into a decision model of the stubble replacement problem for sugarcane varieties grown in Florida at that time. A more recent study in Louisiana used net present value methods to estimate the economic returns from the production of sugarcane varieties over an entire crop cycle (Salassi and Milligan, 1997). This study utilized data from advanced variety trials conducted at ten locations across Louisiana from 1990 through 1994.

The basic purpose of this article is to outline a methodology which can be used to determine the optimal number of sugarcane stubble crops to keep in production with the goal of maximizing producer net returns. Time value of money concepts are presented for purposes of evaluating the total cash flow of a sugarcane crop cycle over a multiyear period. Plantcane and stubble crop yields from outfield tests are then used to determine the optimal number of stubble crops for three major sugarcane varieties currently produced in Louisiana.

MATERIALS AND METHODS

Economic evaluation of sugarcane crop cycle length is generally concerned with determining the optimal length of a crop cycle which would maximize economic returns. More specifically, it involves the determination of when to plow out the existing stubble crop and replant to start a new crop cycle. The objective is to determine the optimal number of sugarcane stubble crops to harvest which would maximize average net returns to the producer over the entire crop cycle. Therefore, planting costs, cultivation and harvest costs, as well as yields and raw sugar prices, must be considered over the entire crop cycle. In order to correctly evaluate stubble decisions, the total cash flow from a sugarcane crop cycle, along with the appropriate adjustments for the time value of money, must be considered.

The cash flow stream from a sugarcane crop cycle can be depicted in the following manner:

Time period	Item	Cashflow
0	Planting costs	PC
1	Plantcane net returns	R1
2	First stubble net returns	R2
3	Second stubble net returns	R3
4	Third stubble net returns	R4
:	:	:
n	n-1 stubble net returns	Rn

At the beginning of the crop cycle, planting costs per acre (PC) are incurred with harvest beginning the following year. Net returns per acre to the producer are then received for the harvest of plantcane

(R1) through the final stubble crop harvest (Rn). The decision faced by the producer is when to end the crop cycle with the objective of maximizing net returns. This problem is a farm management example of investment analysis, in which a sum of money is invested which yields annual net returns in the following years (Boehlje and Eidman, 1984; Kay and Edwards, 1999).

The net present value (NPV) of a crop cycle income stream can be represented as:

$$NPV = \frac{R1}{(1+r)^1} + \frac{R2}{(1+r)^2} + \frac{R3}{(1+r)^3} + \frac{R4}{(1+r)^4} + \ldots \frac{Rn}{(1+r)^n} - PC$$

or

$$NPV = \sum_{t=1}^{n} (1+r)^{-t} R_t - PC$$

where NPV is the net present value per acre of the income stream, R1 is the net returns per acre from plantcane, R2 is the net returns per acre from first stubble, R3 is the net returns per acre from second stubble, PC is the initial planting cost per acre, and r is a discount rate. The NPV of income from a crop cycle can be interpreted as the total income from harvest of plantcane and stubble crops less planting costs and all cultivation and harvest costs incurred adjusted for the time value of money.

In order to compare the relative profitability of different crop cycles and to determine breakeven yields and sugar prices required to keep a stubble crop in production for harvest, the NPV of the income stream must be annualized This annualized value (ANPV) can be obtained by multiplying the NPV estimate by a capital recovery factor:

$$ANPV = [\, r / 1 - (1+r)^{-n} \,] \times \sum_{t=1}^{n} (1+r)^{-t} R_t - PC$$

The annualized net present value (ANPV) of a crop cycle income stream can be interpreted as the average net return per year over a particular crop cycle. This is the net income estimate that should be maximized in order to maximize returns from a crop cycle. The decision rule which can be used would state that a sugarcane stubble crop should be kept in production for harvest if the net returns from harvest of that crop would increase the ANPV of the crop cycle income stream. If harvest of the stubble crop would result in a decrease in the average annualized net income, it should be plowed out even if a profit could be made from its harvest. Positive net returns from older stubble crops are no guarantee that average net returns are being maximized.

To evaluate optimal sugarcane crop cycle length for major varieties produced in Louisiana, yield data for plantcane through third stubble crops were obtained from outfield tests conducted by the LSU Agricultural Center, the USDA Sugarcane Research Unit, and the American Sugar Cane League over the 1996-2000 period. Sugar per acre, cane yield in tons per acre, and sugar per ton values for the varieties CP 70-321, LCP 85-384, and HoCP 85-845 are shown in Table 1. Net returns per acre to the producer were estimated for a raw sugar price of 19 cents per pound and with a 30 pound per ton reduction in sugar per ton to reflect a 10 percent trash content in commercially recoverable sugar (CRS). Estimated production costs for various phases of the sugarcane production

cycle in Louisiana were taken from published 2001 estimates (Breaux and Salassi, 2001). Present value of net returns were calculated using a five percent discount rate. Total planting costs per acre of production cane is shown in Table 2 and includes all costs associated with fallow and seedbed preparation, purchase and expansion of seedcane, as well as the final mechanical planting of production cane.

RESULTS AND DISCUSSION

Total NPV and ANPV estimates of net returns were estimated for the varieties CP 70-321, LCP 85-384, and HoCP 85-845 for crop cycles extending through harvest of second and third stubble (Tables 3-5). Planting cost and production cost estimates for 2001 were used in the analysis. Based on the sugar yields used in this analysis, producer net returns would be maximized in the production of all three varieties by extending the crop cycle through harvest of at least third stubble.

Sugar per acre yields for CP 70-321, adjusted for average trash content, ranged from 7,020 pounds per acre for plantcane to 5,663 pounds per acre for third stubble (Table 3). Harvest through second stubble yielded a NPV of $39 per acre and a ANPV of $14 per acre. Estimated net returns per acre from a third stubble crop were $96 per acre, which is higher than the ANPV through second stubble. Therefore, the average net returns over the crop cycle could be increased by extending the crop cycle through harvest of a third stubble crop. After factoring in third stubble net returns, the NPV of the crop cycle increased to $118 per acre, or $33 per acre per year.

Higher sugar per acre yields for LCP 85-384 resulted in higher estimates of net returns per acre compared to other varieties. With plantcane, first stubble, and second stubble sugar per acre yields above 7,400 pounds, the NPV of net returns of a crop cycle through harvest of second stubble was estimated to be $379 per acre, or an average of $139 per acre per year of harvest (Table 4). Third stubble yield of 6,973 pounds of sugar per acre resulted in producer net returns of $221 per acre, higher than the ANPV through second stubble. Extension of the crop cycle through a third stubble harvest increased NPV of net returns to $562 per acre, or $158 per acre on an annual basis.

The NPV of crop cycle net returns for HoCP 85-845 were estimated to be $127 per acre through harvest of second stubble and $336 per acre through harvest of third stubble (Table 5). Commercially recoverable sugar per acre yields declined to 6,622 pounds for second stubble but increased to 7,314 pounds for third stubble. As a result, extension of the crop cycle through harvest of a third stubble crop increased annual net returns by $48 per acre.

Although no yield data were available for fourth stubble yields, breakeven sugar yields required to economically justify harvest of a fourth stubble crop were estimated for each of the three varieties at two different raw sugar price levels (Table 6). In order to maximize net returns over the crop cycle, a fourth stubble crop should be kept in production for harvest only if the projected net returns per acre equal or exceed the ANPV through third stubble. Average CRS values for each variety were used to determine breakeven sugar per acre and tonnage per acre values for a fourth stubble crop. At a raw sugar price of 19 cents per pound, breakeven fourth stubble sugar yields were estimated to be 5,010 pounds per acre for CP 70-321, 6,314 pounds per acre for LCP 85-384, and 5,651 pounds per acre for HoCP 85-845. An increase in projected raw sugar price to 21 cents per pound lowered the required breakeven sugar per acre yields by approximately 500 pounds.

CONCLUSIONS

In order to maximize economic net returns from the production of sugarcane, the optimal length of a crop cycle must be determined. This article presented a methodology for determining the optimal crop cycle length for sugarcane grown in any location. Outfield yield data through third stubble were used to determine optimal crop cycle length for three major varieties of sugarcane grown in Louisiana. Breakeven yields required to economically justify harvest of a fourth stubble crop were also estimated. Although sugarcane yield data through harvest of third stubble used in this study were the most comprehensive data available for the varieties studied, the time period represented by these data is relatively short (1996-2000). This may be a limitation to the results presented here and suggests that this area needs additional research as more time series data becomes available.

Three general conclusions can be drawn from this analysis. First, the economically optimal sugarcane crop cycle length is one which maximizes average net returns per acre over the entire crop cycle. Net returns over a multiyear crop cycle should be adjusted for the time value of money, thereby annualizing the total NPV of returns over the years of harvest. A decision rule which can be used to evaluate older stubble would state that a stubble crop should be kept in production for harvest only if the net returns from that crop would increase the average net returns over the crop cycle. Positive net returns from harvest of older stubble is no guarantee that average returns are being maximized. Secondly, economic evaluation of keeping older stubble in production is variety- and field-specific. Varieties with different yields and production costs will have different breakeven yields. Finally, when considering whether to keep current fields of older stubble in production, include the impact of varying sugar prices and yields. Higher (lower) projected stubble crop yields decrease (increase) required breakeven sugar prices. Lower (higher) projected sugar prices increase (decrease) required breakeven stubble crop yields.

REFERENCES

1. Alvarez, J., D. R. Crane, T. H. Spreen, and G. Kidder. 1982. A yield prediction model for Florida sugarcane. Agricultural Systems. 9:161-179.

2. Boehlje, Michael D., and Vernon R. Eidman. 1984. Farm Management (chapter 8). John Wiley and Sons, New York.

3. Breaux, Janis, and Michael E. Salassi. 2001. Projected costs and returns - sugarcane, Louisiana, 2001. LSU Agricultural Center, Department of Agricultural Economics and Agribusiness, A.E.A. Information Series No. 192.

4. Crane, Donald R., and Thomas H. Spreen. 1980. A model of the stubble replacement decision for Florida sugarcane growers. Southern Journal of Agricultural Economics. 12:55-64.

5. Crane, D.R., T.H. Spreen, J. Alvarez, and G. Kidder. 1982. An analysis of the stubble replacement decision for Florida sugarcane growers. University of Florida Agricultural Experiment Station Bulletin No. 882.

6. Gravois, Kenneth. 1999. The 1999 Louisiana sugarcane variety survey. Sugarcane research annual progress report, 1999. Louisiana Agricultural Experiment Station, Louisiana State University Agricultural Center, Baton Rouge, LA., pp. 91-96.

7. Kay, Ronald D., and William M. Edwards. 1999. Farm Management, 4th edition. WCB/McGraw-Hill, New York.

8. Legendre, Benjamin L. 2000. Sugarcane planting recommendations and suggestions. Louisiana Cooperative Extension Service, Louisiana State University Agricultural Center, Baton Rouge, LA.

9. Salassi, M. E., and S. B. Milligan. 1997. Economic analysis of sugarcane variety selection, crop yield patterns, and ratoon crop plow out decisions. Journal of Production Agriculture. 10:539-545.

10. United States Department of Agriculture. 2001. Sugar and Sweetener Situation and Outlook Report. Economic Research Service, SSS-230, January.

Table 1. Mean sugarcane yields for three commercial varieties across locations, 1996-2000.

Variety	Sugar per acre	Cane yield	Sugar per ton
	(lbs./acre)	*(tons/acre)*	*(lbs./ton)*
Plantcane, 1996-2000:			
CP 70-321	7899	30.0	264
LCP 85-384	8919	33.1	270
HoCP 85-845	7898	32.3	245
First stubble, 1996-2000:			
CP 70-321	7771	29.0	269
LCP 85-384	9414	34.5	273
HoCP 85-845	8115	31.5	257
Second stubble, 1996-2000:			
CP 70-321	6452	25.3	256
LCP 85-384	8429	32.0	264
HoCP 85-845	7574	30.1	250
Third stubble, 1997-2000:			
CP 70-321	6354	24.2	264
LCP 85-384	7847	29.3	268
HoCP 85-845	8215	31.8	260

Table 2. Total sugarcane planting costs per acre.

	Cost per acre	Percent of acre	Total cost per acre
Cost item:	*(dollars per acre)*	*(%)*	*(dollars per acre)*
Fallow / seedbed preparation	231.61	1.00	231.61
Cultured seedcane	499.75	0.03	17.77
Hand planting seedcane	250.78	0.03	8.92
Propagated seedcane	73.91	0.19	15.02
Mechanical planting seedcane	162.01	0.97	156.78
Total planting cost			430.11

Planting cost allocation based on an initial planting of 0.032 acres of cultured seedcane followed by two seedcane expansions using a 5:1 planting ratio.

Table 3. Annualized crop cycle net returns for CP 70-321.

Crop cycle phase	Recoverable sugar yield	Harvest through second stubble	Harvest through third stubble
	(lbs. per acre)	*(dollars per acre)*	
Fallow / Plant [a]	--	($430)	($430)
Plantcane [b]	7020	$181	$181
First stubble [b]	6931	$231	$231
Second stubble [b]	5718	$101	$101
Third stubble [b]	5663	--	$96
NPV of total returns [c]	--	$39	$118
ANPV of total returns [d]	--	$14	$33

[a] Nominal fallow, seedbed preparation and planting cost.
[b] Nominal net returns per acre above cultivation and harvest costs.
[c] Net present value of total net returns over crop cycle.
[d] Annualized net present value of net returns.

Table 4. Annualized crop cycle net returns for LCP 85-384.

Crop cycle phase	Recoverable sugar yield	Harvest through second stubble	Harvest through third stubble
	(lbs. per acre)	*(dollars per acre)*	
Fallow / Plant [a]	--	($430)	($430)
Plantcane [b]	7944	$252	$252
First stubble [b]	8384	$370	$370
Second stubble [b]	7488	$271	$271
Third stubble [b]	6973	--	$221
NPV of total returns [c]	--	$379	$562
ANPV of total returns [d]	--	$139	$158

[a] Nominal fallow, seedbed preparation and planting cost.
[b] Nominal net returns per acre above cultivation and harvest costs.
[c] Net present value of total net returns over crop cycle.
[d] Annualized net present value of net returns.

Table 5. Annualized crop cycle net returns for HoCP 85-845.

Crop cycle phase	Recoverable sugar yield	Harvest through second stubble	Harvest through third stubble
	(lbs. per acre)	*(dollars per acre)*	
Fallow / Plant [a]	--	($430)	($430)
Plantcane [b]	6945	$175	$175
First stubble [b]	7151	$252	$252
Second stubble [b]	6622	$188	$188
Third stubble [b]	7314	--	$254
NPV of total returns [c]	--	$127	$336
ANPV of total returns [d]	--	$47	$95

[a] Nominal fallow, seedbed preparation and planting cost.
[b] Nominal net returns per acre above cultivation and harvest costs.
[c] Net present value of total net returns over crop cycle.
[d] Annualized net present value of net returns.

Table 6. Breakeven fourth stubble yields for three major varieties.

Fourth stubble yield	CP 70-321	LCP 85-384	HoCP 85-845
ANPV [a] (third stubble)	$33	$158	$95
Breakeven yield:			
Sugar per acre (19¢)	5010	6314	5651
Avg. CRS [b]	233	239	223
Est. tons per acre	21.5	26.4	25.3
Sugar per acre (21¢)	4546	5731	5129
Avg. CRS [b]	233	239	223
Est. tons per acre	19.5	24.0	23.0

[a] Annualized net present value of net returns.
[b] Average commercially recoverable sugar in pounds per ton of cane.

SEASONALLY MAINTAINED SHALLOW WATER TABLES IMPROVE SUSTAINABILITY OF HISTOSOLS PLANTED TO SUGARCANE

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ABSTRACT

Subsidence of Histosols, caused by microbial degradation of these drained soils, is a major concern in the Everglades Agricultural Area (EAA) of south Florida. Our objective was to determine if seasonal maintenance of shallow water tables would effectively decrease soil degradation and subsidence while allowing conventional production of sugarcane (*Saccharum* spp.). We compared the effects of seasonally maintained water tables at 0.15 and 0.40 m depths, and the currently practiced 0.60 m depth, on microbial degradation of a Lauderhill soil (Lithic Medisaprist). We maintained seasonal water tables from the beginning of May through September during the typical wet season. Fields were drained to or below 0.6 m from the soil surface during the remainder of the year to allow for conventional harvest and cultural management. We took surface soil samples bimonthly, applied the substrate ^{14}C-benzoate, and monitored $^{14}CO_2$ respiration as an indicator of Histosol degradation. Seasonally maintained water tables at 0.15 and 0.40 m reduced microbial degradation of the organic soil, resulting in modeled subsidence rates of 1.4 cm y^{-1} and 2.0 cm y^{-1}, respectively, when compared to 4.3 cm y^{-1} for the conventional 0.6 m depth. Decreased soil degradation and increased sustainability resulting from shallow water table maintenance was a direct result of increased soil water content and the corresponding decrease in air-filled pore space. Seasonal maintenance of shallow water tables appears compatible with current production practices for sugarcane, and will enable significant conservation of EAA Histosols.

INTRODUCTION

Histosols, the organic soils common to the EAA, are fertile, with high native carbon (C), nitrogen (N), and phosphorus (P) levels. Conventional agricultural practices for sugarcane production in the EAA include maintenance of water tables at or below 0.6 m from the soil surface. The aerobic soil environment created by agricultural drainage enables microbial mineralization of the organic soil, and release of C, N, and P for microbial and plant uptake. Off-loading of excess N and P resulting from soil mineralization has been addressed through development and adoption of on-farm management practices (Izuno et. al., 1995). During soil mineralization, the rate of C lost as carbon dioxide (CO_2) exceeds the rate of C attenuation and storage. This results in land subsidence of up to 4 cm y^{-1} (Stephens and Johnson, 1951; Stephens et al., 1984). However, no sugarcane management practices have been adopted to address the land subsidence issue.

Considering the economic impact of sugarcane production on the EAA region and the state (Schueneman, 1998), it is important to maintain sugarcane production in this region. However, it is also important to explore sugarcane management practices that ensure soil resource and environmental sustainability. One way to reduce microbial degradation and to increase soil resource sustainability is to maintain shallow water tables. This practice would decrease aerobic soil degradation of the organic soil, primarily by reducing the air-filled pore space and the oxygen (O_2) available.

Past research shows that sugarcane is tolerant of, and can be successfully grown in, soils with a seasonally maintained shallow water table (Gascho and Shih, 1979; Kang et. al., 1986; Snyder et. al., 1978). However, past research relating shallow water table management to soil sustainability of EAA Histosols considers only full-season water table maintenance (Stephens and Johnson, 1951; Volk, 1972). The impacts of seasonally maintained water tables on Histosol sustainability are not adequately quantified. We suggest that seasonally maintained shallow water tables can substantially improve soil sustainability, while allowing for current crop management practices and yield. Our objective was to assay the effects of seasonal shallow water table management on soil sustainability.

MATERIALS AND METHODS

The research site was established in 1997 near South Bay, FL (Figure 1) and consisted of seven 6.7 ha fields (180 m x 370 m). The organic soil was a Lauderhill muck soil (Lithic Medisaprist). Bulk density and particle density were determined in the lab and were then used to determine pore space by calculation (Blake and Hartge, 1986a; Blake and Hartge, 1986b; Danielson and Sutherland, 1986).

Three fields under water table management, one each at target water table depths of 0.15 (WT-1), 0.40 (WT-2), and 0.60 m (WT-3) below soil surface (Figure 2), were planted to sugarcane and were separated by four unplanted buffer fields of equal size. Water tables in each field were controlled at the previously mentioned depths using automatically-controlled, diesel-powered pumps positioned at the supply canal inlet and outlet for each experimental field. In response to needs expressed by Glaz (1995), water tables were maintained from approximately May (following Spring germination and stand establishment) through September (Figure 2). This corresponds with the warm, high-rainfall portion of the growing season. During the remainder of the year, fields were drained, with a target water table depth of 0.6 m (Figure 2) to allow for conventional harvest and cultural practices.

Using a stainless steel bucket auger (0.07 m diameter), field soil samples were collected every two months from the surface 0.00-0.15 m of the soil profile, midway between sugarcane rows. We weighed triplicate soil samples, dried them in a 105°C oven for 24 h, and determined soil water content by difference.

Tate (1979a and 1979b) used a substrate-induced respiration assay to successfully model effects of flooded management on microbial decomposition of Histosols of the EAA. We modified the assay, using benzoate instead of salicylate to model organic soil mineralization, as suggested by Williams and Crawford (1983). Williams and Crawford (1983) successfully used benzoate to model

degradation of peat similar in many respects to Histosols of the EAA. In concurrent studies the benzoate assay was sensitive to changes in water management on EAA Histosols (data not shown). We applied ^{14}C(carboxyl)-benzoate at a rate of 861 MBq kg^{-1} wet soil (specific activity, 577MBq $\mu mole^{-1}$, Sigma Chemicals, St. Louis, MO).

We assayed 6 homogenous soil samples from each field. We conducted substrate assays at room temperature (22 ± 1° C) within 6 h of sample collection. Substrates were mixed with 10 g (wet weight) of soil from each of the field samples. Samples were incubated for 2 h (Zibilske, 1994), and evolved CO_2 including $^{14}CO_2$ was collected in a 1M NaOH trap solution. Following incubation, we mixed 1 mL of the trap solution with 5 mL of scintillation cocktail (ScintoSafe Plus 50%, Fisher Scientific, Pittsburgh, PA) and determined rate of $^{14}CO_2$ respired by microorganisms in the soil degradation process (Model LS 3801, Beckman Instruments, Fullerton, CA).

Data were analyzed using the Analysis of Variance procedure in SAS v.8 software (SAS, 1999), and statistical differences between means were determined using Fisher's LSD (a=0.05). Regression analysis was also conducted using the SAS v.8 software.

RESULTS AND DISCUSSION

Seasonal shallow water table maintenance treatments resulted in significant differences in soil water content (Table 1). Seasonal maintenance of water tables at the 0.15 m depth (WT-1) significantly increased water content of the surface soil. Only WT-1 caused soil aeration to fall below 10 % air-filled porosity (Table 1), a minimum volume required for adequate soil aeration and aerobic microbial activity (Paul and Clark, 1989). The depth to the shallow water table was highly variable during the free-drainage period resulting in no significant differences in soil water content, however there was a trend for greater soil water content and decreased air-filled porosity with the seasonal WT-1 treatment when compared to either WT-2 or WT-3 treatments (Table 1). While the seasonal shallow water tables were maintained, WT-2 increased soil water content in comparison to conventional water table management (WT-3). This difference was not significant at the a=0.05 level, but was significant at the a=0.10 level.

Assay results (Table 2) indicated shifts in responses to changes in water table management similar in magnitude to those for gross respiration reported by Volk (1972), who evaluated water table impacts on subsidence of EAA Histosols in lysimeters with re-packed soil. During periods of shallow water table maintenance, the conventional water management practice (WT-3) resulted in the greatest assayed microbial activities (Table 2 and Figure 3).

Elevated assay results associated with conventional management (WT-3) indicate significantly reduced sustainability of the organic soil relative to either WT-1 or WT-2, the seasonally maintained shallow water tables. Moreover, when compared to WT-3, seasonal shallow water table treatments generally improved sustainability of organic matter throughout the periods of free drainage (Table 2). We maintained shallow water tables for only four to five months during the warm, wet portion of each year. This suggests that WT-1 and WT-2 result in residual suppression of soil degradation which has not been previously reported for Histosols of the EAA

region. This is likely a result of reduced aerobic microbial populations during the beginning of the free drainage periods (Table 1).

The WT-1 treatment resulted in greater overall Histosol sustainability when compared to WT-2 (Table 2). However, maintenance of either WT-1 or WT-2 decreased microbial degradation of the organic soil by up to 50 % when compared to WT-3. This in turn suggests that WT-1 and WT-2 increase Histosol sustainability by as much as two times that of WT-3, the conventional water management practice.

During the short duration of this study, direct measurement of subsidence was not practicable. To relate our benzoate assay to soil subsidence, we regressed our benzoate assay results (periods under shallow water table management) on subsidence rates for full-season shallow water table management as reported by Stephens and Johnson (1951). This regression analysis resulted in the following equation:

$$\text{Subsidence} = 3.63 \times \text{BA} - 1.63 \qquad \text{Adjusted } R^2 = 0.90 \qquad [1]$$

where subsidence is in units of cm y^{-1}, and BA (benzoate assay) is in units of mmoles h^{-1} Mg^{-1}. We then fit our data for overall treatment effects to equation [1], resulting in modeled overall subsidence rates of 1.4 cm y^{-1} and 2.0 cm y^{-1}, for WT-1 and WT-2, respectively. The conventional water management practice, WT-3, resulted in an overall subsidence rate of 4.3 cm y^{-1} using the same fitting procedure.

These estimates are comparable to projections of Stephens and Johnson (1951) that indicate WT-1, WT-2 and WT-3 would result in subsidence rates of 0.6, 2.2 and 3.7 cm y^{-1}, respectively, if maintained throughout the year. Maintaining seasonal shallow water tables for only five months out of a year resulted in projected subsidence rates only slightly higher than those projected by Stephens and Johnson (1951) for full-season shallow water table management. Stephens and Johnson (1951) used elevation changes to measure subsidence rather than an assay. This would take into account decomposition throughout the soil profile. Our projections likely overestimate subsidence rates for the entire soil profile, as they are based on assay of the surface 0.00-0.15 m of the soil profile, and the greatest potential soil degradation rates. Correlation of benzoate assay results with directly measured soil subsidence rates is needed to validate the model for the Lauderhill soil and other Histosols of the EAA.

CONCLUSIONS

As a result of maintaining seasonal shallow water tables for only five months out of a year, our assay indicates subsidence rates slightly greater than that projected for full-season shallow water table management. These data support seasonal shallow water table management as a means of reducing subsidence and improving sustainability of valuable EAA soil resources. Shallow water tables not only increase soil sustainability during the portion of the year when they are maintained, but can also residually increase sustainability during the harvest season when fields are drained. This study should be replicated on other sites with different organic soil characteristics. Improved

correlation of assay results to directly measured subsidence rates should show that seasonal water table management is as effective as full-season maintenance in improving soil sustainability.

Given the current sugarcane varieties and production technology, an immediate shift to full-season shallow water table management is not realistic without negatively influencing sugarcane production and the EAA and Florida agricultural economies. WT-2 appears the best fit with current sugarcane varieties and production technology. The WT-1 treatment provides the greatest potential increase in soil sustainability. Research should be conducted to develop new sugarcane varieties suitable for production under seasonally maintained shallow water tables.

Shih and others (1997) reported decreased subsidence rates for the last 10 years based on changes in soil elevation on known transects throughout the EAA. They attribute decreased subsidence in part to shallow water table management, a result of Best Management Practice implementation for P off-loading (Shih et al., 1997). Decreased soil degradation and mineralization would result in reduced nutrient off-loading as indicated by Davis (1991). Future research should also address the effects of seasonal shallow water table management on nutrient off-loading. Improved sugarcane management including shallow water table maintenance can be an environmentally and economically sound production system. As a conservation practice, seasonal shallow water table management could double the production life of valuable EAA soil resources.

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REFERENCES

1. Blake, G.R., and K.H. Hartge. 1986a. Bulk Density. p. 363-375. In A. Klute (ed.). *Methods of Soil Analysis, Part 1- Physical and Mineralogical Methods.* ASA-SSSA, Madison, WI..

2. Blake, G.R., and K.H. Hartge. 1986b. Particle Density. p. 377-382. In A. Klute (ed.). *Methods of Soil Analysis, Part 1- Physical and Mineralogical Methods.* ASA-SSSA, Madison, WI..

3. Danielson, R.E., and P.L. Sutherland. 1986. Porosity. p. 443-461. In A. Klute (ed.). *Methods of Soil Analysis, Part 1- Physical and Mineralogical Methods.* ASA-SSSA, Madison, WI..

4. Davis, S.M. 1991. Growth, decomposition, and nutrient retention of *Cladium jamaicense* Crantz and *Typha domingensis* Pers. in the Florida Everglades. Aquat. Bot. 40:203-224.

5. Gascho, G.J., and S.F. Shih. 1979. Varietal response of sugarcane to water table depth. 1. Lysimeter performance and plant response. Soil and Crop Science Society of Florida Proceedings. 38:23-27.

6. Glaz, B. 1995. Research seeking agricultural and ecological benefits in the Everglades. J. Soil Water Conserv. 50:609-612.

7. Izuno, F.T., A.B. Bottcher, F.J. Coale, C.A. Sanchez, and D.B. Jones. 1995. Agricultural BMPs for phosphorus reduction in South Florida. Trans. ASAE. 38:735-744.

8. Kang, M.S., G.H. Snyder, and J.D. Miller. 1986. Evaluation of Saccharum and related germplasm for tolerance to high water table on organic soil. J. Am. Soc. Sugarcane Technol. 6:59-63.

9. Paul, E.A., and F.E. Clark. 1989. *Soil microbiology and biochemistry*. Academic Press, Inc., San Diego, CA. p.17.

10. SAS. 1999. *SAS Procedures Guide, Version 8*. SAS Institute, Inc., Cary, N. C., 1643 pp.

11. Schueneman, T.J. 1998. An overview of Florida sugarcane. Florida Cooperative Extension Service, IFAS, University of Florida, Gainesville, SS-AGR-232.

12. Shih, S.F., B. Glaz, and R.E. Barnes, Jr. 1997. Subsidence lines revisited in the Everglades Agricultural Area, 1997. Agricultural Experiment Station, IFAS, University of Florida, Gainesville, Bulletin 902.

13. Snyder, G.H., H.W. Burdine, J.R. Crockett, G.J. Gascho, D.S. Harrison, G. Kidder, J.W. Mishoe, D.L. Myhre, F.M. Pate, and S.F. Shih. 1978. Water table management for organic soil conservation and crop production in the Florida Everglades. Agricultural Experiment Station, IFAS, University of Florida, Gainesville, Bulletin 801.

14. Stephens, J.C., L.H. Allen, Jr., and E. Chen. 1984. Organic soil subsidence. In T.L. Holzer (ed.). Man-induced land subsidence: Geological Society of America Reviews in Engineering Geology. 6:107-122.

15. Stephens, J.C., and L. Johnson. 1951. Subsidence of organic soils in the upper Everglades region of Florida. Soil and Crop Sci. Soc. Fla. Proc. 11:191-237.

16. Tate, R.L., III. 1979a. Effect of flooding on microbial activities in organic soils: carbon metabolism. Soil Sci. 128:267-273.

17. Tate, R.L., III. 1979b. Microbial activity in organic soils as affected by soil depth and crop. Appl. Environ. Microbiol. 37:1085-1090.

18. Volk, B.G. 1972. Everglades Histosol subsidence: 1. CO_2 evolution as affected by soil type, temperature, and moisture. Soil and Crop Sci. Soc. Fla. Proc. 32:132-135.

19. Williams, R.T., and Crawford, R.L. 1983. Effects of various physiochemical factors on microbial activity in peatlands aerobic biodegradative processes. Can. J. Microbiol. 29:1430-1437.

20. Zibilske, L.M. 1994. Carbon Mineralization. p. 835-863. In R.W. Weaver et al. (ed.). *Methods of Soil Analysis, Part 2- Microbiological and Biochemical Properties.* ASA-SSSA, Madison, WI.

Table 1. Treatment impacts on soil water content and air-filled porosity for the period when shallow water tables were maintained, for the drained period enabling conventional harvest and cultivation, and for the water management practice overall.

	Average Soil Water Content [Air-Filled Porosity†]		
Treatment	Shallow Water Table	Drained	Overall‡
	m^3m^{-3} [%]		
WT-1§	0.77 [1] a¶	0.72 [6] a	0.74 [4] a
WT-2	0.67 [11] b	0.59 [19] a	0.62 [16] b
WT-3	0.59 [19] b	0.59 [19] a	0.59 [19] b

†Air-filled porosity determined as the difference between calculated total porosity and volumetric water content.

‡Overall refers to the overall water treatment effect, being the average water content or air-filled porosity for the entire year, including the periods of shallow water table management and free drainage.

§Treatments are based on the depth at which the seasonal shallow water table was maintained with WT-1=0.15 m depth, WT-2=0.4 m depth, and WT-3=0.6 m depth.

¶Statistical comparisons are valid in a soil depth, within a column. Means followed by the same letter are not significantly different (Fisher's LSD, a = 0.05).

Table 2. Water management impacts on the benzoate assay of soil degradation for the period when shallow water tables were maintained, for the drained period enabling conventional harvest and cultivation, and for the water management practice overall.

	Benzoate Assay of Histosol Degradation		
Treatment	Shallow Water Table	Drained	Overall[†]
	mmoles h^{-1} Mg^{-1} dry soil		
WT-1[‡]	0.68 a[§]	0.97 a	0.84 a
WT-2	0.95 b	1.05 a	1.00 b
WT-3	1.50 b	1.71 a	1.63 b

[†]Overall refers to the overall water treatment effect, being the average benzoate assay of Histosol degradation for the entire year, including the periods of shallow water table management and free drainage.

[‡]Treatments are based on the depth at which the seasonal shallow water table was maintained with WT-1=0.15 m depth, WT-2=0.4 m depth, and WT-3=0.6 m depth.

[§]Statistical comparisons are valid in a soil depth, within a column. Means followed by the same letter are not significantly different (Fisher's LSD, a = 0.05).

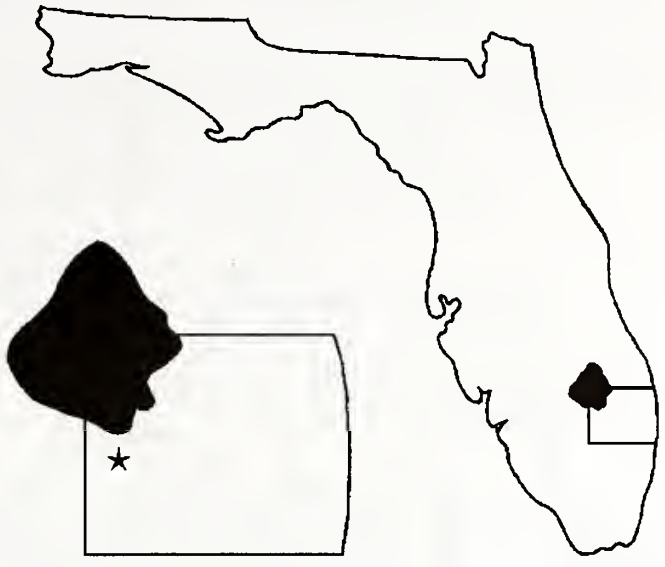

Figure 1. The research site (★) located in the Everglades Agricultural Area lies south of Lake Okeechobee (shaded black) in western Palm Beach County, Florida.

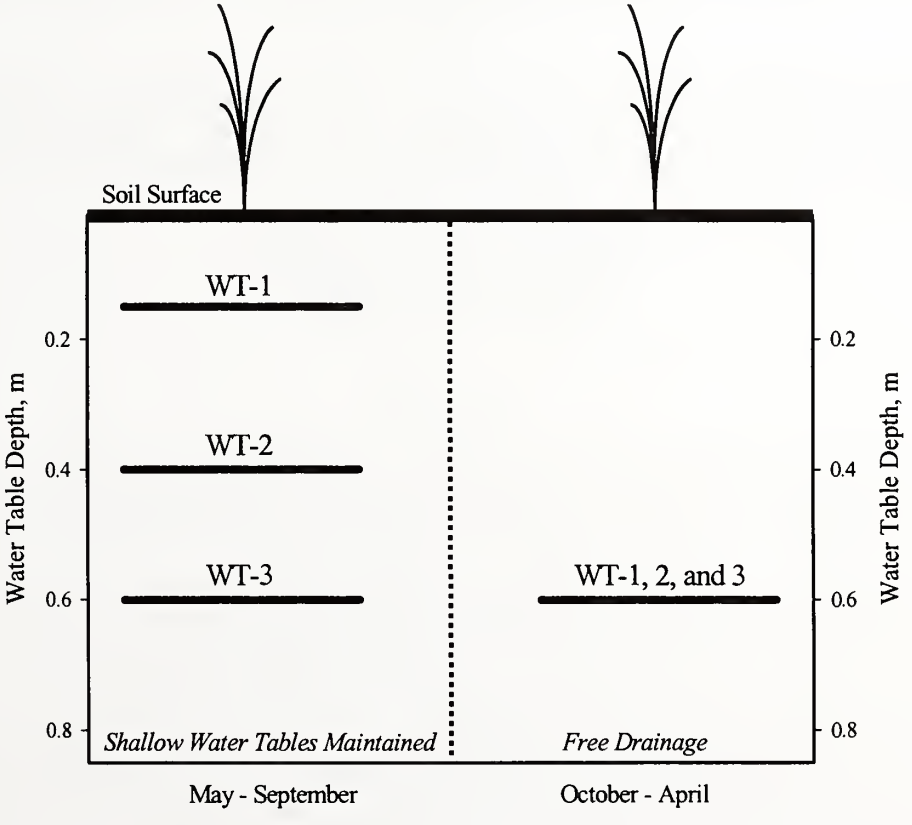

Figure 2. Water table depth for each treatment [WT-1=0.15 m depth, WT-2=0.4 m depth, and WT-3=0.6 m depth] during seasonal shallow water table maintenance and during free drainage.

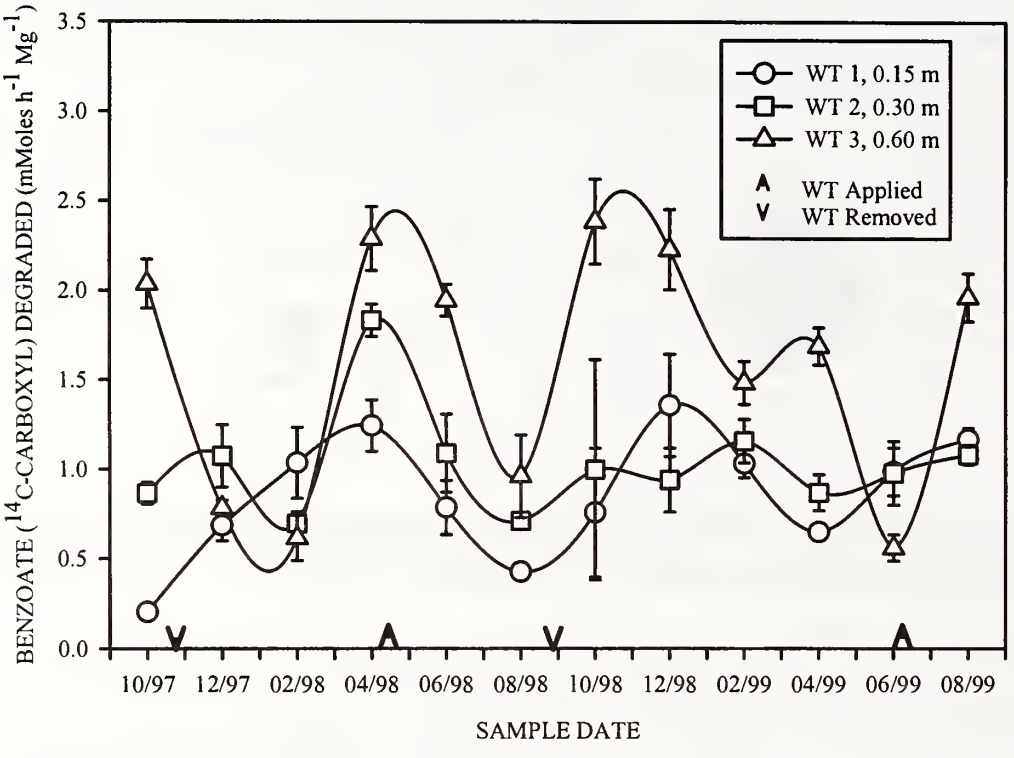

Figure 3. Study-long assay results as affected by water table management. Error bars indicate standard error of the mean. Treatments are based on the depth at which the seasonal shallow water table was maintained with WT-1=0.15 m depth, WT-2=0.4 m depth, and WT-3=0.6 m depth.

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Sugarcane Genotype Repeatability in Replicated Selection Stages and Commercial Adoption

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ABSTRACT

The sugarcane (interspecific hybrids of *Saccharum* spp.) breeding and selection program in Canal Point (CP) Florida increased the number of genotypes advanced to its final selection stage, Stage IV, from 11 to 14. This change resulted from recently reported evidence that replications could be decreased without reducing experimental precision in Stage IV. The major purpose of this study was to determine if advancing an additional three new genotypes to Stage IV would improve the likelihood of identifying successful cultivars. A secondary objective was to determine if genotypes with high or mediocre yields in the penultimate stage, Stage III, could be expected to have similar yields in Stage IV. Data were reviewed from 24 cycles of Stage III, and 16 cycles of Stage IV. Genotype correlations between Stage III and Stage IV were significant but low for sugar yield (Mg sugar ha^{-1}) ($r = 0.27$) and economic index ($ ha^{-1}) ($r = 0.28$). No genotype that ranked worse than 15th in both sugar yield and economic index in Stage III was later used on more than 1% of Florida's annual sugarcane hectarage. It is usually necessary to select from genotypes ranking worse than 15th in Stage III to advance 11 genotypes to Stage IV, because genotypes are normally discarded

due to disease susceptibility and poor agronomic type. It is unlikely that advancing more than 11 genotypes from Stage III would improve the likelihood of identifying productive commercial cultivars, unless other changes are made that improve the quality of genotypes advanced to Stage III.

INTRODUCTION

The sugarcane breeding and selection program at Canal Point, Florida is a cooperative program conducted by the USDA-Agricultural Research Service, the Florida Sugar Cane League, Inc., and the University of Florida Institute of Food and Agricultural Sciences. A previous study examined the final replicated testing stage (Stage IV) of the CP program (Brown and Glaz, 2001). Before that study, 11 promising genotypes were tested at 10 locations in Stage IV. Each genotype was replicated eight times and harvested as three annual crops, the plant-cane, first-ratoon, and second-ratoon crops at each location. The 11 promising genotypes in Stage IV were advanced from approximately 130 genotypes that were annually advanced from Stage II to Stage III (Glaz et al., 2001). Major criteria for advancement from one stage to the next are high yields, economic index, disease resistance or tolerance, and agronomic traits. A principal conclusion of Brown and Glaz (2001) was that experimental precision would remain similar in Stage IV if replications were reduced from eight to four.

The Florida Sugarcane Variety Committee selects the genotypes to advance from Stage III to Stage IV. This committee is composed of personnel representing growers, mills, and research and extension agencies participating in the CP breeding and selection program. Many criteria are considered in the selection process by committee members. However, most of the genotypes advanced to Stage IV in any given year can be classified into three groups using yield, disease, and agronomic criteria. The first group of genotypes has high yields and acceptable disease profiles and agronomic characteristics at all locations in Stage III. The second most desirable group is composed of genotypes with high yields at some locations. If 11 genotypes are not yet selected, the remaining entries are selected from among genotypes that had mediocre yields in Stage III but may have had some other redeeming characteristics, such as desirable agronomic traits, high theoretical recoverable sugar yields, or excellent disease resistance.

The committee usually limited its selections to 11 genotypes due to resources assigned to Stage IV. However, Brown and Glaz (2001) proposed a redistribution of resources in Stage IV that would not compromise experimental precision and allow for testing of more genotypes. In most years, there were not more than 11 genotypes in the first two groups of genotypes advanced from Stage III to Stage IV. However, several genotypes from the third group usually needed to be discarded when only 11 genotypes were advanced.

Among the genotypes with high yields, several usually have severe disease susceptibilities. The committee is very strict about not advancing such genotypes to Stage IV. Due to this policy and the ever increasing disease pressures on sugarcane in Florida, the committee often selected genotypes that ranked below 20th in yield or economic index in Stage III to advance 11 relatively disease-free genotypes.

Kang et al. (1988) reported that genotype repeatability was low between the two stages for 11 genotypes tested for one Stage III and one Stage IV cycle. Glaz and Miller (1982) reported that Stage IV results predicted reasonably well the commercial yields of five released genotypes. A logical follow-up to the studies of Brown and Glaz (2001), Kang et al. (1988), and Glaz and Miller (1982) was to determine how well genotype performance in Stage III corresponded to performance in Stage IV, and ultimately to commercial success for many Stage III and IV cycles. With this information, a more informed choice could be made about whether to reduce replications and increase the number of genotypes in Stage IV. The major purpose of this study was to determine if advancing an additional three new genotypes to Stage IV would improve the likelihood of identifying successful cultivars. This led into a secondary objective which was to determine if a genotype with high or mediocre yields in Stage III would be expected to have similar yields in Stage IV.

MATERIALS AND METHODS

Results from 24 Stage III cycles from the CP 69 through the CP 92 series of the CP sugarcane cooperative breeding and selection program were reviewed. The CP 69 series was planted in Stage III in 1970; and the final harvest of the CP 92 series in Stage III was in 1995. Stage III is the penultimate selection stage, and the first stage of the program in which genotypes are planted at multiple locations, replications, and annual crop cycles. About 130 new genotypes are now annually advanced to Stage III. These remain in the field for a plant-cane and a first-ratoon harvest. This study specifically focused on 21 to 42 of the Stage III genotypes in each Stage III cycle for which data were collected for both the plant-cane and first-ratoon crops.

Sixteen Stage IV cycles were reviewed; these cycles included the CP 77 through the CP 92 series. The CP 77 series was planted in Stage IV in 1980; and the final harvest of the CP 92 series in Stage IV was in 1999. Stage IV is the final selection stage in the CP program. Ten to 13 new genotypes were advanced to most of these Stage IV cycles, but only 10 or 11 were planted at all Stage IV locations. The genotypes in Stage IV were analyzed from the plant-cane through the second-ratoon crop. The characteristics compared between Stage III and Stage IV were sugar yield, (Mg sugar ha^{-1}), and economic index, measured in \$ ha^{-1} (Deren et al., 1995). The economic index calculation accounts for costs such as planting, milling, and transportation of cane to the mill. For calculations of economic index, the same costs were used over all years of the study. Also, theoretical recoverable sugar (kg sugar Mg^{-1} cane) was discussed for some genotypes. Theoretical recoverable sugar (TRS) was calculated according to Arceneaux (1935) until 1993 and according to Legendre (1992) since 1993.

Sugar yield and economic index were reported for both Stage III and Stage IV as a percentage of a commercially grown check cultivar. The check was CP 63-588 in Stages III and IV in the CP 77 and 78 series. In the CP 79 series, the check remained CP 63-588 in Stage III but was CP 70-1133 (Rice et al., 1978) in Stage IV. From the CP 80 through the CP 92 series, the check was CP 70-1133 in both Stage III and Stage IV.

Stage III was planted at four locations each year, three with organic soils and one with a sand soil. In most cases, Stage IV was planted at these same locations, on the same days as Stage III. The organic soils were Terra Ceia mucks (Euic, hyperthermic Typic Medisaprists), Pahokee mucks (Euic,

hyperthermic Lithic Medisaprists), Lauderhill mucks (Euic, hyperthermic Lithic Medisaprists), and Dania mucks (Euic, hyperthermic, shallow Lithic Medisaprists). The sand soils were Malabar sands (Loamy, siliceous, hyperthermic Grossarenic Ochraqualfs) and Pompano Fine sands (Siliceous, hyperthermic Typic Psammaquents). Stage IV was planted at an additional 5 to 8 locations each year. One of these locations had Pompano Fine sand soils, and another had Torry muck soils (Euic, hyperthermic Typic Medisaprists). The Torry mucks have 30-50% organic matter rather than 70-85% organic matter which is characteristic of the organic soils at the Stage III locations. The remaining Stage IV tests were on organic soils similar to the organic soils of the Stage III locations.

Stage III plots were 4.6 m long with rows spaced 1.5 m apart. Plots were two rows wide, with a border row surrounding the Stage III experiment, but not individual plots. Each Stage III plot had a 1.5 m alley on one end and a 6 m alley on the other end. Stage III experiments were planted in randomized complete-block designs with two replications. Stage IV plots were 10.7 m long with rows spaced 1.5 m apart and 1.5 m alleys, and planted in randomized complete-block designs. From the CP 77 through the CP 88 series, plots were four rows wide with four replications per experiment. From the CP 89 through the CP 92 series, plots were two rows wide with eight replications per experiment. A border row surrounded all Stage IV experiments, and in the case of the CP 89 through the CP 92 series, a border row surrounded each Stage IV plot. Agronomic practices, such as fertilization, pesticide application, cultivation, and water control, were conducted by the landowner in whose field each experiment was planted.

Sugar yield was estimated by multiplying cane tonnage by TRS. Cane tonnage was estimated by multiplying stalk number by stalk weight in all Stage III tests and in all Stage IV tests after the CP 88 series. Stalk number was estimated by counting total millable stalks per plot during the summer. Stalk weight was estimated from a 10-stalk sample collected in October in Stage III and from October through April in Stage IV. The TRS was estimated from the juice extracted from the same 10-stalk sample. In Stage IV, from the CP 77 through the CP 88 series, cane tonnage was estimated by weighing entire plots, and TRS was estimated from 15-stalk samples. The stalk samples from which TRS and stalk weights were estimated were collected from sugarcane that was burnt in the field before it was cut and sampled for the Stage IV CP 77 through CP 88 series. All other stalk samples were of stalks not previously burnt.

RESULTS AND DISCUSSION

By the year 2000, 32 CP sugarcane cultivars were released in Florida since the CP 69 series finished its second year of testing in Stage III in 1972 (Table 1). With sugar yield used as the ranking criterion, 18 of these 32 cultivars ranked among the top four places in Stage III (Fig. 1). Eight of these 32 cultivars ranked number one in Stage III in sugar yield. Five cultivars ranked from fifth through eighth place, seven ranked from ninth through twelfth place, one ranked in fourteenth place, and one ranked below fifteenth place.

Ranking based on economic index resulted in a similar distribution as for sugar yield (Fig. 2). Seventeen genotypes ranked from first through fourth place in Stage III, five ranked fifth through eighth, seven ranked from ninth through thirteenth place, and three cultivars ranked below fifteenth in economic index in Stage III.

The only genotype from Stage III with a rank inferior to 15th that was released on the basis of sugar yield was CP 89-1509 (Tai et al., 2000) (Table 1). CP 89-1509 was released for production on sand soils only; it was not evaluated on organic soils in Stage IV due to its low yields on organic soils in Stage III. Using economic index as the selection criterion, three genotypes that ranked inferior to 15th in Stage III were released. One was CP 89-1509. Also released were CP 85-1308 (Tai et al., 1995) and CP 85-1432 (Deren et al., 1994). None of these cultivars has been used on more than 1% of Florida's sugarcane hectarage in any one year.

These 24 cycles of Stage III data show that the better the ranking for either sugar yield or economic index in Stage III, the more likelihood that the genotype would eventually be released. Twenty-eight of 31 CP cultivars released since 1979 ranked better than 15th in both sugar yield and economic index in Stage III. Only one has been released that ranked below 15th in both sugar yield and economic index, and two ranked inferior to 15th in economic index, but better than 15th in sugar yield. Of these three cultivars, one was a special release for sand soils.

Monitoring the level of commercial use after a genotype's release is a further measure of its success. We considered that a cultivar was commercially successful in Florida if it was used at least for one year on > 1% of Florida's sugarcane hectarage. With this lenient criterion, only 14 of the 32 released cultivars became commercially successful (Table 1). Eleven of these 14 cultivars ranked first through fourth in Stage III using sugar yield as the ranking criterion. The worst rank in Stage III was ninth. Using economic index as the ranking criterion gave similar results, except that one cultivar ranked 10th and one 13th in Stage III.

Five of the CP cultivars that were tested in Stage III since 1970 were used on more than 15% of the hectarage for at least one year (Table 1). The lowest ranking in Stage III for any of these "widely used" cultivars in Stage III was for CP 72-1210 (Miller et al., 1981); it ranked sixth in both Mg sugar and \$ ha^{-1}. Cultivars CP 70-1133 and CP 80-1743 (Deren et al., 1991) were first in both categories, CP 72-2086 (Miller et al., 1984) second in both categories, and CP 80-1827 (Glaz et al., 1990) third in both categories in Stage III.

Most genotypes that later became commercial cultivars ranked among the top 15 in Stage III in either sugar yield or economic index. Further, the worst rank in Stage III for either sugar yield or economic index of any widely used cultivar was sixth. A conservative conclusion is that as long as there are at least 11 genotypes advanced from Stage III to Stage IV, Stage III, under its current structure, is adequate for identifying genotypes that will be widely used commercial cultivars in Florida. For the goal of identifying successful commercial cultivars (used on at least 1% of commercial hectarage for at least 1 year) for Florida, these data indicate that sufficient confidence can be placed in Stage III rankings to warrant not increasing the number of Stage IV entries beyond 11 if doing so would require advancing genotypes from Stage III that ranked worse than 15th in sugar yield and economic index.

For genotypes that are advanced from Stage III to Stage IV but not released commercially, another measurement of their success is how well they yielded in Stage IV. A benefit of identifying high-yielding genotypes in Stage IV is that they become a source of parental clones with reliable probabilities of producing commercially acceptable progeny. In general, both sugar yield and economic index as a percent of the check cultivar in Stage III were not good predictors of production

in Stage IV. Correlations were significant but low (Fig. 3 and 4). This indicates that some genotypes that had poor yields in Stage III had high yields in Stage IV and vice versa. Therefore, we looked specifically at performance in Stage IV of (1) genotypes that ranked worse than 14th in sugar yield or economic index in Stage III and (2) genotypes that ranked either first or second in sugar yield in Stage III.

From the CP 77 through the CP 92 series, 40 genotypes advanced from Stage III to Stage IV ranked worse than 14th in Stage III in either sugar yield or economic index (Table 2). Twenty-seven of these genotypes ranked worse than 14th in Mg sugar ha^{-1} in Stage III. Five of these 27 proceeded to rank either first or second in sugar yield in Stage IV. Twenty-five genotypes ranked worse than 14th in economic index in Stage III. Six of these 25 ranked either first or second in economic index in Stage IV. Of these six, CP 85-1308 eventually became a commercial cultivar. Approximately 20% of the genotypes that were mediocre in Stage III were highly successful in Stage IV. Several of these genotypes probably would have been released commercially except for disease susceptibilities that manifested after they were advanced to Stage IV. Attempts were made to use all of these successful Stage IV genotypes in crosses for several years at Canal Point.

A more detailed analysis further refines the strategy of advancing genotypes from Stage III to Stage IV. The lowest ranked genotype in Stage III to later rank either first or second in Stage IV was CP 85-1308, which ranked 21st in economic index in Stage III (Table 2). However, it also ranked seventh in sugar yield in Stage III. Cultivar CP 85-1308 helps identify a characteristic of other genotypes that had poor rankings in Stage III, but then ranked either first or second in Stage IV in one of these characters. Each of these genotypes ranked better than 20th in either sugar yield or economic index in Stage III. Thus, the selection committee could choose not to advance to Stage IV any genotype that ranked below 20th in both sugar yield and economic index. However, the selection committee should be careful not to follow the above guideline when there are several genotypes with consecutive ranks and similar percentages of the check that rank below 20th in both sugar yield and economic index.

Another issue is how soon within the selection program decision makers can be reasonably certain that they have identified genotypes that will perform well commercially. In the case of the CP program, this question could be posed as: if a superior genotype is identified in Stage III, is it necessary to further evaluate it in Stage IV or could its release be immediately put on a fast track? There were 25 genotypes that ranked either first or second in sugar yield in Stage III from the CP 77 through the CP 92 series (Table 3). Of the 14 that ranked first in Stage III, two ranked first in Stage IV, and 6 became commercial cultivars. Of the 11 genotypes that ranked second in Stage III, two ranked first in Stage IV and only these two became commercial cultivars. Thus, 8 of the 25 genotypes that ranked either first or second in Stage III became commercial cultivars. However, 8 others of the 25 genotypes that ranked first or second in Stage III then ranked among the lowest 6 Stage IV genotypes in sugar ha^{-1} and \$ ha^{-1}. This shows that although Stage III successfully identified some high-yielding Stage IV genotypes, it also incorrectly predicted that an equal number would be high yielding.

There are several explanations for the poor correlations between Stage III and Stage IV yields. Stage III has smaller plots, fewer replications, and fewer locations than Stage IV. Probably of more importance, all Stage III samples for TRS were taken during the final three weeks of

October. For Stage IV, TRS samples were collected from October through April, the typical Florida harvest season. Some genotypes remain low in TRS in October and through November and sometimes December, others remain low throughout the harvest season. Recently, additional TRS sampling was begun for Stage III in January and February. This new practice may help improve agreement between Stage III and Stage IV genotype performance.

Another important reason that genotype performance may not agree well between Stage III and Stage IV is that Stage III data are collected through the first-ratoon crop and Stage IV through the second-ratoon crop. Genotype CP 90-1113 serves as an example that second-ratoon yields can be markedly different from those of plant cane and first ratoon for a given genotype. In Stage III, CP 90-1113 ranked first in sugar yield and second in economic index (Table 3). In Stage IV, CP 90-1113 had high sugar yields in the plant-cane crop (Glaz et al., 1995) but ranked among the lowest in sugar yield in the second-ratoon crop (Glaz et al., 1998). Alvarez and Schueneman (1991) reported that the cost of planting is high relative to other costs in the Florida sugarcane cycle. Due to this high cost, the Canal Point program tries to release genotypes that will maintain high yields through at least three annual harvests. Therefore, it is critical to identify genotypes such as CP 90-1113 in Stage IV before they are released. However, this decline in yield does not occur with sufficient frequency among genotypes to warrant extending Stage III one more crop year.

Poor repeatability between the two selection stages can also be explained by using CP 80-1743 as an example. CP 80-1743 was the highest ranking genotype in its Stage III cycle for both sugar yield and economic index but was mediocre in Stage IV for both characters (Table 3.) From the CP 77 through the CP 88 series, yields were estimated in Stage III by counting stalks and weighing a 10-stalk sample. In Stage IV, whole plots were weighed. After the CP 88 series, yields were estimated in both stages by counting stalks and weighing stalk samples. The Stage III procedure was probably the more accurate for CP 80-1743 because its plot weights were substantially reduced in almost all Stage IV plots by severe rat damage after stalk counting would have occurred but before plots were weighed. Similar damage was not caused to other genotypes in the same Stage IV tests; and CP 80-1743 was identified as a mediocre genotype in Stage IV for sugar yield, although it was identified as a genotype with a high TRS (Glaz et al., 1985). It was only due to later work of Eiland and Miller (1992) that CP 80-1743 was released. CP 80-1743 is currently the most widely grown cultivar in Florida (Glaz, 2000), which suggests that rat damage in experimental plots does not predict similar damage in commercial fields.

Another reason that may account for differences in genotype performance between Stage III and Stage IV is that the genotypes are evaluated in each stage in different years. For Florida, Kang et al. (1987) reported significant genotype x year interaction for plant-cane sugar yields of Stage III genotypes; whereas, Brown and Glaz (2001) suggested that genotype performance across years was similar in Stage IV. Milligan et al. (1990) reported that genotype x year effects were most important in ratoon crops in Louisiana, but not more important than genotype x location effects. Since Stage IV tests genotypes during later years than Stage III, genotype x year interaction may play a role in the differences in genotype performance noted between Stages III and IV.

This study reviewed 24 cycles of Stage III and 16 cycles of Stage IV data. During these cycles, at least 10 or 11 genotypes per year were advanced to all Stage IV locations where they were evaluated as potential commercial cultivars for Florida. The intent of the committee responsible for

advancing genotypes from Stage III to Stage IV was generally to advance the genotypes with the highest rankings for sugar yield and economic index. However, due to concerns with pests and agronomic type, several lower ranking genotypes from Stage III were routinely advanced to Stage IV.

Stage III results were analyzed by comparing them to actual commercial use and to Stage IV data. One conclusion was that advancing 11 genotypes from Stage III to Stage IV was sufficient for identifying commercial cultivars that would be widely used in Florida. The data showed that it would be very unlikely to identify widely used cultivars from genotypes that ranked worse than 15th in both sugar yield and economic index in Stage III as it is currently structured.

The study of Brown and Glaz (2001) has helped improve a limiting factor in the CP program, the low number of genotypes that can be analyzed in Stage IV. To take advantage of this opportunity, we recommend improving the caliber of genotypes that are advanced to Stage III to improve the likelihood of identifying cultivars from 14 advanced genotypes to Stage IV. The most logical immediate approach to achieve this objective is to expand genotype numbers in the three selection stages prior to Stage III: Seedlings, Stage I, and Stage II. However, Tai et al. (1980) reported that sugar yield in Stage II was not an effective predictor of sugar yield in Stage III. Further, much of the percentage of increased genotypes may be lost to disease susceptibility if new diseases or races of current diseases appear. Therefore, ongoing monitoring and review would be an important component of this strategy.

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REFERENCES

1. Alvarez, J. and T.J. Schueneman. 1991. Costs and returns for sugarcane production on muck soils. Information Report EI 91-3, Food and Resource Economics Department, Institute of Food and Agricultural Sciences, University of Florida.

2. Arceneaux, G. 1935. A simplified method of making theoretical sugar yield calculations in accordance with Winter-Carp-Geerligs formula. International Sugar Journal 37:264-265.

3. Brown, J.S. and B. Glaz. 2001. Analysis of resource allocation in final stage sugarcane clonal selection. Crop Science 41:57-62.

4. Deren, C.W., J. Alvarez, and B. Glaz. 1995. Use of economic criteria for selecting clones in a sugarcane breeding program. Proc. Int. Soc. Sugar Cane Tech. 21:2, 437-447.

5. Deren, C.W., B. Glaz, P.Y.P. Tai, J,D. Miller, and J.M. Shine, Jr. 1991. Registration of 'CP 80-1743' sugarcane. Crop Sci. 31:235-236.

6. Deren, C.W., J.M. Shine, Jr., P.Y.P. Tai, B. Glaz, J,D. Miller, and J.C. Comstock. 1994. Registration of 'CP 85-1432' sugarcane. Crop Sci. 34:1405.

7. Eiland, B.R. and J.D. Miller. 1992. Performance of 12 sugarcane cultivars grown on organic soil and subjected to mechanical harvesting. J. Am. Soc. Sugar Cane Technologists 12:58-64.

8. Glaz, B. 2000. Sugarcane variety census: Florida 2000. Sugar y Azucar 95(12):22-24, 26-29.

9. Glaz, B., J.C. Comstock, P.Y.P. Tai, J.D. Miller, J. Follis, J.S. Brown, and L.Z. Liang. 2001. Evaluation of new Canal Point sugarcane clones: 1999-2000 harvest season. U.S. Department of Agriculture, Agricultural Research Service, ARS-157.

10. Glaz, B. and J.D. Miller. 1982. Comparison of commercial and experimental yields in sugarcane. Proceed. III Inter-American Sugar Cane Seminar: Varieties and Breeding. p. 139-143.

11. Glaz, B., P.Y.P. Tai, J.C. Comstock, and J.D. Miller. 1998. Evaluation of new Canal Point sugarcane clones: 1996-97 harvest season. U.S. Department of Agriculture, Agricultural Research Service, ARS-146.

12. Glaz, B., P.Y.P. Tai, J.L. Dean, M.S. Kang, J.D. Miller, and O.Sosa, Jr. 1985. Evaluation of new Canal Point sugarcane clones: 1984-85 harvest season. U.S. Department of Agriculture, Agricultural Research Service.

13. Glaz, B., P.Y.P. Tai, J.D. Miller, C.W. Deren, J.M Shine, Jr., J.C. Comstock, and O.Sosa, Jr. 1995. Evaluation of new Canal Point sugarcane clones: 1994-95 harvest season. U.S. Department of Agriculture, Agricultural Research Service, ARS-109-1994.

14. Glaz, G., P.Y.P. Tai, J.D. Miller, and J.R. Orsenigo. 1990. Registration of 'CP 80-1827' sugarcane. Crop Sci. 30:232-233.

15. Kang, M.S., B. Glaz, J.D. Miller, and P.Y.P. Tai. 1988. Clonal repeatability of the stability-variance statistic in sugarcane. J. Am. Soc. Sugar Cane Technologists 8:50-55.

16. Kang, M.S., J.D. Miller, P.Y.P. Tai, J.L. Dean, and B. Glaz. 1987. Implications of confounding of genotype x year and genotype x crop effects in sugarcane. Field Crops Res. 15:349-355.

17. Legendre, B.L., 1992. The core/press method for predicting the sugar yield from cane for use in cane payment. Sugar Journal 54(9):2-7.

18. Miller, J.D., P.Y.P. Tai, B. Glaz, J.L. Dean, and M.S. Kang. 1984. Registration of CP 72-2086 sugarcane. Crop Sci. 24:210.

19. Miller, J.D., E.R. Rice, J.L. Dean, and P.Y.P. Tai. 1981. Registration of CP 72-1210 sugarcane. Crop Sci. 21:797.

20. Milligan, S.B., K.A. Gravis, K.P. Bischoff, and F.A. Martin. 1990. Crop effects on broad-sense heritabilities and genetic variances of sugarcane yield components. Crop Sci. 30:344-349.

21. Rice, E.R., J.D. Miller, N.I. James, and J.L. Dean. 1978. Registration of CP 70-1133 sugarcane. Crop Sci. 17:526.

22. Tai, P.Y.P., B. Glaz, J.D. Miller, J.M. Shine, Jr., J.E. Follis, and J.C. Comstock. 2000. Registration of 'CP 89-1509' sugarcane. Crop Sci. 40:1498.

23. Tai, P.Y.P., J.D. Miller, C.W. Deren, B. Glaz, J.M. Shine, and J.C. Comstock. 1995. Registration of 'CP 85-1308' sugarcane. Crop Sci. 35:1213.

24. Tai, P.Y.P., J.D. Miller, B.S. Gill, and V. Chew. 1980. Correlations among characters of sugarcane in two intermediate selection stages. Proc. Int. Soc. Sugar Cane Tech. 17:2, 1119-1128.

Table 1. Commercial sugarcane cultivars released in Florida that were tested in Stage III since 1970, the year each cultivar was advanced from Stage III to Stage IV, number of genotypes with which each cultivar was compared, and its rankings for sugar yield and economic index in Stage III.

Cultivar	Year advanced to Stage IV	Number of genotypes in Stage III	Rank in Stage III		Highest commercial hectarage
			Mg sugar ha^{-1}	$ ha^{-1}	%
CP 69-1052	1972	24	1	1	<1.0
CP 70-1133	1973	21	1	1	30.7
CP 72-1210	1974	22	6	6	61.0
CP 72-2086	1976	31	2	2	18.0
CP 73-1547	1976	31	4	13	9.8
CP 74-2005	1977	35	4	4	5.8
CP 75-1082	1978	32	11	12	<1.0
CP 75-1553	1978	32	5	5	<1.0
CP 75-1632	1978	32	14	7	<1.0
CP 77-1776	1980	28	11	4	<1.0
CP 78-1247	1981	38	11	8	<1.0
CP 78-1628	1981	38	1	1	7.9
CP 78-2114	1981	38	9	10	6.1
CP 80-1743	1983	23	1	1	22.1
CP 80-1827	1983	23	3	3	18.2
CP 81-1238	1984	38	3	3	<1.0
CP 81-1254	1984	38	1	1	1.6
CP 82-1172	1985	30	5	3	<1.0
CP 84-1198[†]	1987	36	21	32	3.8
CP 85-1308	1988	41	7	21	<1.0
CP 85-1382	1988	41	3	10	<1.0
CP 85-1432	1988	41	6	17	<1.0
CP 85-1491	1988	41	11	4	<1.0
CP 88-1508	1991	42	3	4	1.3
CP 88-1540	1991	42	12	12	<1.0
CP 88-1762	1991	42	1	2	4.1
CP 89-1509	1992	42	29	21	<1.0
CP 89-2143	1992	42	2	1	1.2
CP 89-2377	1992	42	1	2	<1.0
CP 92-1213	1995	42	10	9	<1.0
CP 92-1640	1995	42	4	6	<1.0
CP 92-1666	1995	42	1	2	<1.0

[†]A note describing CP 84-1198 suggests an error in its Stage III data. Therefore, CP 84-1198 is not discussed in the text.

Table 2. Rank and % of check in Stages III and IV for sugar yield and economic index of 40 genotypes from 16 years of Stage III that ranked worse than 14th in either sugar yield or economic index in Stage III.

	Mg sugar ha^{-1}				$ ha^{-1}			
Genotype	Stage III	Stage IV	Stage III	Stage IV	Stage III	Stage IV	Stage III	Stage IV
	----Rank----		% of check		----Rank----		% of check	
CP 77-1404	17	8	99.2	95.6	9	9	117.0	78.3
CP 78-1263	17	7	103.4	114.0	17	8	108.3	115.8
CP 78-1979	12	10	111.1	99.5	19	10	107.1	89.0
CP 79-1580	15	5	115.6	84.5	13	7	129.9	76.9
CP 81-1435	8	3	101.0	94.1	19	5	97.2	95.3
CP 81-2062	5	5	103.7	90.2	33	10	79.8	81.6
CP 83-1351	17	5	90.4	84.4	12	5	89.8	81.4
CP 83-1773	13	1	93.3	100.9	15	1	85.9	93.2
CP 84-1572	18	2	79.7	91.8	16	2	76.0	86.4
CP 85-1308	7	2	97.6	109.4	21	2	84.8	117.5
CP 85-1432	6	3	98.1	104.0	17	3	90.8	113.8
CP 86-1180	25	9	85.4	79.5	14	9	93.4	80.0
CP 86-1747	15	2	90.7	98.7	25	2	85.1	93.9
CP 86-1882	19	5	88.6	89.1	7	3	96.0	91.3
CP 86-1427	7	7	97.3	88.7	15	4	93.2	89.9
CP 87-1018	16	10	89.4	76.0	8	10	90.7	60.0
CP 87-1121	19	9	89.1	92.4	13	9	87.8	80.2
CP 87-1274	15	2	89.9	107.3	10	1	89.7	104.0
CP 87-1475	8	5	99.2	102.6	21	3	81.1	103.2
CP 87-1733	21	8	84.6	96.4	24	5	79.3	99.6
CP 88-1165	13	5	95.4	99.4	16	7	94.0	95.2
CP 88-1561	15	6	93.8	98.9	11	2	101.7	107.6
CP 88-1834	14	2	94.7	103.2	27	4	87.4	105.1
CP 88-1836	17	7	93.0	96.0	14	6	95.0	97.1
CP 89-1331	20	8	96.0	94.4	9	8	103.6	99.2
CP 89-1632	34	9	84.1	88.8	27	9	90.0	91.9
CP 90-1151	3	7	103.4	93.9	16	7	81.7	96.3
CP 90-1436	14	3	86.5	105.9	17	1	81.4	110.8
CP 90-1464	19	1	82.1	106.7	18	2	80.8	110.7
CP 90-1510	23	9	80.9	83.8	9	10	90.6	82.9
CP 90-1535	24	6	80.2	97.0	5	4	97.1	104.8
CP 90-1549	29	4	74.4	101.5	27	6	68.9	98.1
CP 91-1865	12	9	92.8	87.1	20	10	87.8	85.8
CP 91-1880	16	11	89.9	85.8	14	11	93.2	84.2
CP 91-1883	30	8	83.1	87.4	19	9	89.6	85.9
CP 91-1914	20	1	87.9	101.4	15	1	93.2	107.5
CP 92-1320	15	10	91.9	90.6	13	9	87.1	89.9
CP 92-1641	24	5	84.6	98.7	20	3	80.1	106.1
CP 92-1647	27	11	81.0	78.8	24	11	76.0	79.5
CP 92-1684	18	7	90.6	94.9	16	8	85.1	91.8

Table 3. Rank and % of check from 16 years of Stages III and IV for sugar yield and economic index of 25 genotypes that ranked first or second in sugar yield in Stage III.

	Mg sugar ha^{-1}				$ ha^{-1}			
Genotype	Stage III	Stage IV	Stage III	Stage IV	Stage III	Stage IV	Stage III	Stage IV
	----Rank----		% of check		----Rank----		% of check	
CP 77-1055	2	2	113.0	117.3	5	1	134.2	117.6
CP 77-1148	1	5	129.5	99.4	1	10	193.4	77.9
CP 78-1156	2	6	127.8	114.3	2	3	153.5	118.6
CP 78-1628†	1	2	156.6	122.2	1	2	183.8	128.8
CP 79-1288	1	8	161.3	79.7	1	6	216.5	77.9
CP 79-1380	2	1	152.9	94.1	2	3	165.3	84.8
CP 80-1743†	1	7	113.3	85.1	1	6	131.8	85.8
CP 80-1827†	2	1	96.7	105.7	3	1	97.6	110.7
CP 81-1254†	1	1	109.7	104.5	1	1	126.9	119.2
CP 81-2149	2	9	108.2	85.8	10	9	104.5	83.9
CP 82-1505	2	4	104.4	94.5	5	7	102.6	90.2
CP 82-1587	1	9	109.3	78.9	1	9	102.6	78.8
CP 85-1207	1	5	114.2	99.1	2	5	118.9	102.2
CP 85-1808	2	8	104.9	84.8	1	8	120.9	92.3
CP 86-2024	1	8	122.7	83.5	1	8	136.1	85.5
CP 87-1226	1	3	110.7	105.3	11	8	88.7	90.7
CP 88-1762†	1	4	109.0	101.0	2	5	118.1	103.0
CP 88-1912	2	3	108.7	101.9	1	3	119.9	105.8
CP 89-2143†	2	1	131.9	113.9	1	1	150.9	122.1
CP 89-2377†	1	3	132.8	105.4	2	6	131.7	106.5
CP 90-1113	1	10	107.6	83.7	2	9	117.3	88.4
CP 91-1924	1	3	125.2	96.1	1	2	152.8	99.8
CP 91-2246	2	7	103.3	88.2	2	6	111.2	90.4
CP 92-1167	2	2	108.3	108.4	5	4	102.8	106.1
CP 92-1666†	1	1	119.5	111.9	2	1	113.6	112.7

†These genotypes were later released as commercial cultivars in Florida.

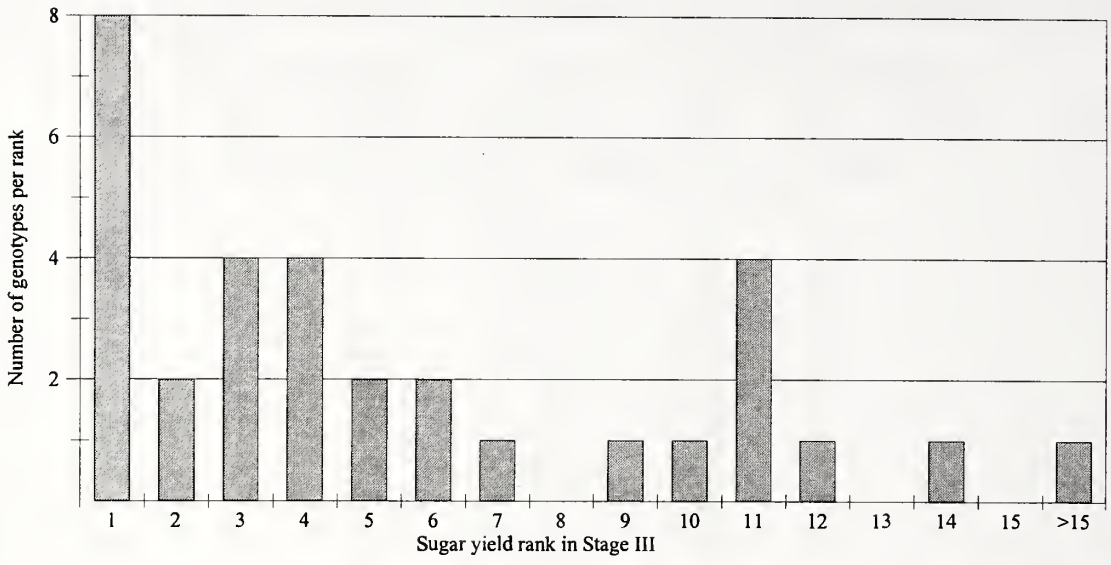

Figure 1. Rank of sugar yield (Mg sugar ha^{-1}) in Stage III and number of genotypes with the same rank for 32 sugarcane genotypes that became commercial cultivars in Florida from the CP 69 through the CP 92 series.

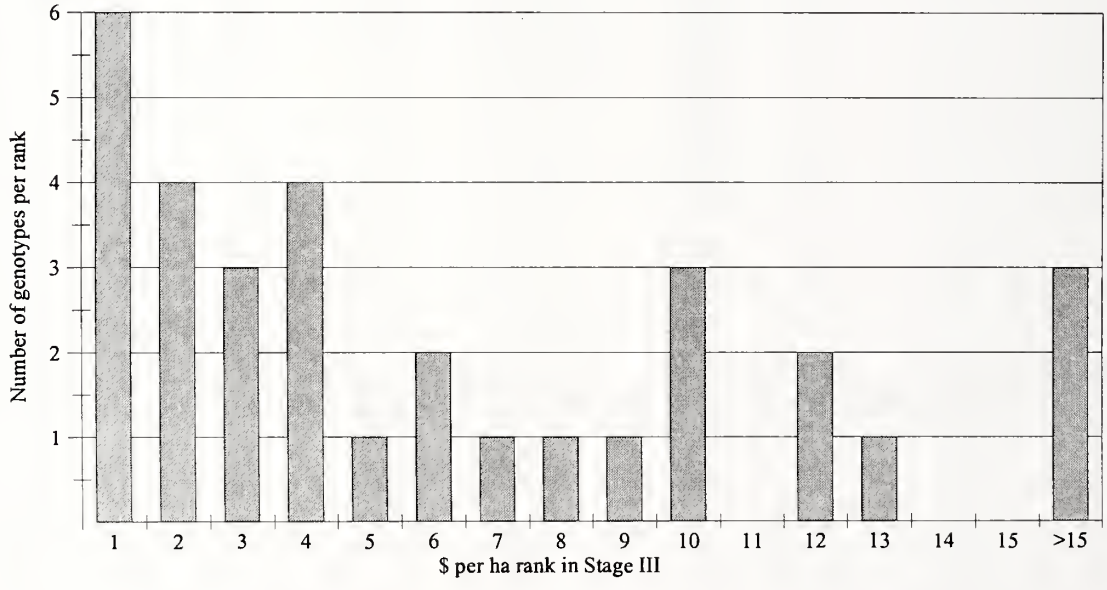

Figure 2. Rank of economic index ($ ha^{-1}) in Stage III and number of genotypes with the same rank for 32 sugarcane genotypes that became commercial cultivars in Florida from the CP 69 through the CP 92 series.

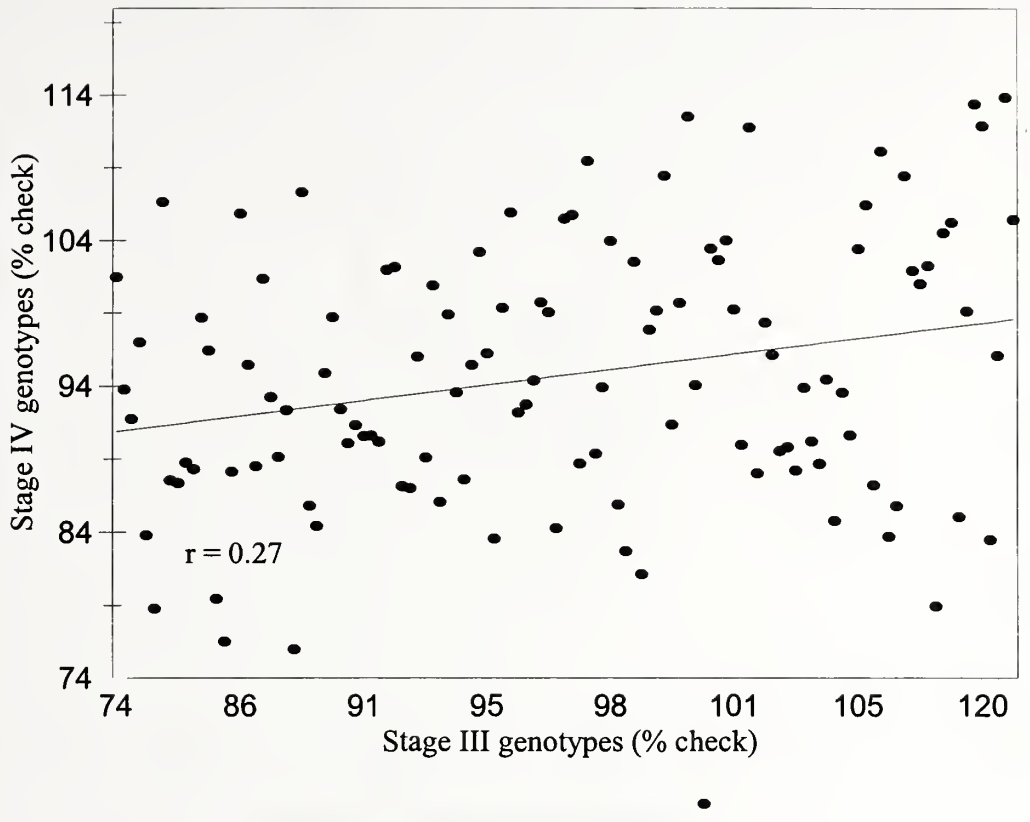

Figure 3. Correlation of sugar yield (measured as Mg sugar ha^{-1}) as percent of check cultivar in Stage III with sugar yield as percent of check cultivar in Stage IV for 117 genotypes from 16 Stage III and Stage IV cycles.

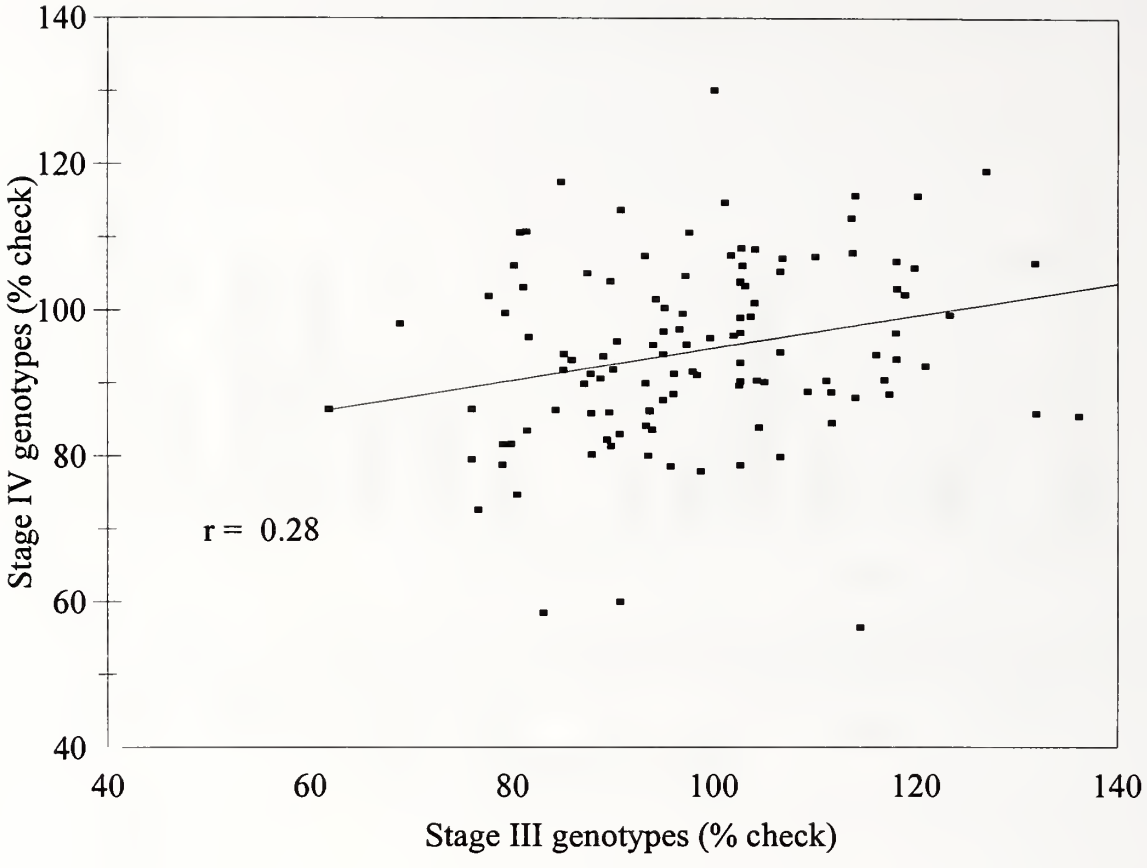

Figure 4. Correlation of economic index ($ ha^{-1}) as percent of check cultivar in Stage III with economic index as percent of check cultivar in Stage IV for 117 genotypes from 16 Stage III and Stage IV cycles.

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SECTION

COMPARING THE EFFECTS OF SULPHUR DIOXIDE ON MODEL SUCROSE AND CANE JUICE SYSTEMS

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ABSTRACT

Sulphur dioxide (SO_2) has been used for centuries to minimize color in food processing and fruit and vegetable storage. In the sugar industry, it is used routinely by sugar beet processors to reduce and prevent color formation in white refined sugar. Sugarcane processors throughout the world use SO_2 to produce plantation white sugars. This study was undertaken to determine the effect of SO_2 on pure sucrose solutions in comparison to real factory sugarcane juice streams. Sugar systems included 15 brix pure sucrose, clarified juice and mixed juice from a Louisiana sugarcane mill. A pH of 8.0 was obtained by adding milk of lime then lowered to approximately pH 5.0 with either SO_2 or HCl (control). Several samples ranging from pH 5 to 8 were processed at 0-120 min at 85^0 C. Analyses included pH, SO_2, color, calcium, and invert (as a measure of sucrose loss). Results indicated that the model system was much more sensitive to low levels of SO_2 than real juice samples which demonstrated a greater buffering capacity. The pH levels of the model sucrose solution dropped rapidly, and invert levels increased with time. There was 1.6 % loss of sucrose in the SO_2 trial as compared with no sucrose loss with HCl. Clarified juice resisted changes in pH with both SO_2 and HCl. Sucrose loss at 120 min of processing and a pH of 5.0 was only 0.88 %. There was a maximum color reduction of 10-15 % in the SO_2 trial, whereas no color reduction or sucrose loss was observed in the HCl trial. The mixed juice was very resistant to pH changes, and a minimum pH of 6.0 was achieved with 4800 ppm SO_2. No sucrose loss was observed in either trial with mixed juice, and color reduction was the same in both the SO_2 and HCl trials. In real juice streams, SO_2 reduced color by 10-15 % more than clarification alone but also induced some sucrose loss (0.88%) after a lengthy time.

INTRODUCTION

Sulphur dioxide has traditionally been used in food processing and produce storage to minimize color formation due to browning reactions associated with amino acids interacting with invert sugars in the Maillard reaction. Sugar beet processors routinely use sulphur dioxide in process streams for the same purpose. Among sugar cane processors worldwide there is mixed interest in usage of sulfitation. In the United States, sulfitation has rarely been used in cane raw sugar factories since the 1950's. Today, there is renewed interest in the effectiveness of sulfur dioxide as a color retardant as many US factories are considering the production of high quality low color raw sugar to be sold as a food grade sugar.

Under normal ambient temperature and pressure, sulphur dioxide is a colorless, pungent smelling, nonflammable gas. In very low concentrations this gas can cause extreme eye and respiratory irritation, thus must be used in a controlled environment (Anonymous, 1996). The

Egyptians and Romans burned sulfur to form sulfur dioxide (SO_2) as a means of sanitizing wine-making equipment and today SO_2 is used to treat most light colored dehydrated fruit and vegetables to prevent undesirable enzymatic and non enzymatic "browning" reactions. Sulfur dioxide provides the added benefit of acting as a food preservative and functions as an antioxidant (McWeeny, 1981). Sulfite additive has been used extensively in the food industry to retard Maillard reactions. McWeeny (1981) discussed the two main groups of reactions between sugars, ascorbic acid and their dehydration products and bisulfite, primarily the hydroxy sulfonate and organo sulfur compounds.

Browning reactions, of whatever type, are caused by the formation of unsaturated, colored polymers of varying composition. Compounds that engender browning usually contain a carbonyl or potential carbonyl grouping (Hodge, 1953). Browning can be inhibited by compounds that block or eliminate or combine with carbonyl groups. The multiplicity of studies regarding browning reaction theories is reviewed thoroughly in Hodge's (1953) review article.

The purpose of sulfiting purified and clarified thin beet juices are 1) to control juice color formation; 2) to improve the boiling properties of the juices; and 3) reduce the excess alkalinity (McGinnis, 1982). Two methods of sulfuring are 1) by sulfur stove, burning elemental sulfur for production of sulfite and 2)bubbling sulfur dioxide through process streams. Also produced during these processes is the undesired sulfate ion that can interfere with crystallization causing an increase in molasses purity and production. The oxidation of sulfite to sulfate is greatly retarded as the sugar concentration is increased. Sulfitation can control juice color by interfering with chromophoric molecular groups include carbonyl (ketones), carbonyl (aldehydes), carboxyl, and amido. "These compounds are characterized by an electron imbalance, an electronically excited state, a molecular resonance, an absorption of specific bands of transmitted light, and to the beholder, color" (McGinnis, 1982). Color compounds in cane and beet sugar products include naturally occurring pigments along with a large heterogeneous variation of color compounds produced during processing. It has been estimated that for a 98.5°pol raw sugar, colorants account for approximately 15-20 % of the weight of non sugars. In granulated refined sugar the estimate is approximately 30 ppm (Clarke and Godshall, 1988).

In the cane sugar factory, the major role of sulfur dioxide has been to make white sugar rather than raw sugar through inhibition of color forming reactions. This is achieved by addition of SO_2 to the alkenic double bond in an α,β- unsaturated carbonyl intermediate as well as to the carbonyl group, which yields β-sulfonated aldehydes that are of comparatively low reactivity in reactions leading to the production of browning compounds by the Maillard reaction and degradation of invert sugars (Shore, et al., 1984). Sulfur dioxide also has the ability to inhibit or retard enzymatic browning reactions. Sulfur dioxide added as 300-500 ppm to raw beet juice resulted in minimal (5%) color reduction (Shore, et al., 1984). Onna and Sloane (1978) reported that 300 ppm decreased color in syrup and whole raw sugars by about 25% with crystal color reduced by 46%. Final refined granulated sugar from this process had 35% less color.

During processing and storage at elevated temperatures, sugar products will darken. All industries that use sugar products are in turn susceptible to color changes in their products which may or may not be desirable (Zerban, 1947). When cane and beet juices are heated and limed during clarification, invert sugar disappears and the color of juices increases with the amount of lime added.

Much of this color is bound to calcium precipitate in the defecation process. Color changes additionally occur during heating and evaporation processes, since the juices are exposed to continual heating (70-75°C) over several hours at slightly alkaline pH in the beet industry and slightly acid pH in the cane industry. The higher the alkalinity of clarified beet juice, the greater the color increase. The color of clarified cane juice also increases during evaporation and crystallization even though it is kept on the slightly acid side.

In cane and beet processing, there are many variations in procedure for adding sulfur dioxide. There is cold sulfitation with SO_2 added to cold raw juice then limed; alkaline sulfitation where juice is limed then sulfited and again sulfite added to syrup prior to pan boiling. Hot sulfitation where juice is heated first then sulfited and limed, this method is used to reduce the solubility of calcium sulfite. Other modification of these procedures are used according to plant capabilities etc. In Northern Europe, a method of combining sulfitation with preliming of diffusion juice was developed. Small additions of SO_2 to an acidic(pH 5.5-6.0) diffusion juice improved filtration and sedimentation, as well as reduced juice color development (Dandar, et al., 1973) Effect on sucrose recovery was not discussed. Indonesian cane processors have developed a similar process using sulfitation with lime with the production of a high standard quality white consumption sugar for export (Marches, 1953). This plantation white sugar is the result of two sulfitation procedures, first at original clarifier when added with lime and second as syrup sulfitation prior to vacuum pan.

Sulfitation in Louisiana is a very old process, possibly originating with French or English settlers (Spencer, et al.,1945). Cold raw juice was pumped through a sulfur tower with a countercurrent of sulfur dioxide to produce a fairly good, irregular, near or off-white sugar. By the late 1930's use of sulfur dioxide was on the decline and was then mainly used for production of direct consumption molasses.

This study was undertaken to determine the effect of sulphur dioxide on model and real cane process streams. This work is part of SPRI's continuing research on determining the effect of invert and pH on sucrose recovery and color formation.

MATERIALS AND METHODS

Sugar Solutions: 15 brix pure sucrose, clarified cane juice and mixed raw cane juice.

Sulfitation: Sugar systems were brought to a pH of 8.00 with milk of lime (cold lime). The pH was then adjusted with either sulphur dioxide (SO_2) or hydrochloric acid(HCl), as a control, to approximate cane juice pH of 5-6. Sulphur dioxide was bubbled through the sugar system using a micro valve controller. Samples were taken as pH dropped from 8 to 5.

Processing: The pure sucrose solution was then processed in a gyratory shaker for up to 60 min at 85°C. Clarified juice and mixed juice were treated for up to120 min. Time was extended for juice samples due to lack of significant reactions at 60 min.

Analyses: Samples were analyzed for pH, SO_2 by ICUMSA rosaniline colorimetric method, calcium by HPIC, color by ICUMSA method, invert by HPIC.

HPIC Calcium: DX 500 with IonPac CS12 column with CSRS Suppressor, isometric 1.0 ml/min 20mM H_2SO_4, and conductivity detection.

HPIC Invert: DX 500 with CarboPac PA1 column, gradient 1 ml/min 100-200 mM NaOH and amperometric detection.

RESULTS AND DISCUSSION

In order to achieve a similar pH among the three sugar systems, it was necessary to use different amounts of sulphur dioxide. Figure 1 shows the relative sensitivity of the pure sucrose solution compared to either of the factory process streams. Both juice streams demonstrated a huge buffering capacity that was not present in the pure sucrose solution.

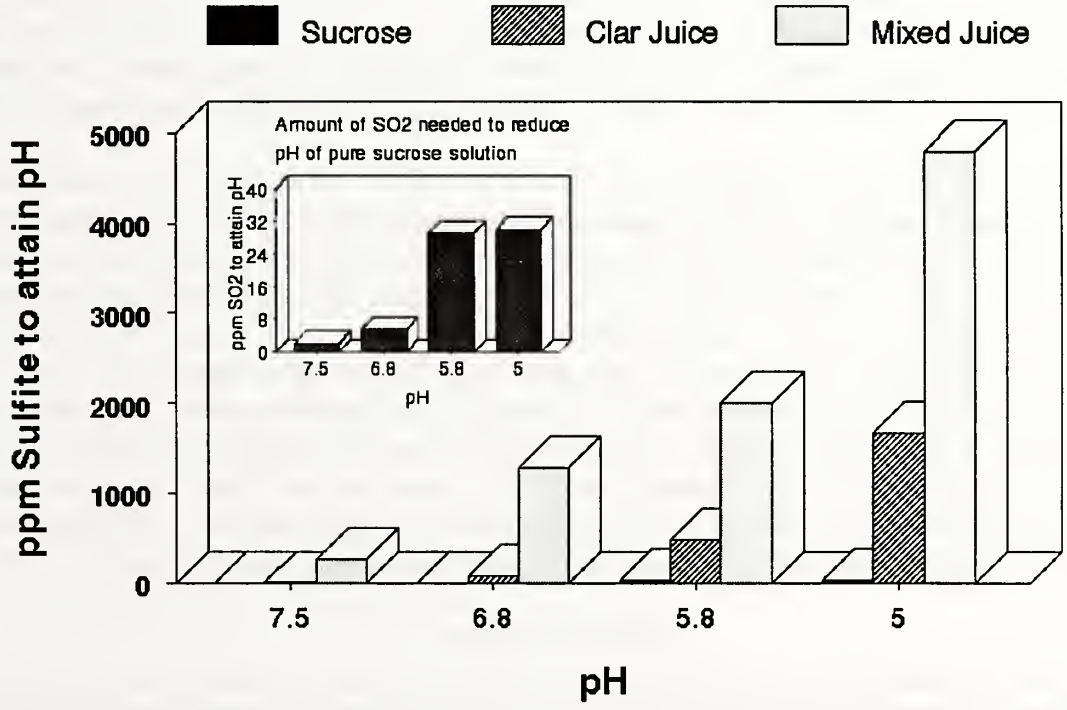

Figure 1. The amount of SO_2 required to adjust the pH of pure sucrose solution, clarified juice and mixed juice from pH 8.0. Insert: Amount of SO_2 required to lower pH of pure sucrose solution.

Tables 1-3 summarize the results of treating the various solutions with sulfur dioxide.

The pure sucrose model system responded to minimal amounts of sulphur dioxide (2-29 ppm) with a rapid reduction in pH (Table 1). Processing times up to 60 minutes with pH below 6.1 also indicated rapid deterioration in sucrose as evident by the increase in glucose. When sucrose loss is calculated as 2 X the relative increase in glucose (DeBruin, 1998), in this model system, glucose increased by as much as 8000 ppm on solids after 60 minutes of processing at a beginning pH of 5.9. This calculated to loss of 1.6% sucrose based on solids. In contrast, under the same conditions, the HCl control system had minimal sucrose loss (.03% on solids) which was directly attributable to acid hydrolysis. No changes occurred in color or calcium residuals with either of these process systems. After heat treatment no residual SO_2 remained.

The clarified juice results (Table 2) were very different from those of the model sucrose system. The observation time was increased to 120 min because no significant changes were noted at 60 min. The juices were treated with 0-1700 ppm SO_2. These high levels were needed to bring the pH down to the desired level. The SO_2 treated samples generally showed a decrease in color over time, with more color decrease (up to 15 %) in the highest treatment level. These results were similar to those reported by Kort (1995) who showed a 15% reduction in color with >200ppm SO_2. However, some earlier papers reported a somewhat better color reduction of 25-35% with 250-500 ppm SO_2 (Onna and Sloan,1978; Fort and Walton, 1932). The HCl-treated samples showed some color increase. Glucose formation was insignificant throughout, indicating little or no sucrose hydrolysis with either SO2 or HCl. No residual SO_2 remained when initial treatment was <500 ppm.

The mixed raw juice results (Table 3) were also different from those of the model sucrose system. As with the clarified juice, the process time was increased to 120 min because few significant changes were noted at 60 min. These juices were treated with up to 4700 ppm SO_2 to achieve the same pH range as with the model system. The rate of clearance of SO_2 from the juice systems during processing is noted on the table. Calcium levels (data not shown) dropped an average of 100-400 ppm with the lower pH and greater SO_2 concentrations. This in effect was a sulfo-defecation or clarification process induced by liming, reduction to acid pH, and heat processing. The calcium likely becoming bound up in colorant and/or polysaccharide and was precipitated. There was a small but consistent drop in glucose in both SO_2-treated and HCl-treated samples. There was also a significant color drop in both SO_2-treated and HCl-treated samples. Silva and Zarpelon (1977) reported a similar drop in color using mixed juice systems through the sulfo-defecation process.

CONCLUSIONS

There is renewed interest in the United States to produce a high quality food grade sugar at the raw sugar mill. Several means for achieving high quality, low color sugar exist, one of which is sulfitation. The USFDA currently has a 10 ppm limit on residual sulphur dioxide allowed in food products. If sulphitation is being considered for white sugar production, the manufacturer must take caution to keep residuals below this limit.

It is apparent through these studies that attempting to predict juice stream behaviors by model sucrose solutions is not a valid hypothesis for SO_2 treatment. However, a positive result gained from

this study was that with minimal application of sulphur dioxide, color can be reduced by at least 10-20%. Currently in Louisiana during late season, raw sugar quality meets all the criteria for Blanco-Directo (Bennett and Ross, 1988) except for color and turbidity (Table 4). The authors feel that by using a color minimizer, such as sulphur dioxide or other, Louisiana raw sugar could meet the quality standards for food ingredient sugar such as the Blanco-Directo sold to soft drink processors in some Caribbean countries, or other locations where sugar is used to sweeten food ingredients.

ACKNOWLEDGMENTS

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REFERENCES

1. Anonymous. 1996. Sulfur Dioxide. *Food Chemicals Codex*, 4th edition. National Academy Press.

2. Bennett, M.C. and Ross, B.G. 1988. Blanco-Directo production at Hawaiian-Philippines Company. Proceeding of Workshop on White Sugar Quality, Viewpoint of producers and users. SPRI, pp 3-6.

3. de Bruijn, J.M., Struijs, J.L., and Bout-Diederen, M.E. 1998. Sugar degradation and colour formation. Proceedings on Sugar Processing Research, SPRI Conference. Savannah, GA., pp127-143.

4. Clarke, M.A. and Godshall, M.A, eds. *Chemistry and Processing of Sugarbeet and Sugarcane*. Chapter 13, The nature of colorants in sugarcane and beet sugar manufacture. Elsevier Science Publishers, Amsterdam.

5. Dandar, A., Basatko, J. and Rajinakova, A. 1973. Influence of sulphitation of beet juice before progressive preliming according to Dedek and Vasatko on the purification effect. Zucker 26(11) 593-597.

6. El-Kadar, A.A. El-Kadar, Mansour and Yassin, A.A. 1983. Influence of clarification on sugar cane juices by the sulphitation and phosphatation processes. Proceedings ISSCT, XVIII Congress, pp 507-530, Havana, Cuba.

7. Fort, C.A. and Walton, C.F. 1932. Effect of clarification on quality of raw and plantation white sugars. Industrial and Engineering Chemistry, Vol.25, No 6:675-681.

8. Hodge, J.E. 1953. Dehydrated foods: Chemistry of browning reactions in model systems. Agri. and Food Chem., Vol. 1, No 15:928-943.

9. Kort, M.J. 1995. Sulphitation of mixed juice. Sugar Processing Research Institute, Annual Report. Dalbridge, South Aftica.

10. Marches, J. 1953. Clarification of cane juices by means of the sulphitation process. *Principles of Sugar Technology,* Chapter 15, edited by P. Honig. Elsevier Publishing Company.

11. McGinnis, R.A. 1982. *Beet Sugar Technology, 3rd edition.* Sulfitation, pp 265-274.

12. McWeeny, D.J. 1981. Sulfur dioxide and the Maillard reaction in food. Prog. Fd. Nutr. Sci., Vol.5, pp. 395-404.

13. Onna, K. And Sloane, G.E. 1978. 1977 juice sulfitation test at Puna Sugar Company. Reports, Hawaiian Sugar Technologists, Vol 36:26-28.

14. Silva, J.F. and Zarpelon, F. 1977. Color and ash levels in process streams at three factories producing raw, sulfitation white and high pol raw sugars. Processing:2787-2795.

15. Shore, M., Broughton, N.W., Dutton, J.V. and Sissons, A. 1984. Factors affecting white sugar colour. Sugar Technology Reviews, 12:1-99.

16. Spencer, G.L. Meade,G.P., and Wiley, J. 1945. *Cane Sugar Handbook*, 8th edition, pp109-110.

17. Zerban, F. W. 1947. The color problem in sucrose manufacture. Technical Report Series No. 2, Sugar Research Foundation, Inc. New York.

Table 1: Effect of SO_2 on 15.2 Brix model sucrose solutions. Solution initially brought to pH 8.0 with milk of lime.

Minutes at 85°C	Initial and residual SO_2, ppm	Final pH with SO_2	Glucose * with SO_2 ppm solids	Final pH with HCl	Glucose * with HCl ppm solids
0	0	7.9	35	7.9	45
15	0	7.5	27	7.3	49
30	0	7.4	33	7.1	50
60	0	7.3	48	7.0	65
0	2	7.6	28	7.3	37
15	0	6.9	37	6.85	43
30	0	6.6	76	6.75	32
60	0	6.5	78	6.5	79
0	5.4	7.0	28	6.8	28
15	0	6.3	65	6.6	64
30	0	6.2	80	6.3	71
60	0	6.1	132	6.15	130
0	12.6	6.5	27	6.5	30
15	0	6.0	565	6.3	44
30	0	5.9	1073	6.1	78
60	0	5.6	1406	5.9	121
0	29	5.9	27	6.0	28
15	0	5.1	2166	5.9	66
30	0	4.9	2983	5.8	87
60	0	4.6	8193	5.7	152

*Fructose showed near identical values to glucose, indicating the acid hydrolysis of sucrose. No color formation was observed in any of the treated solutions

Table 2: Effect of SO_2 on 13.3 Brix clarified juice. Solution initially brought to pH 8.0 with milk of lime.

Minutes at 85°C	Initial and residual SO_2	Final pH with SO_2	Glucose with SO_2 % solids	Color ICU	Final pH with HCl	Glucose with HCl % solids	Color ICU
0	0	6.7	2.63	11,100	6.6	2.63	10,902
30	0	6.6	2.70	11,346	6.6	2.70	11,686
60	0	6.5	2.66	11,494	6.5	2.55	11,095
120	0	6.3	2.75	10,924	6.2	2.61	11,627
0	83	6.0	2.65	10,581	6.2	2.56	10,744
30	0	6.0	2.66	10,399	6.2	2.55	10,819
60	0	5.9	2.76	10,636	6.1	2.62	11,465
120	0	5.8	2.83	10,769	6.0	2.86	11,781
0	487	5.6	2.74	10,414	5.8	2.54	10,824
30	294	5.5	2.75	9,615	5.7	2.40	11,557
60	194	5.4	2.78	9,527	5.7	2.68	11,435
120	1	5.4	2.91	9,406	5.7	2.81	11,496
0	943	5.2	2.67	10,203	5.4	2.66	10,411
30	825	5.2	2.53	9,677	5.4	2.58	10,830
60	644	5.1	2.82	8,956	5.4	2.48	10,954
120	247	5.1	2.82	9,166	5.3	2.73	11,466
0	1677	5.0	2.68	9,767	5.0	2.53	10,205
30	1554	4.9	2.67	9,121	5.0	2.62	10,584
60	1423	4.9	2.78	8,670	5.0	2.71	10,489
120	1185	4.8	3.12	8,490	5.0	2.89	10,536

Table 3: Effect of SO_2 on 13.3 Brix mixed raw juice. Solution initially brought to pH 8.0 with milk of lime.

Minutes at 85°C	Initial and residual SO_2	Final pH with SO_2	Glucose with SO_2 % solids	Color ICU	Final pH with HCl	Glucose with HCl % solids	Color ICU
0	0	6.8	4.24	27,167	8.1	4.34	25,333
30	0	7.7	3.38	26,500	7.8	3.83	21,667
60	0	7.6	3.43	26,500	7.6	3.82	18,973
120	0	7.2	3.36	22,825	7.2	3.97	19,116
0	271	7.5	3.99	27,167	7.5	4.18	25,333
30	122	7.4	3.26	25,000	7.5	3.70	21,667
60	5	7.4	3.25	26,333	7.4	3.77	18,260
120	0	6.9	3.31	22,682	6.9	3.86	19,116
0	1291	6.8	3.86	25,833	6.8	4.60	25,833
30	848	6.8	3.19	23,333	6.8	3.63	21,000
60	579	6.7	3.25	24,500	6.5	3.81	17,689
120	0	6.6	3.35	21,398	6.4	3.78	17,974
0	2009	6.2	3.99	26,500	6.3	4.56	25,500
30	1900	6.2	3.25	23,667	6.2	3.81	22,167
60	1549	6.1	3.25	23,833	6.0	3.88	18,117
120	1479	5.9	3.40	20,970	6.0	4.02	18,545
0	4746	5.7	4.43	28,000	5.9	4.62	25,333
30	4653	5.6	3.61	24,333	5.8	4.31	20,167
60	4423	5.6	3.79	24,667	5.6	3.73	17,404
120	3962	5.5	3.87	19,971	5.4	3.79	17,404

Table 4. Quality comparison of Blanco Directo and Louisiana raw sugars.

Specification	Blanco Directo	Louisiana Raw
Pol	99.7	99.8
Color (natural)	150	484
Turbidity	50	100
Ash	0.5	0.06
Invert % solids	0.2	0.05
SO_2 residual	5 ppm	not treated

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THE EFFECT OF TWO LOUISIANA SOILS ON CANE JUICE QUALITY

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ABSTRACT

As part of ongoing investigations on the effect of various field practices on the quality of cane juice in Louisiana, we noted that cane juice color decreased significantly when soil was added to assess the effect of soil on cane juice quality. In a study of the 1999/00 crop in Louisiana, with addition of 5% and 10% soil to the cane juice, it was noted that polysaccharide was also removed, the first time this had been reported. These observations run contrary to expectations that soil will degrade the quality of cane juice. Raw juice from green cane, which had been topped, but still retained side leaves, was treated with 10% added soil. Two soils from the Louisiana cane growing area, Sharkey clay and Norwood silty clay loam were tested. The juice was treated for 30 minutes in a shaker either at room temperature (25°C) or heated (80°C). Changes in pH, color, total polysaccharide, ash and filtration rate were noted. Both soils decreased color and total polysaccharide and increased the filtration rate. pH and ash were not significantly changed.

INTRODUCTION

The goal of cane harvesting is to obtain the highest quality cane juice possible in order to facilitate production of raw sugar, and to obtain the highest yield, in order to maximize raw sugar production. The quality of cane juice is affected by many factors -- the variety and maturity of the cane, weather conditions, diseases, harvesting conditions, cut-to-crush delays, and the amount of trash incorporated into the crushed cane.

The 12th Edition of the Cane Sugar Handbook (Chen and Chou, 1993) defines field trash as leaves, tops, dead stalks, roots, soil, etc., delivered together with cane.

In South Africa (Chen, 1985) it was reported that for each 1% addition of tops to clean cane, the color of clear juice was increased by 1.3%, while with each 1% addition of mud to clean cane, the color of clear juice was increased by 3.6%. Purchase, *et al.*, (1991) confirmed the deleterious effect of leafy trash on the color and turbidity of juice. Ivin and Doyle (1989) in Australia, documented the harmful effect of leafy trash on cane juice quality. Legendre, *et al.*, (1996) showed a 1.6% decrease in raw juice color for each 1% added increment of a silty clay loam (Mhoon) from Louisiana, and a 13% increase in juice color for every 1% leafy cane trash added, up to the 10% level. When mixtures of leafy trash and soil were added to juice, the competing effects of the mud (removed color) and the leafy trash (added color) were clearly evident. Godshall, *et al.*, (2000) studied the effects of various harvest practices in Louisiana on the color and polysaccharide concentration in cane

juice. The presence of green leaves, especially tops, significantly increased both color and polysaccharides in cane juice.

Figures 1 and 2 show the results of a previously unpublished study conducted on samples for the American Sugar Cane League. Addition of 5% Sharkey clay to cane juice from topped cane with side leaves decreased color to the level of hand stripped clean cane juice. Addition of 10% Sharkey clay to the same juice decreased polysaccharide to the level of hand stripped clean cane juice, representing a decrease of 20% color and 30% polysaccharide.

Figure 1. Effect of 5% and 10% Sharkey clay on juice color

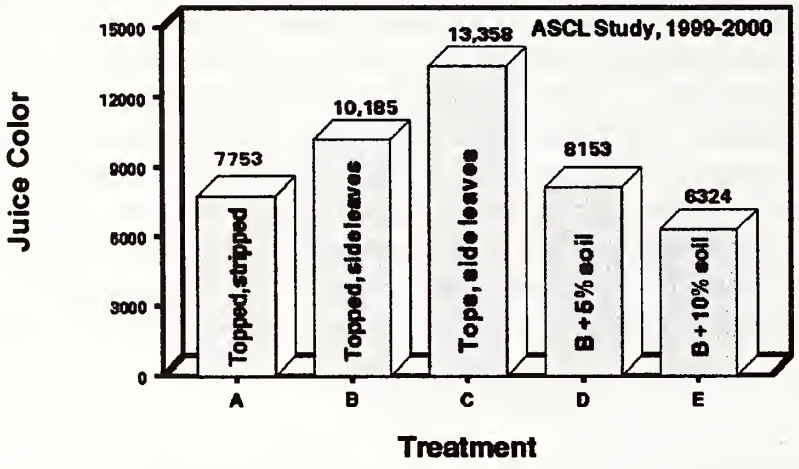
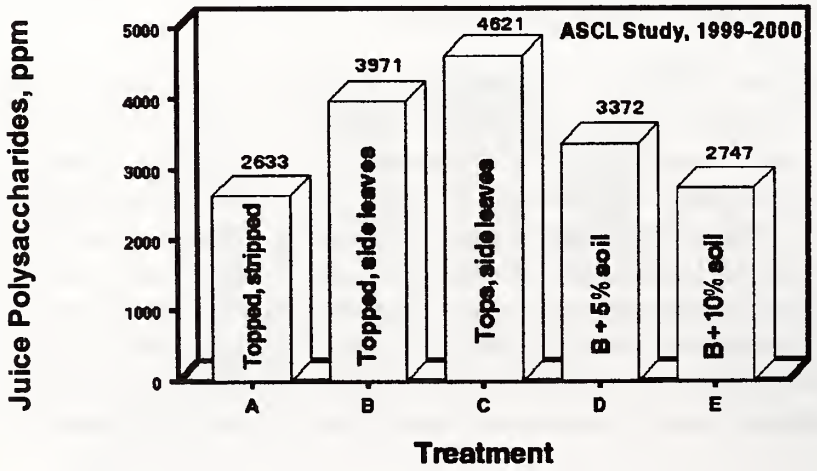


Figure 2. Effect of 5% and 10% Sharkey clay on juice polysaccharide level.



Polysaccharides in Cane Juice

Polysaccharides are naturally present in milled cane juice. They include starch and soluble cell wall polysaccharides that are released when cane is crushed and the cells disrupted. Sugarcane polysaccharides are associated with high molecular weight color in cane juice, may increase viscosity, and contribute to increased color and turbidity in raw sugar. The levels of polysaccharides in cane juice range from 0.4-0.8% dissolved solids, with leaves and tops contributing to the higher levels (Godshall, *et al.*, 2000). The concentration of polysaccharide in cane juice is also influenced by the cane variety, but not as much as whether or not green leaves are included in the crush.

Louisiana Soils

Sugarcane in mainly grown in the soil areas known as the Subtropical Mississippi Valley Alluvium, with the dominant soils being Sharkey, Mhoon and Commerce. Some cane is also grown in the extreme southern part of the Red River Valley Alluvium in Norwood soil. Commerce and Mhoon soils are friable silt loams and silty clay loams. Sharkey soil is clayey. The Sharkey series consists of very deep, poorly drained, very slowly permeable soils that formed in clayey alluvium. These soils are on flood plains and low terraces of the Mississippi River. Norwood soils occupy low natural levees at the highest elevations of the flood plains. The reddish-brown color of Norwood is a characteristic of the geological sediments of the Permian Red Bed deposits on the eastern slope of the Rocky Mountains which were carried into Louisiana by the Red and other rivers. Norwood is a silty loam soil (Lytle).

MATERIALS AND METHODS

Norwood (fine-silty, mixed, superactive, hyperthermic Fluventic Eutrudept) and Sharkey (very-fine, smectitic, thermic Chromic Epiaquerts) soils were provided by Chris Finger at the USDA Sugarcane Research Unit in Houma, Louisiana. The soils were washed and decanted of trash and dried and sieved (<2 mm) before using.

Raw cane juice consisted of 6 samples from green cane, topped, with side leaves, left on a heap for 1, 2 or 3 days (2 samples of each), provided by the American Sugar Cane League. Samples had been kept deep frozen prior to use and were microwave defrosted.

To test the effect of the soil, 5 g of soil was added to 50 ml of cane juice, then placed on a gyratory shaker for 30 min. Experiments were conducted at 25°C and 80°C. Treated juice was analyzed for pH, color, total polysaccharides (TPS), ash and filtration rate. Color and conductivity ash were measured using standard ICUMSA methods (ICUMSA 1998). Total polysaccharides were determined by the SPRI method (Roberts, 1980). Filtration rate was determined as ml cane juice that passed through a 47 mm diameter, 0.45µ pore-size membrane in 5 minutes, using vacuum at 30 in Hg, and reported as ml/min.

Soil chemical analysis was done by the Soil Testing Laboratory at Louisiana State University. Organic matter was determined by Walkley-Black wet oxidation (Nelson and Sommers, 1982), soil

pH by a 1:1 soil:water ratio in deionized water, and ions were extracted with 1M ammonium acetate, pH 7.0, and analyzed by ICP. Soil texture was determined by the hydrometer method (Day 1965).

RESULTS AND DISCUSSION

Properties of the Soils

Tables 1a and 1b show the properties of the two soils under test. The cation exchange capacity (CEC) is the sum of the basic cations present on the soil matrix. It is used as an index of the total exchange capacity of the soil. The magnitude of the CEC is strongly correlated to the soil's content of clay and organic matter. The greater CEC for the Sharkey soil is associated with this soil's higher clay content and the predominance of smectite (principally montmorillonite) minerals in the clay fraction. Montmorillonite, and other smectite clay minerals, are expansible layer silicates. They possess a high CEC, large surface area and due to their ability to adsorb large quantities of water have a significant shrink-swell potential (Borchardt, 1977).

Table 1a. Chemical properties of Louisiana soils

Soil	pH	CEC* meq/100 g	P	Na	K	Ca	Mg
			mg/kg soil (ppm)				
Sharkey	6.0	30.5	162	68	325	4215	1007
Norwood	7.5	9.4	175	31	201	1307	269

Table 1b. Physical properties of Louisiana soils

Soil	Organic Matter, %	Sand, %	Silt, %	Clay,%	Texture & Color
Sharkey	0.51	28.5	22.2	49.3	Clay, brown
Norwood	0.98	46.8	39.6	13.6	Loam, red

*CEC = Cation Exchange Capacity.

Effect of Heat on Cane Juice

Table 2 reports the composition of the cane juice at room temperature, and Table 3 shows the composition of the juice after 30 min at 80°C. Heat decreased the juice color by 4.33% and total polysaccharide concentration by 6.05%. Ash increased 4.69% and filtration rate increased 14.9%. There was essentially no change in pH (0.02 pH unit decrease at 80°C). The data are summarized in Table 4.

Note should be made of the fact that the total polysaccharide concentration did not change during the 3 days the green cane stalks were on the heap. An earlier study had shown that whole, green stalks, piled in a small heap in cool weather remained stable for 3 days (Godshall, et al., 2000).

Table 2. Analytical results on cane juice before soil treatment. (Control, 25°C)

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.64	11,091	4717	2.72	0.98
G-36, 37 (Day 1)	5.68	9,281	5795	2.52	0.70
G-49, 50 (Day 2)	5.60	12,150	5688	2.69	0.78
G-51, 55 (Day 2)	5.66	9,372	5463	2.35	0.94
G-81, 83 (Day 3)	5.62	9,127	4814	2.51	0.95
G-82, 84 (Day 3)	5.50	9,752	5184	2.59	0.88
Mean	5.62	10,129	5277	2.56	0.87

ICU = ICUMSA Color Units
TPS = Total polysaccharide

Table 3. Analytical results on heated cane juice before soil treatment. (Control, 80°C, shaken 30 min)

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.41	11,170	4569	2.77	1.1
G-36, 37 (Day 1)	5.66	9,098	5474	2.66	0.74
G-49, 50 (Day 2)	5.58	11,015	5359	2.80	0.95
G-51, 55 (Day 2)	5.66	8,666	4796	2.50	1.0
G-81, 83 (Day 3)	5.62	9,072	4473	2.65	1.1
G-82, 84 (Day 3)	5.58	9,118	5076	2.67	1.1
Mean	5.59	9,690	4958	2.68	1.0

Table 4. Summary of cane juice, heated and not heated. (The effect of heat on cane juice.)

Sample	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
25°C	5.62	10,129	5277	2.56	0.87
80°C	5.59	9,690	4958	2.68	1.0
% change in heated	-0.53%	-4.33%	-6.05%	+4.69%	+14.9%

Effect of Soil on Cane Juice

Tables 5 and 6 report the effect of Sharkey clay on cane juice at 25°C and 80°C.

Table 5. Analytical results on cane juice after treatment at 25°C with Sharkey clay

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.67	10,222	4731	2.57	2.8
G-36, 37 (Day 1)	5.67	7,585	4012	2.34	1.8
G-49, 50 (Day 2)	5.62	10,080	4204	2.49	2.8
G-51, 55 (Day 2)	5.68	8,028	3780	2.35	2.4
G-81, 83 (Day 3)	5.62	7,726	3135	2.38	3.4
G-82, 84 (Day 3)	5.54	8,578	4019	2.44	2.8
Mean	5.63	8,703	3980	2.43	2.67

Table 6. Analytical results on cane juice after treatment at 80°C with Sharkey clay

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.56	10,139	3534	2.64	1.1
G-36, 37 (Day 1)	5.59	7,891	4531	2.53	0.74
G-49, 50 (Day 2)	5.52	10,254	4305	2.68	0.94
G-51, 55 (Day 2)	5.59	7,991	4014	2.44	1.1
G-81, 83 (Day 3)	5.53	9,420	3911	2.55	1.2
G-82, 84 (Day 3)	5.49	9,439	4188	2.59	1.1
Mean	5.55	9,189	4081	2.57	1.03

The effect of Sharkey on cane juice color in each sample at 80° C is shown in Figure 3 and on polysaccharides in Figure 4. In Figure 3, It is noted that samples 5 and 6 had a slight increase in color compared to the controls. Since this was cane juice from cane left on the heap row for 3 days, it is possible that changes in the type of colorant in the cane had occurred over that period of time. The same effect was noted with the Norwood soil on the day 3 samples. The removal of polysaccharides, however, was not affected in samples 5 and 6.

Figure 3. Effect of Sharkey clay on juice color at 80°C.

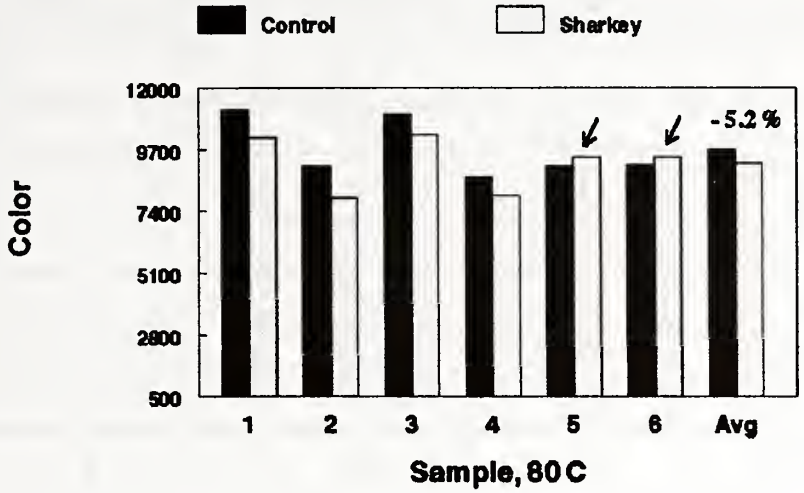
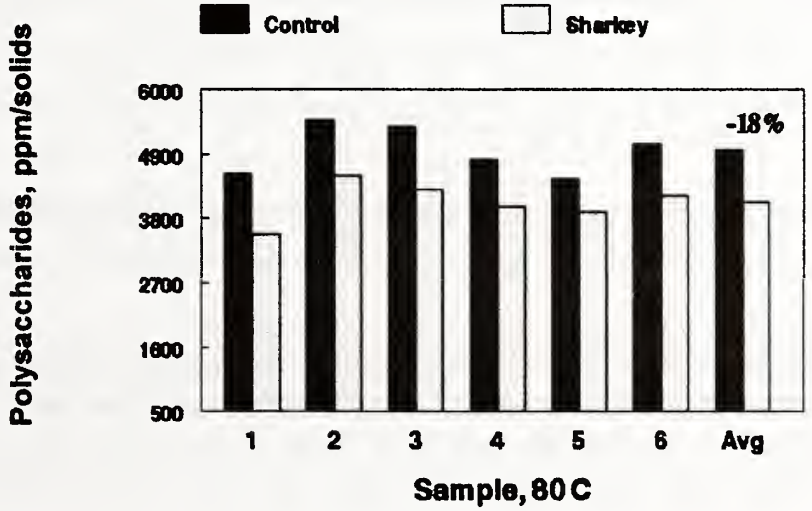


Figure 4. Effect of Sharkey clay on juice polysaccharides at 80°C.



Tables 7 and 8 report the effect of Norwood on cane juice at 25°C and 80°C.

Table 7. Analytical results on cane juice after treatment at 25°C with Norwood clay loam

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.68	10,790	3911	2.71	1.2
G-36, 37 (Day 1)	5.86	8,488	4896	2.63	0.7
G-49, 50 (Day 2)	5.80	10,932	4587	2.77	1.0
G-51, 55 (Day 2)	5.85	8,459	4246	2.53	1.2
G-81, 83 (Day 3)	5.78	9,150	3810	2.60	1.3
G-82, 84 (Day 3)	5.74	9,887	4327	2.51	1.3
Mean	5.79	9,618	4296	2.63	1.1

Table 8. Analytical results on cane juice after treatment at 80°C with Norwood clay loam

Juice	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
G-33, 34 (Day 1)	5.51	10,828	3455	2.74	1.4
G-36, 37 (Day 1)	5.71	8,611	4509	2.61	1.0
G-49, 50 (Day 2)	5.65	10,415	4019	2.82	1.5
G-51, 55 (Day 2)	5.72	8,329	3888	2.51	1.4
G-81, 83 (Day 3)	5.61	9,173	3529	2.62	1.4
G-82, 84 (Day 3)	5.54	9,209	4063	2.68	1.4
Mean	5.62	9,428	3911	2.66	1.35

Table 9a compares the mean results of all treatments. Table 9b shows the percentage changes with soils treatment; comparisons are made for the same temperature of treatment.

Table 9a. Summary of means of treated and untreated samples

Treatment	pH	Color, ICU	TPS, ppm	Ash, %	Filtration rate (ml/min)
Control, 25°C	5.62	10,129	5277	2.56	0.87
Control, 80°C	5.59	9,690	4958	2.68	1.0
Sharkey, 25°C	5.63	8,703	3980	2.43	2.67
Sharkey, 80°C	5.55	9,189	4081	2.57	1.03
Norwood, 25°C	5.79	9,618	4296	2.63	1.1
Norwood, 80°C	5.62	9,428	3911	2.66	1.35

Table 9b. Summary of changes in treated cane juice samples. Treatments are compared to untreated cane juice at their respective heating regime.

Treatment	pH	Color	TPS, ppm	Ash, %	Filtration rate (ml/min)
Sharkey, 25°C	+0.18%	-14.1%	-24.6%	-5.08%	+207%
Sharkey, 80°C	-0.72%	-5.2%	-17.7%	-4.10%	+3.0%
Norwood, 25°C	+3.02%	-5.0%	-18.6%	+2.73%	+26.4%
Norwood, 80°C	+0.54%	-2.7%	-21.1%	-0.75%	+35.0%

pH. pH showed no significant change for either soil or either temperature. There was a 3% increase in pH in the Norwood treated juice at 25°C.

Color. Sharkey clay removed 14.1% color at 25°C but only 5.2% at 80°C. Norwood removed 5.0% at 25°C and 2.7% at 80°C . Both soils take out more color at 25°C than at 80°C, indicating a release of color at the higher temperature. The higher color retention by Sharkey clay is a function of its higher ion exchange capacity for the charged colorants in cane juice. As previously stated, this retention is probably associated with the montmorillonite present in the clay fraction.

Total Polysaccharides. Both soils removed significant amounts of polysaccharides. Sharkey clay removed 24.6% polysaccharides at 25°C and 17.7% at 80°C . These results are similar to those previously encountered with the Sharkey clay (unpublished results mentioned in the Introduction). Norwood removed 18.6% at 25°C and 21.1% 80°C .

Ash. Sharkey clay gave a 4-5% decrease in ash, which was contrary to what might have been expected. Both soils had been washed, so ash solubilized from the soils was probably already removed. The decrease in ash caused by Sharkey clay may also be a function of the exchange capacity of the Sharkey clay. Whether these soils contribute to the ash load in juice in the field still needs to be investigated. Norwood clay loam caused a small increase of ash, 2.73% at 25°C and a very slight decrease of 0.75%, at 80°C.

Filtration rate. Norwood increased the filtration rate 26.4% at 25°C and 35.0% at 80°C. Sharkey clay doubled the filtration rate at 25°C (207%), but showed no change at 80°C. This result is probably anomalous, as many filtrations with Sharkey clay in cane juice had shown as much as a 10-fold increase in filtration rate at room temperature. However, with this series, the clay was allowed to settle for only a few minutes, and it is possible that the fines clogged the filter membrane. It should be noted that this filtration test is very stringent, as sample is filtered through a very tight medium of 0.45 μ, and a different filtration medium may show different results.

CONCLUSIONS

This study has shown that two soils, Norwood and Sharkey, found in the Louisiana cane growing area have the ability to remove a small amount of color and a significant amount of polysaccharide from cane juice, while improving filterability. At the same time, the ash level of the juice is not changed, or is slightly decreased, and there is no deleterious effect on pH. Sharkey soil, because of its clay content and greater ion exchange capacity, removes slighly more color, but both Norwood and Sharkey remove about the same amount of polysaccharide.

The larger color removal by Sharkey clay in earlier studies is attributed to the fact that the samples had stayed in contact with the soil over a long storage period prior to analysis, whereas the samples in the current study had been exposed to the soil for only 30 min. However, the removal of polysaccharides was not affected by storage.

These results are of interest because they are contrary to the reports from South Africa and Australia, which indicate large color increases in cane juice in the presence of soils.

This work is not intended to advocate or recommend bringing soil in with harvested cane. The cleaner the juice, the better in the long run. Soil has destructive effects on the mills, increases the burden to the clarifier, and contributes to disposal costs. The results are of considerable interest because they can help explain some anomalous behavior in cane juice quality when there is a lot of mud brought into the mill. It may be possible, in the future, to consider how to exploit the beneficial effects of the soils in the cane growing area of Louisiana.

REFERENCES

1. Chen, J.C.P., and Chou, C.C.. (1993) Cane Sugar Handbook, 12th Edition, John Wiley & Sons, Inc., New York, 55, 563, 886-903.

2. Chen, J.C.P. (1985) Meade-Chen Cane Sugar handbook, 11th Edition, John Wiley & Sons, Inc., New York, 59.

3. Day, P.R. (1965) Particle fractionation and particle-size analysis. Pages 545-567, *In* C.A. Black (ed.) Methods of Soil Analysis - Part 1. Agronomy Society of America, Inc., Madison, WI.

4. Fors, A., and Arias, R. (1997) The effects of trash components in factory performance. Sugar J., Dec. 1997, 25-26.

5. Godshall, M.A., Legendre, B.L., Richard, C., and Triche, R. (2000) Effect of harvest system on cane juice quality. Proc. Sugar Processing Research Conf., 222-236.

6. ICUMSA Methods, 1994/ First Supplement, 1998. Methods of the International Commission for Uniform Methods of Sugar Analysis, ICUMSA Publications, Norwich England. Method GS1-7, Raw Sugar Solution Colour; Method GS1/3/4/7/8-13, Conductivity Ash in Raw Sugar.

7. Ivin, P.C., and Doyle, C.D. (1989) Some measurements on the effect of tops and trash on cane quality. Proc. Australian Soc. Sugar Cane Technol, 1-7.

8. Legendre, B.L., Godshall, M.A. and Miranda, X.M. (1996) A preliminary study on the effect of sugarcane leaves and mud on color in sugarcane juice. Proc. Sugar Processing Research Conf., 447-452.

9. Lytle, S.A. The morphological characteristics and relief relationships of representative soils in Louisiana. http://www.agctr.lsu.edu/hudnall/4058/32.pdf

10. Nelson, D.W. and L.E. Sommers. (1982) Total carbon, organic carbon and organic matter. Pages 539-577. *In* Methods of Soil Analysis. Agronomy No. 9, Part 2, American Society of Agronomy, Madison, WI

11. Purchase, B.S., Lionnet, G.R.E., Reid, M.J., Wienese, A., and DeBeer, A.G. (1991) Options for and implications of increasing the supply of bagasse by including tops in trash with cane. Proc. Sugar Processing Research Conf., 229-243.

12. Roberts, E.J. (1980) Estimation of the soluble polysaccharides in sugar: A rapid test for total polysaccharides. Proc. Technical Session Cane Sugar Refining Research, 130-133.

A NEW POLARIMETRIC METHOD FOR THE ANALYSIS OF DEXTRAN AND SUCROSE

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ABSTRACT

A new method for dextran quantification has been developed and field-trialled in Jamaica, in association with the Sugar Industry Research Institute. The method uses a near infrared (NIR) polarimeter and a specific dextranase. The dextranase selectively breaks down the dextran into sugars of lesser specific rotations without affecting any other substance present in the juice. The initial dextran concentration is derived from the calibration curve of the change in observed optical rotation (OR) due to enzymatic hydrolysis and output automatically by the polarimeter. Readings are not affected by the molecular weight of the dextrans, the entire procedure takes less than 10 minutes to perform and it is semi-automated. Use of a NIR polarimeter negates the need for lead acetate clarification. The method is suitable for both juice and raw sugar samples.

Keywords: Dextranase, Near Infrared (NIR) polarimeter, Polysaccharides.

INTRODUCTION

Dextran is produced by microorganisms which infect the cane and feed on the sucrose; therefore, the presence of dextran immediately indicates lost sugar. The bacteria are mainly Leuconostoc species and are ubiquitous in the soil. They enter the cane at places of exposed tissue caused by machine harvesting, cutting, burning, growth, freezing, disease and pests. Any delay in the kill-to-mill time allows the bacteria to proliferate and the dextran levels to soar, especially in wet muddy cane.

The name dextran refers to a large family of glucose polymers whose structures and subsequent properties can vary widely. Technically the molecular weight (M_r) can range between 1500 and several million; therefore, a dextran of say 1 million M_r has potentially thousands of possible structures due to its branched nature. This massive variation in structure poses a huge challenge for any analyst trying to detect the molecules especially against a substantial background of saccharides with similar structures and properties.

Consequences of Dextran

Dextran is highly dextrorotatory, approximately three times that of sucrose, and, since the farmer is largely paid on the basis of the polarimeter reading, there is an obvious need for assaying for dextran in the core lab. This would allow correction of the falsified reading and identification of the sources of dextran contamination entering the factory. The problems associated with dextran contamination in both the factory and the refinery are well documented in the literature and so are briefly summarised below in Table 1.

Table 1. Summary of the detrimental effects of dextran in terms of the resulting losses.

Production losses	Sucrose losses	Direct financial losses
Increased viscosity leads to reduced throughput due to: -poor filterability -reduced evaporation rate -reduced flocculation rate -slow mud settling Poor crystallization (elongation)	As dextran formed in cane To molasses (melassigenic effect)	False pol reading leads to overpayment to farmer In trade of raw sugar as part of dextran penalty system using unreliable tests

Most dextrans are insoluble in alcohol making sugars and syrups containing it unsuitable for the production of alcoholic beverages. The two most important factors in the purchase of raw sugar are the polarisation and the crystal size distribution. Both of these are dramatically affected by the presence of dextran. The affination rate (removal of molasses from the crystal surfaces) is greatly reduced, leading to further losses of sucrose to the molasses. It is for this reason that high penalties are imposed on dextran contamination when importing raw sugar for refining.

Typically, the problem is treated in retrospect by the addition of crude dextranase enzyme. The enzyme works by hydrolysing the large dextran molecules into smaller oligosaccharide products which do not affect the viscosity as much. This is an expensive treatment largely because of the cost of the enzyme. Without accurate knowledge of the dextran levels in the process, it is impossible to gauge the correct amount of dextranase required.

Dextran detection is and long has been dominated by two equally questionable techniques, namely the haze test (Keniry et al., 1969) and the Roberts test (Roberts, 1983). Both tests exploit dextran's tendency to precipitate out of solution in alcohol. This approach has long been proved unreliable and inaccurate as well as non-specific, costly and time-consuming (Kubik et al.; 1994, DeStefano and Irey, 1986; Curtin and McCowage, 1986; and Brown and Inkerman, 1992).

Many alternative tests have been proposed and investigated, often as modifications on the theme of alcohol precipitation with various chemical and/or enzymatic inclusions. Although these tests are often arguably more accurate and reproducible, they are generally expensive and labor-intensive to perform. Hence, they are unattractive to the majority of sugar technologists. There is a longstanding need for a fast, accurate, simple and inexpensive method for the detection and quantification of dextran.

The Optical Activity Dextran Kit

Until recently, most polarimeters used the sodium wavelength of 589nm, which is yellow light. To achieve accurate results sugar samples had to be clarified and largely decolourised using lead subacetate. Now multi-wavelength instruments are readily available. Measurements of the sucrose content of cane juices by NIR polarimetry at 880nm are not affected by the yellow/brown

color remaining after conventional filtration using a filteraid. Readings obtained using NIR polarimetry in comparison to those at the sodium wavelength have been previously shown to be more reproducible and more sensitive to interference by high dextran concentrations (Wilson, 1996).

Not only does the poisonous and environmentally unsound lead subacetate treatment damage enzymes; it also removes an unknown portion of the dextrans, making it an unsuitable clarifier in both this and other dextran methods. This latter point, of dextran removal, is also the case with a number of the more recent commercial clarifiers. In this method a conventional filter-aid is employed which successfully clarifies the juice or sugar solution without removing dextran. This filter-aid is paramount to the successful clarification of the juice sample.

This procedure is centered on the use of a NIR polarimeter manufactured by Optical Activity Ltd. in conjunction with a specific dextranase totally free of invertase activity. The dextran is hydrolysed into smaller dextrans and constituting smaller units such as isomaltotriose, isomaltose and glucose, each of which is less optically active than dextran. The hydrolytic reactions are rapid when the enzyme is used in excess. The change in rotation between that of the original sample and that observed at a predetermined time after the addition of dextranase can be calibrated to the original concentration of dextran present in the sample.

MATERIALS AND METHODS

The NIR polarimeter used was a SacchAAr 880, manufactured by Optical Activity Ltd. The polarimeter sample tube (also manufactured by Optical Activity Ltd.) was an A2 with a bore of 4mm and 200mm path length. The tube is jacketed and the temperature maintained at 20°C using an Index Instruments Ltd. thermocirculator.

The enzyme concentration in the sample and the total sample volume were previously optimised for this procedure and are 1 ml enzyme solution (see below) added to 19 ml sample. A selected pure dextranase preparation with activity of 30,400 units/ml is diluted 1:5 in distilled water. It is always used at this dilution, except for those experiments that involve the use of impregnated filter papers. In order to assist the user and prevent any error in measuring quantities of liquid, the enzyme will be available commercially in this form. These papers will consistently carry the required amount of dextranase to carry out the reaction within the desired time limit and have already been tested in field trials during the work with the Sugar Industry Research Institute of Jamaica.

RESULTS

Effect of Molecular Weight

It was necessary to determine if the extent of the change in rotation due to hydrolysis is influenced by molecular weight. The following different molecular weight range dextrans were dried for a week in a desiccator containing P_2O_5 and then made up to 4000ppm in distilled water:

-9,5kDa (Sigma Cat. No. D-9260)
-71.4kDa (Sigma Cat. No. D-3759)
-2,000kDa (Sigma Cat. No. D-5376)

After quantifying the control readings, 1ml of dextranase solution was added to 19ml of dextran solution, rapidly shaken and injected into the sample tube. The results (Table 2) were recorded when the readings had reached a stable minimum. It can be observed that there is no systematic or significant effect of M_r on the change in OR due to enzymatic hydrolysis. The variability in the results is thought to be due to structural and preparative differences between the commercially available dextrans reflected by differences in appearance (powders / flakes).

Table 2. The change in OR due to enzyme action for three different molecular weight dextrans.

M_r of Dextran (Daltons)	Change in OR °Z due to enzyme action
9,500	1.26
71,400	1.19
2,000,000	1.34

Confirmation of Enzymatic Specificity

Many commercial enzyme preparations contain several enzyme activities in addition to the major activity that is purchased. It was necessary to ensure that the dextranase preparation was unable to hydrolyse sucrose and non-dextran polysaccharides.

A selection of possible alternative saccharides were chosen and 5% solutions made up in distilled water. 1ml of dextranase solution was added to 19ml of the analyte solution and the OR observed for 20 minutes. Little or no change in the reading over time (other than that accounted for by the controls and the accuracy of the instrument) indicates no reaction (Table 3).

Table 3. The effect of dextranase on other possible analytes.

Analyte	Result
Sucrose	No reaction
Dextrin	No reaction
Xylan	No reaction
Pectin	No reaction

Although the above list is non-exhaustive, there are no apparent reactions with these substances, which form the majority of dissolved carbohydrates constituent in sugar samples.

Calibration Curve Constructed in 15% Sucrose

Using the calibration curve and the preloaded filter papers, it becomes possible to transform the assay from a fairly technical laboratory assay into a kit for use by unskilled workers. The calibration data will be incorporated into the software of the polarimeter negating the need for lengthy calculations and reducing the chances of operator error.

Using an 188kDa dextran (Sigma Cat No, D4876), solutions of 8000ppm, 4000ppm, 2000ppm, 800ppm, 400ppm and 200ppm were made up in 15% sucrose (since sucrose is known to mildly retard the rate of the reaction with dextran via non-competitive inhibition).

The dextranase solution was added to the dextran just prior to injection into the polarimeter and the OR followed for 15 minutes. The readings were recorded at 5-second intervals by a data collection program.

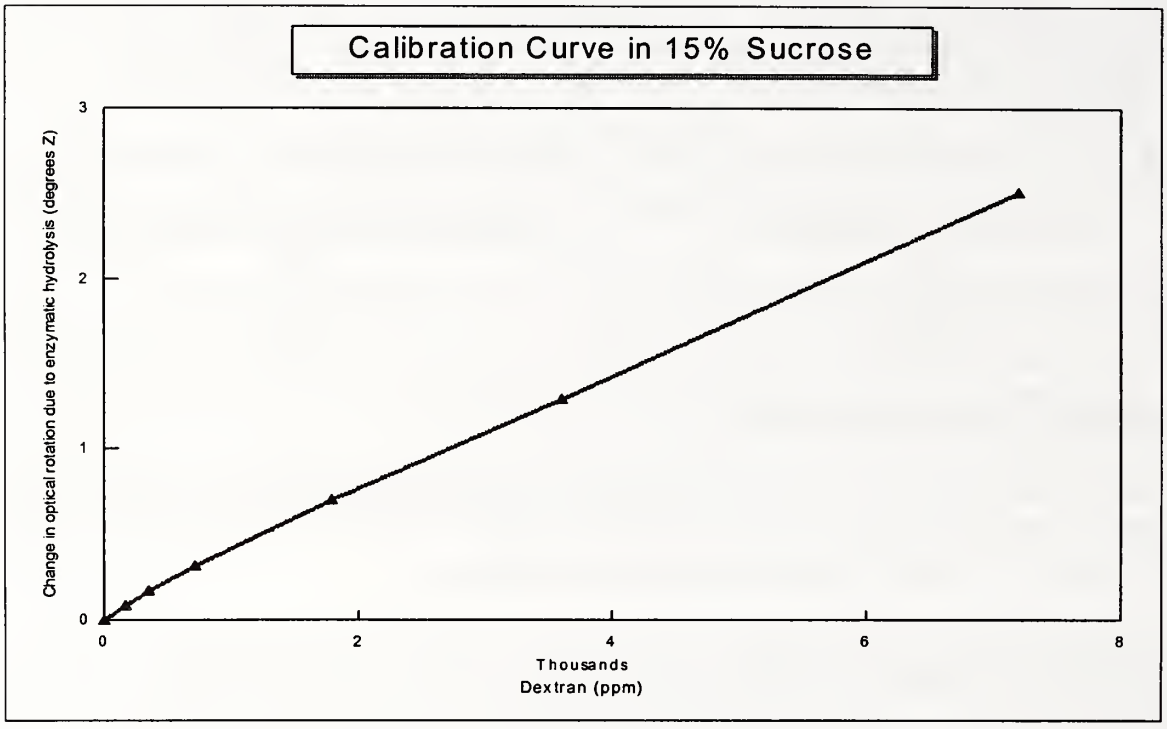

Figure 1. The relationship between dextran concentration and change in OR due to hydrolysis by dextanase enzyme.

The relationship shown in Figure 1 is clearly linear in character but has a slight curve (which in this data is a 39.5% change in x/y). This relationship is reproducible on a day-to-day basis and has been curve-fitted and the algorithm incorporated into the instrument's software to allow accurate automatic readings of dextran concentration to be instantly generated.

Detecting Spiked Dextran in Cane Juice

"Dextran-free" cane juice was obtained and subjected to standard addition with a known mass of dextran to demonstrate that dextran could be detected and quantified in the cane juice as effectively and accurately as in distilled water.

A 2000ppm solution of dextran (71.4kDa) was made up in distilled water and the OR determined. 200ml of cane juice were vacuum filtered with filteraid (2g/100ml) and the OR determined. 0.1g dextran was weighed into a 50ml flask, which was filled to the mark with cane juice and the OR determined. All three samples where then subjected to the new dextran method (Table 4).

Table 4. Change in OR (°Z) due to enzyme treatment in spiked samples of water and cane juice.

Sample	OR °Z before enzyme treatment	OR °Z after enzyme treatment	Change in OR °Z
Water + dextran	2.13	1.52	0.61
Juice	50.47	50.47	0.00
Juice + dextran	52.60	52.00	0.60

The assay behaves the same in cane juice as in water as shown by the essentially identical values of change in rotation due to dextranase addition.

Confirmation of the Analytical Precision and Reliability

Using a 40% raw cane sugar solution high in natural dextran the assay was performed 10 times on the same sample to demonstrate the precision of the test and therefore the reliability of a single measurement approach.

The results showed absolutely no variance within the accuracy range of the instrument, which is +/- 0.02°Z. This indicates the measurements are entirely repeatable under standard laboratory conditions.

Observation of Dextran Growth Over Time

The following work was carried out during field trial work in association with SIRI at their Central Laboratory, Mandeville, Jamaica. Using green cane deliberately contaminated with dextran-producing bacteria, the test was performed repeatedly over a 4-day period to demonstrate the growth of dextran over time.

Enough cane was crushed from the pile to collect 500ml of raw juice. Filter-aid was added in the concentration of 2g/100ml and after stirring, the mixture was vacuum filtered through a Millipore AP20 prefilter (as before). The OR of the clear cane juice was determined on the polarimeter. 60ml of juice were incubated on a shaker for 7 minutes with 1 dextranase-impregnated filter / 30ml and the OR determined at 10 minutes (after addition of impregnated filters).

The increase of dextran levels is clearly seen in the rising values of the difference between the control and test readings (Table 5). The dextran is calculated by using the quadratic equation fitted to the calibration curve. The lack of exposure of the cane to mud and rain during the test period would explain why the increase of dextran is less than that expected in an average cane yard.

Table 5. Increase in dextran over time. The dextran is calculated by using the quadratic equation fitted to the calibration curve.

Day	Control (OR°Z)	Test OR (°Z)	Difference OR (°Z)	Dextran (ppm)	Corrected OR (°Z)
1	60.35	59.61	0.74	1431.72	58.80
2	59.43	58.57	0.86	2279.23	56.97
3	61.80	60.85	0.95	2551.58	59.04
4	60.12	59.00	1.12	3064.16	56.81

SUMMARY

From the above set of experiments, it is evident that the theoretical basis of the assay remains sound when put into practice. The enzyme selected for this work appears to be specific for a single substrate, namely dextrans. The calibration curve has been previously shown to be unaffected by factors such as molecular weight of the substrate and the pH of the medium in which measurements are made with detection limits that cover the entire range of market requirements. This assay procedure is robust, rapid, simple to perform and through subsequent development of the instrument is now semi-automated. The presence of dextran in sugar represents financial losses at almost every stage of the process from cane to cube. It is hoped that this new analytical method will now make it possible for both the factory and the refinery to identify dextran sources and take an informed approach to employing the correct remedial actions in both the short and long term.

ACKNOWLEDGEMENTS

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REFERENCES

1. Brown, C. F. and Inkerman, P. A. 1992. Specific method for quantitative measurement of the total dextran content of raw sugar. J. Agric. Food Chem. 40:227-233.

2. Curtin, J. H. and McCowage, R. J. 1986. Dextran measurement in cane products. Proc. ISSCT. 19:755-764.

3. DeStefano, R. P. and Irey, M. S. 1986. Measuring dextran in raw sugars - historical perspective and state of the art. J. Am. Soc. Sugar Cane Technol. 6:112-120.

4. Imrie F. K. E. and Tilbury R. H. 1972. Polysaccharides in sugar cane and its products. Sugar Technol. Rev. 1:291-361.

5. Keniry, J.S., Lee, J. B. and Mahoney, V.C. 1969. Improvements in the dextran assay of sugar cane materials. Int. Sugar J. 71:230-233.

6. Kubik, C., Galas, E. and Sikoro, B. 1994. Determination of dextran in raw beet juices by the haze / enzymatic method. Int. Sugar J. 96(1149):358-360.

7. Muller, E.G. 1981. Dextran. Tate and Lyle's SIA. 43(5):147-148.

8. Roberts, E. J. 1983. A quantitative method for dextran analysis. Int. Sugar J. 85:10-13.

9. Wilson, T. E. 1996. A comparison of raw sugar polarisation methods. Int. Sugar J. 98(1168):169-174.

AGRICULTURAL ABSTRACTS

The Louisiana Basic Breeding Program-Past, Present, and Future

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With the extraordinary success of LCP85-384, a *Saccharum spontaneum* BC_4 derivative, released in 1993, and the release of HoCP85-845, also a S. *spontaneum* BC_4 derivative, it is obvious that the USDA-ARS Basic Breeding Program at Houma, LA has provided tremendous dividends to the Louisiana sugar industry. Both clones were bred during the year 1980, and both involved *S. spontaneum* clone, US56-15-8. Some questions we need to address now are "What has happened during the past 20 years of crossing with basic germplasm that would give us reason to believe that further benefits can be expected from the basic breeding program?" "Where are we today in our basic breeding program?" "What must we do to maximize the likelihood of success in the future?" A review of our own program along with other breeding programs, particularly in Argentina, indicate that, with an intensified effort and some modifications in our breeding and selection approach based on lessons learned from the past, we should expect to see further substantial genetic improvement through basic breeding. Topics discussed will include: 1) number of BC generations needed to obtain commercial cultivars, 2) years needed between BC generations, 3) need for recombination between BC generations to exploit desirable recessive traits, 4) use of marker-assisted selection, 5) formation of complex *S. spontaneum* crosses, and 6) greater focus on populations rather than individuals.

Assessment of Stalk Cold Tolerance of Louisiana Varieties During the 2000-2001 Crop Year

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The exposure of sugarcane to damaging frosts occurs in over 20 of the 79 sugarcane-producing countries of the world, but is most frequent on the mainland of the United States. The frequent winter freezes in the sugarcane area of Louisiana forced the industry to adapt to a short growing season (7-9 months) and a short milling season (about 3 months). Field experiments consisting of 3-row plots (18 ft) by 45 ft long are routinely planted at the Ardoyne Farm of the USDA-ARS, SRRC at Houma, Louisiana, for the estimating stalk cold tolerance of commercial and candidate varieties. For the 2000-2001 crop-year study, two commercial varieties, CP

70-321 and CP 79-318, with known cold tolerance were planted in the test as controls. Other commercial varieties included LHo 83-153, LCP 85-384, HoCP 85-845 and HoCP 91-555.

Freezing temperatures that affected the Louisiana Sugar Industry during the 2000-2001 crop-year occurred on December 20, 2000, when the minimum temperature recorded in the field at the Ardoyne Farm was 24°F, and again on December 21, December 30 through January 5, 2001 and January 9 and 10. The lowest temperature of 22°F was recorded on January 4. Freezing conditions prevailed for 8-15 hours during each freeze incident. Stalks of all varieties were frozen to the ground following the initial freeze with freeze cracks evident only after the January 4 freeze.

Samples were taken the date of the first freeze and again at 7, 14, 22 and 30 days after the first freeze. Criteria used to measure overall stalk cold tolerance included changes in Brix, sucrose, purity, yield of theoretical recoverable sugar per ton of cane, pH, titratable acidity, dextran by both the Rapid Haze and ASI II Methods and fiber content of juice and/or cane and mean stalk weight. On each date of harvest, 15-stalk samples were collected from each of the four replications of all varieties and were divided into two sub-samples on four of the five sampling dates to compare the analyses of juice extracted by the conventional 3-roller mill (10 stalks) and the pre-breaker/press method (5 stalks). On the remaining sampling date, juice was extracted from all 15 stalks by the 3-roller mill. Significant changes were noted in all criteria for all varieties, with the exception of mean stalk weight, at 22 and 30 days after the first freeze. Further, significant differences were also noted between varieties on each sampling date. Overall, the ranking of varieties for stalk cold tolerance, from best to worse, when considering all criteria was as follows: CP 70-321, LHo 83-153, LCP 85-384, HoCP 85-845, HoCP 91-555 and CP 79-318. Accordingly, the classification of stalk cold tolerance (post-freeze resistance) for these varieties based on the results obtained during the 2000-2001 crop year is as follows: Very Good - CP 70-321; Good - LHo 83-153; Good to Moderate - LCP 85-384; Moderate - HoCP 85-845; Moderate to Poor - HoCP 91-555; and Poor - CP 79-318. The stalk cold tolerance for both CP 70-321 and CP 79-318 is well documented from previous studies. There were only slight differences in the pH and titratable acidity of the juice when comparing extraction methods. Although the concentration of dextran in the juice as an average of all varieties and all dates of sampling was considerably different between the two methods of analyses (1,592 and 4,102 ppm for the Rapid Haze and ASI II Methods, respectively), the ranking amongst varieties was similar when comparing the two methods ($r = 0.98$).

Post-Freeze Performance of 16 Sugarcane Cultivars Following the December 31, 2000 Freeze Event in Florida

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Freezing temperatures occurred for an extended period of time on the night of December 31, 2001 and morning of January 1, 2000. Temperatures below –2°C occurred for more than four hours in much of the Everglades Agricultural Area. The performance of 16 cultivars planted in six experiments planted at five locations was characterized by determining sugar content per gross ton of cane. Replicated variety trials at five locations were sampled serially on two-week intervals following the freeze event until March 20, 2000 and ground for sugar yield. Four of the five locations were exposed to freezing temperatures for more than 10 hours while one location received no freeze injury. Sucrose content of the 16 cultivars occurring at least at two of the freeze damaged experiments were contrast with sucrose content at the freeze protected location. CP89-2143 had the highest sugar per ton of cane at 80-days post-freeze and demonstrated relative losses comparable to CP72-2086, a known "freeze-tolerant" cultivar. CP85-1308 showed the greatest relative losses following the freeze event. CP80-1743, CP84-1198, CP85-1382 and CP88-1762 demonstrated relative losses similar to CP70-1133, a known "freeze-susceptible" cultivar.

Sugarcane Tissue Phosphorus Concentration as Affected by P Rates Applied to a Florida Histosol

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Approximately 85% of the sugarcane (*Saccharum officinarum L*) acreage in Florida are located in the Everglades Agricultural Area, where soils are typically organic in nature. Phosphorus, K, and several micronutrients are commonly applied to histosols to produce acceptable yields. Because of increasing environment concerns, P application to all agricultural crops has been receiving increased attention. Though many studies on sugarcane response to P

fertilizer have been carried out worldwide, little information is available on the effects of P fertilization, especially with respect to seasonal tissue P concentration, for sugarcane grown on Florida's histosols. The objective of this field study was to assess tissue P concentration of sugarcane varieties at the different growth stages in response to increasing P rates. Five P rates (0, 34, 67, 101, 135 kg P_2O_5 kg^{-1}) and four sugarcane varieties (CP70-1133, CP72-2086, CP78-1628, and CP80-1827) were evaluated in a randomized complete block design (RCBD), in six replications at two sites. Top visible dewlap (TVD) leaf samples were collected at the early, grand growth, and late crop stages. Results indicated increases in tissue P concentration as P rate increased, especially in the early stages of crop growth. Phosphorus concentration was also highest in the early stages and lowest in late stages, nearing harvest date. First year, i.e., plant, sugarcane had higher tissue P concentration than first ratoon cane. Variety CP80-1827 presented the highest tissue P concentration in all the samplings. Interpretation and utilization of sugarcane tissue P concentrations for determining plant nutritional status and fertilizer recommendation should take into account time of sampling, P rate applied, and variety planted.

Sugarcane Root and Soil Microbial Responses to Intermittent Flooding

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Sugarcane is one of the most environmental friendly agricultural crops grown in the Everglades Agricultural Area because it can tolerate short periods of flooding and has been reported to have less soil organic matter oxidation compared to other agricultural crops. Soil oxidation results primarily from aerobic microbial activity. Since flooding reduces soil oxygen levels, flooding as well as growing sugarcane may reduce soil organic matter oxidation. One concern regarding flooding of sugarcane is that mechanical harvesters would reduce yields of subsequent ratoons by pulling entire stools from the soil due to weakened root systems caused by the flooding. An experiment was conducted to determine the combined effect of water-table depth and intermittent flooding on soil organic matter oxidation potential and sugarcane root growth. Sugarcane was grown in 1.5 X 2.6 X 0.6 (wide, long, and deep, respectively) m polyethylene lysimeters out doors. Lysimeters were filled with a Pahokee muck soil. After plants reached an 8-cm height, intermittent flooding treatments were imposed consisting of 7 days flooding followed by 14 days drained to 16, 33, and 50-cm depths. A continuous 50-cm water table was used as a control. Starting July 10, soil samples were taken during the drain period on day 0, 3, 7, and 14 and analyzed for oxidation potential. Soil sampling continued over 5 consecutive cycles. On Jan. 19, 2001 sugarcane was harvested and shortly afterwards, root samples were taken. Root samples were extracted by taking four-6.4-cm cores to 0 to 15-, 15 to 30-, and 30 to 45-cm depths at a distance about 5 cm from the rows of sugarcane. Roots were washed and analyzed for dry wt, length, volume, surface area, and diameter. Soil organic matter

oxidation potential averaged over 5 drain cycles indicated that soil oxidation started increasing immediately after drainage and reached its maximum activity about one week later. Also, there appeared to be a residual effect of flooding as the oxidation potential of the flooding treatments was less than the continuously drained treatment over the 14-day drain cycle. The 16-cm water table had soil oxidation potentials that were less than half those of the other flooding treatments. Average root dry wt, length, surface area, and volume from high water table treatments in the sampled area were about twice those from continuously drained treatment. It appears that with intermittent flooding, roots around the sugarcane stool can compensate for unfavorable root environments by developing more roots in the less aerated soil compared to continuously drained soil. Combining raised water tables with intermittent flooding should improve both soil conservation and sugarcane root growth.

Effect of Nitrogen Fertilizer Rates on Producer Economic Returns of Variety LCP 85-384 on a Heavy-Textured Soil in Louisiana

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Recommended nitrogen fertilizer rates for "strong" stands of sugarcane (*Saccharum* spp.) on heavy-textured soils in Louisiana are 112 to 135 kg N/ha for plant cane, and 157 to 179 kg N/ha for stubble cane. The high sugar yields (20% higher than the next best variety) obtained with variety LCP 85-384 raise questions about whether this variety has different nitrogen fertilizer requirements than other recommended varieties grown in Louisiana. To answer this question, twelve site-years of yield data from nitrogen rate studies with LCP 85-384 on a Baldwin silty-clay loam (thermic Vertic Ochraqualf) soil were used to determine economic returns (based on $0.42/kg of sugar, $0.66/kg of N, and the producer giving half of his crop to the sugar mill and landlord) to producers. The best economic returns for plant cane in five studies were at 0, 56, 67, 135, and 157 kg N/ha, respectively, compared to the recommended nitrogen application rate of 112 to 135 kg/ha. The highest economic returns for first-stubble cane in five studies were 67, 112, 112, 112, and 135 kg N/ha compared to the recommended rate of 157 to 179 kg N/ha. Consequently, the recommended N application rate for LCP 85-384 first-stubble cane appears to be too high and better economic yield responses could be obtained if it were fertilized like plant cane. There was only one site-year of data for second- and

third-stubble cane. In both cases, highest economic returns were obtained at 202 kg N/ha compared to the 135 kg N/ha rate.

Production Trends of the Major Cane Sugar Producing Countries in the World

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Over 130 countries produce sugar about 134 million Mg sugar in 1999 to 2000 crop, of which 27 of them produced over one Mg sugar. Six countries, Brazil, India, China, USA, Australia, and Thailand generated 61% of the word cane-sugar production (97 million Mg) in 1999 to 2000. Total cane-sugar production from these six countries plus South Africa, the major cane sugar producer in Africa, has significantly increased in recent decades. Approximately 60% of the increase was due to expanded growing area.

The highest sugar production per area in the world is and has been in Hawaii with average production over 11 Mg sugar ha^{-1}. Thailand and Louisiana demonstrated the largest increases in total sugar production (244% and 145% Mg sugar) and per area production (145% and 87% Mg sugar ha^{-1}) in the last 20 years. Australia has maintained without significant change the highest average sucrose content (14 sucrose %cane) in the world since the 1920s. In the last 12 years sugar production per area (Mg sugar ha^{-1}) increases have been due mostly to improvements in cane yield production with little to no change in sucrose content. Perhaps we have reached a genetic plateau for sucrose content.

Potential Effect of Yellow Leaf Syndrome on the Louisiana Sugarcane Industry

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A three-year field study was conducted to determine the effect of sugarcane yellow leaf virus (SCYLV) on two cultivars of sugarcane (LCP 82-89 and LHo 83-153). Yield loss (sugar

per unit area) was observed in LCP 82-89, with the greatest loss in the second-ratoon crop (23%). Quality components, % Brix, % sucrose, % purity, and starch concentration, of the stalks did not differ between SCYLV-infected and uninfected; however, in the tops, leaves and the immature portion of the stalk, % Brix, % sucrose, % purity, and starch concentration were higher in SCYLV-infected plants of both cultivars. Dextran content was inconsistent. Tops of stalks are normally removed by the mechanical harvester; however, they may not be removed if the cane is lodged and/or during wet weather harvesting. Green leaves and immature tissue containing elevated levels of starch delivered to the mill may reduce processing efficiency.

A collection of 407 parental sugarcane clones grown at Canal Point, Florida and used for making crosses for the Louisiana Industry were assayed for infection by SCYLV. As a result of natural spread, SCYLV infection was found in approximately 50% of the cultivars, indicating a high level of susceptibility to infection within the Louisiana germplasm.

Although visible symptoms of yellow leaf syndrome (YLS) caused by SCYLV are rarely observed in Louisiana, yield loss was observed in SCYLV-infected LCP 82-89 in the absence of symptoms and the virus in both cultivars affected quality components in leaves. With the recent discovery of *Melanaphis saccharalis* in Louisiana, a demonstrated vector of SCYLV, and the demonstration of yield and quality effects on sugarcane even in the absence of symptoms, YLS is a potential problem to the Louisiana industry.

Feeding Effects of Yellow Sugarcane Aphid on Sugarcane

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Feeding by yellow sugarcane aphid, *Sipha flava* (Forbes), can cause reddening, premature yellowing and death of sugarcane leaves. Prolonged feeding by large populations of this aphid can lead to plant death. We report here the results of experiments using a susceptible sugarcane cultivar (CP80-1827) to quantify the growth and yield effects of early season *S. flava* feeding. Two-month old plants grown from single-eye setts in 5-gallon buckets were first subjected to yellow sugarcane aphid feeding for 8 to 10 weeks. Plant damage was rated on the number of leaves (0, 1, 2, 3, and 4) below the TVD on the primary stalk with <50% *S. flava* damage symptoms. These ratings were used to group plants for comparison of growth and yield effects against plants grown without aphid exposure (controls). Aphids were then removed and the plants transplanted into the field where they were maintained aphid-free for 7 months until harvest. *S. flava* feeding resulted in the production of longer, faster growing leaves and internodes, but also thinner, lighter stalks compared to the controls. Each leaf and internode that was produced after aphids were removed from the plants expanded slightly less than the previous one and gradually approached the length of these structures on control plants, but node diameters remained thinner on previously infested stalks. Internode volumes were reduced an average of 21% on plants in the highest damage category. Aphid-damaged stalks with thin internodes at their bases were more likely to lodge from wind and rat damage than controls.

Apparent sucrose was lower in juice from plants previously infested by *S. flava* than from those not exposed to the aphids. When combined with the reductions in internode volume and weight, even light *S. flava* damage (i.e., two out of six leaves below TVD with >50% damage) resulted in a 6% reduction in sugar yield. Heavy damage (i.e., six out of six leaves below TVD with >50% damage) to sugarcane plants from yellow sugarcane aphid feeding early in the season reduced sugar yield by 19%.

Relative Abundance and Diversity of Aphid Species Collected in Traps Adjacent to Sugarcane Fields in Florida

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Even with the rapid expansion of the state's sugarcane industry during the 1960s, sugarcane mosaic, caused by the sugarcane mosaic virus potyvirus (SCMV), remained a disease of minor importance in Florida for nearly four decades. Although detected in sugarcane and weeds, disease incidence rarely exceeded several percent. Since the late 1990s, however, observers have noted a marked increase in SCMV incidence, particularly in the variety CP72-2086. A mainstay of the Florida industry, presence of SCMV in this variety could have serious repercussions. For even though CP72-2086 has demonstrated yield tolerance, it could serve as a significant pathogen reservoir, facilitating the spread of SCMV to other susceptible, but less tolerant varieties. In nature, SCMV is transmitted mechanically (i.e. planting of infected seed pieces) and by aphid species in a semi-persistent manner. With a paucity of baseline information on aphid diversity and populations in the Everglades Agricultural Area, investigations were conducted using standard yellow sticky traps to monitor aphid activity adjacent to sugarcane fields. Five traps were positioned for a 14-day period at monthly intervals along transects paralleling sugarcane fields located in areas representative of the western, central, and eastern cane-growing areas of the EAA. Cumulative numbers of aphids trapped peaked in March and then again in November. A total of 23 identifiable species were collected, representing 12 genera. Two of these species, *Rhopalosiphum maidis* and *Schizaphis graminium*, have been demonstrated to be capable of transmitting SCMV in nature. Two aphid species that commonly colonize sugarcane, *Sipha flava* and *Melanaphis sacchari*, were trapped relatively infrequently. Possible associations of the recent surge in SCMV in Florida and aphid populations will be discussed.

Fifteen Years of Recurrent Selection for Sugarcane Borer Resistance

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The sugarcane borer, *Diatraea saccharalis* (F.), is an important insect pest of sugarcane in the Americas and the key insect pest of sugarcane in Louisiana. Long managed in Louisiana using an IPM program primarily relying on insecticides, there is increasing economic and environmental pressures to reduce the management program's dependency on insecticides. Plant resistance is an attractive alternative to insecticides.

In 1986 we began a satellite recurrent selection program to increase levels of borer resistance among parental lines used in the Louisiana Commercial Breeding Program. Following the initial crosses in 1985 among resistant parents identified from the USDA's 1983 Series, approximately 75,000 seedlings have been evaluated. Fifty-one selections were given the in-house designation RSB (recurrent selection borer). Of these 51 selections, 33 were assigned permanent numbers (US) and 18 were identified as having commercial potential. A total of 17 selections were registered with the Crop Science Society of America as germplasm clones. Biparental crosses have been made among these resistant clones and selections are being made to advance a new generation of recurrent selection.

Mexican Rice Borer on Sugarcane and Rice: Significance to Louisiana and Texas Industries

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The sugarcane borer *Diatraea saccharalis* (F.) is the most common stem borer in the upper Texas rice belt, but the Mexican rice borer (MRB) *Eoreuma loftini* is becoming an increasing problem, particularly in the southern region of the Texas Rice Belt – Calhoun, Jackson, Victoria, and Matagorda Counties. The MRB was introduced prior to 1980 from Mexico into the Lower Rio Grande Valley where it immediately became a serious pest of sugarcane. In 1987, the MRB was first detected in the Texas Rice Belt in Jackson and Victoria Counties. In 2000, pheromone traps were set out in most Texas Rice Belt counties around

sugarcane in East Texas, and in Southwestern Louisiana sugarcane producing parishes to determine the spread of this insect since 1987. County Extension Agents , farmers, and Texas and Louisiana Agricultural Experiment Station scientists helped monitor the traps. In addition, personnel from both state departments of agriculture participated. The traps used were baited with synthetically produced MRB pheromone. Results of the 2000 trapping program showed the MRB had moved north into five new Texas Rice Belt counties – Wharton, Brazoria, Colorado, Waller, and Fort Bend. No MRB were collected in counties east of Harris where Houston is located.

About 1000 acres of sugarcane are now grown in Texas east of Houston near Beaumont, which is the eastern region of the Texas Rice Belt. Based on pheromone trapping, sugarcane grown in this area is free of MRB. Sugarcane farmers in Southeast Texas and Southwest Louisiana are concerned about the possible introduction of the MRB, which could become a serious pest of sugarcane in these regions. In the Lower Rio Grande Valley, the MRB is the number 1 pest of sugarcane; in fact, some fields are not harvested due to heavy damage. Consequently, the MRB has the potential to become a threat to rice and sugarcane in Southeast Texas and Southwest Louisiana.

Data from the Lower Rio Grande Valley suggest that drought stresses sugarcane is far more susceptible to MRB damage than healthy sugarcane. Thus, the pest potential in irrigated sugarcane is less compared to rain fed sugarcane, which represents over 95% of sugarcane in Louisiana.

Data from 1999 and 2000 indicate MRB is the predominant borer attacking rice in Jackson County (and possibly Calhoun and Matagorda Counties). MRB damage is similar to that of the sugarcane borer. The larvae cause deadhearts and whiteheads. Replicated small plot studies in Jackson County in 1999 showed that a combination of MRB and a small percentage of sugarcane borers reduced rice yields 3000 lb/acre. These are exceedingly high yield losses which may not be representative of the entire area but do show the potential for damage. Research by Texas A&M and LSU AgCenter scientists is currently being conducted to determine rice and sugarcane varietal susceptibility to MRB, gain additional biological knowledge of the MRB in order to better time control tactics, and evaluate selected insecticides using an integrated pest management approach. This research is partially funded by grants from the USDA CSREES Critical Issues, Rice Research Foundation, and the American Sugarcane League.

Economically Optimal Crop Cycle Length for Major Sugarcane Varieties in Louisiana

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The widespread adoption of the high-yielding variety LCP85-384 has resulted in two significant changes in the production sector of the Louisiana sugarcane industry. Plant

characteristics of this variety make it very suitable for combine harvesting and helped to promote the conversion from whole stalk harvesting to combine harvesting in the state. Secondly, the variety is also an excellent Stubbling variety, resulting in the expansion of standard sugarcane crop cycles beyond harvest of second stubble. Outfield trials yield data over the 1996-2000 period for major sugarcane varieties produced in Louisiana was used to determine the optimal crop cycle length, which would maximize the net present value of producer returns. Cane yield and sugar per ton data for plant cane through third stubble was used to estimate the annualized net return of crop cycles through harvest of second and third stubble and to determine the breakeven level of fourth stubble yields which would justify production and harvest. Analysis of yield and net return data for the varieties CP 70-321, LCP 85-384, and HoCP 85-845 indicated that minimum yield levels necessary to keep older stubble in production for harvest depend directly upon the yields of the prior crop cycle phases and differ significantly across varieties.

Optimum Maturity of CP Sugarcane Clones for Harvest Scheduling in Florida

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Variety maturity tests were conducted on 16 Canal Point (CP) clones at 5 locations over 3 years in the Everglades Agricultural Area in Florida. Cane sugar quality was measured at biweekly intervals during the October to March harvest season in each year. A quadratic response function of lbs. sucrose per gross ton of cane (SPT) vs. sampling date was calculated for each clone using the entire 3-year data set, and date and magnitude of maximum SPT calculated. CP89-2143 and CP72-2086 had the highest predicted SPT at 305 and 285 on Feb 9 and Feb 13, respectively. Model fit varied greatly between clones, with R^2 values ranging from 0.23 – 0.72. In general, clones with higher R^2 values tended to have maximum SPT after February 1. The SPT data was then divided into "early", "middle", and "late" maturity classes and the CP clones ranked based on average SPT within a given class. Results of this analysis will be discussed in terms of a harvest scheduling aid for Florida growers.

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Protox Inhibitor Herbicide Effects on *Pythium* and Root Rot of Sugarcane

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A complex of root pathogens contributes to yield decline of sugarcane. Pythium root rot, caused by *P. arrhenomanes*, is one component of the disease complex. Root rot control would increase yield and could allow additional ratoons to be obtained. Herbicides can have non-target effects, such as enhancing or reducing root disease severity. Protoporphyrinogen oxidase (protox) inhibitor herbicides may reduce fungal disease severity in other crops by inducing host resistance. In addition, visual growth increases in sugarcane early growth following application of one protox inhibitor herbicide have been observed. Therefore, lab and greenhouse experiments were conducted to determine protox inhibitor herbicide effects on *Pythium*, root rot severity, and sugarcane growth.

Three protox inhibitor herbicides, Milestone (azafeniden), Spartan (sulfentrazone), and Valor (flumioxazin) were evaluated for their effects on *in vitro* mycelial growth rate of *P. arrhenomanes*, *P. ultimum,* and *P. aphanidermatum* and Pythium root rot and growth of sugarcane in two greenhouse experiments. Effects on sugarcane growth and root rot were evaluated after herbicide leaf or soil application at the recommended rate and 1/10 and 1/20 the recommended rate. Three types of soil were used, field soil (FS), sterilized field soil (SFS), and sterilized field soil infested with *P. arrhenomanes* (SFS+P).

All three herbicides strongly reduced *Pythium* mycelial growth *in vitro*. No growth of *P. arrhenomanes* occurred when rate one or above was applied in the growth medium. Mycelial growth inhibition still occurred at a 200-fold dilution of the recommended rate. Milestone had the strongest effect followed by Spartan and Valor. In the greenhouse, all three herbicides reduced *P. arrhenomanes* root colonization in some cases, but results were erratic between experiments. Milestone and Valor were phytotoxic in sterile and nonsterile soils, and with a short duration experiment, the damage may have made it difficult to detect effects on root rot severity and plant growth. No treatment clearly reduced visual root rot symptoms. Only 1/10 rate Spartan applied to leaves significantly reduced *P. arrhenomanes* colonization in SFS+P and increased plant growth. In field soil, more treatments reduced *Pythium* root colonization, but only leaf-applied Spartan at rate one and 1/10 rate Valor increased some component of sugarcane growth.

No consistent effects on disease severity and plant growth were shown. However, the greenhouse experimental system may not have been sufficient to clearly demonstrate the effects of the protox inhibitor herbicides on sugarcane root rot. Although variable, the results suggest these herbicides may be capable of reducing *P. arrhenomanes* infection and increasing plant growth through reduced root rot severity. The slight increases in plant growth following leaf application of herbicide suggest an indirect effect through induced resistance.

Irrigation of Sugarcane on Clay in a High-Rainfall Environment

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Variable yield responses to irrigation of sugarcane, *Saccharum spp.,* in Louisiana's humid climate have made it difficult to evaluate its economic soundness. Nevertheless, the occurrence of several droughts during the past decade in southern Louisiana has intensified the interest in supplemental irrigation. During the severe drought of 2000, a study to evaluate the response of LCP 85-384 plant cane to irrigation was conducted on an Alligator clay soil (thermic Vertic Haplaquept), a soil textural class that tends to restrict root development under drought conditions. Irrigation was scheduled when stalks elongated 5 cm or less per week. Supplemental water was supplied in furrows on May 5, May 25, July 21 and August 28 for a cumulative total of 1130 m^3 . The experimental site received a total of only 50.5 cm of rain from May through October, a rainfall deficit of 38.4 cm when compared to a 25-yr average for the same period. Height difference at harvest between the irrigated and non-irrigated plots was 50 cm. Yields mirrored the plant height disparity, with irrigated plots producing 44% higher cane (P = .06) and sugar (P = .08) yields than the control plots. The magnitude of the yield responses to irrigation in this experiment, 22.6 Mg ha^{-1} of cane and 2.41 Mg ha^{-1} of sugar, was comparable to that observed elsewhere under similar dry conditions.

Effect of Tissue Culture Method on Sugarcane Yield Compnents

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Vegetative propagation is conducive to the spread of systemic sugarcane diseases, such as ratoon stunting disease (RSD). This important disease is now controlled in Louisiana largely by planting commercial seed-cane initially produced through tissue culture. Kleentek® seed-cane has been available to farmers since the late 1980s. In the early years, farmers sometimes noted that tissue culture derived plants had smaller stalk diameter and weight and a higher stalk population. The tissue culture method used at that time was leaf roll callus culture. Since then, the method has been changed to direct regeneration from the apical meristem to

attempt to reduce or eliminate differences between tissue culture derived plants and the original varieties.

To determine whether tissue culture method affects yield or its components, three varieties, CP 70-321, LCP 85-384, and HoCP 85-845, were compared in three successive crops, plant cane through second ratoon, at three locations. Experiments were planted with stalks from three sources: Kleentek plants derived from callus (undifferentiated cells) produced from the leaf roll above the apical meristem, Kleentek plants directly regenerated from an apical meristem, and original plants from conventional bud propagation. Stalks of plants derived from both tissue culture methods were typical of Kleentek seed-cane farmers would purchase for planting that had been rogued for phenotypic variants (off-types) and increased by bud propagation. Yield components compared included stalk diameter, length, weight, sucrose content, and population; cane tonnage; and sugar yield. Plants were visually inspected for off-types in May, August, and at harvest.

Differences in yield components between the two tissue culture methods and bud-propagated cane only occurred in CP 70-321. Stalk diameter and stalk weight were lower and stalk population was higher for plants derived from leaf roll callus compared to bud propagated cane. However, all yield components were similar for plants derived from apical meristem and bud propagation. Individual plant off-types were not observed in cane produced by either tissue culture method. In summary, variety and tissue culture method affected persistent, uniform variation in plant growth habit resulting from tissue culture that changed some yield components. However, apical meristem culture was suitable for production of seed-cane, as sugarcane derived by meristem culture of all three varieties did not differ significantly from the original germplasm for any measured trait.

Genes Expressed During Regeneration in Tissue Culture

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Regeneration from tissue culture by way of somatic embryogencis is common in many varieties of sugarcane, but many economically important varieties of sugarcane are recalcitrant. Better understanding of the genetic control of embryogenesis could lead to the ability to transfer this trait to important varieties lacking it. This could assist in the rapid progation of these varieties and in the construction of beneficial transgenic varieties. We used differential display techniques to compare genes expressed in mRNA samples from non-cmbryogenic, proembryogenic, and embryogenic callus from variety CP 72-1210 and from non-embryogenic callus from the recalcitrant variety TCP 87-3388. Several novel sequences were identified. One codes for a hypothetical protein containing several phosphorylation sites. Another codes for a hypothetical protein with a glycosylation site and a camp controlled phosphorylation site. The

third codes for a hypothetical protein with a 37% homology to extension in canola. The last codes for a hypothetical protein that has a 93% homology to a putative glucose-6-phosphate/phosphate translocator in rice. Whether these sequences are unique to a specific tissue type is still under investigation.

A Technique to Breed for Ratoon Stunting Disease in Sugarcane

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Ratoon stunting disease (RSD) caused by *Clavibacter xyli* subsp. xyli is one of the most important sugarcane (interspecific hybrids of *Saccharum* spp.) diseases in Florida. The objective of this study was to evaluate the effectiveness of stubble inoculation and determine if it could be used in a program to breed for RSD resistance. Field grown seedling sugarcane plants were inoculated at maturity by cutting with knives dipped in juice infected with ratoon stunting disease bacteria (RSD). The regrowth from these stools was sampled at the base of the mature stalks and RSD susceptibility was based on the number of colonized vascular bundles determined using the tissue blot immunoassay. After selection based on vegetative characteristics in Seedlings, the average RSD rating of 12 crosses with 658 selections was 1.52. When resampled as mature plants in Stage I, the average rating was 4.15. The plants were reinoculated and replanted into a Stage I sized plot. There were 67 clones selected for advancement to Stage II. They had an average RSD rating of 1.75. One major advantage of this system is that it requires no special planting in which to evaluate RSD resistance. The major disadvantage of this system from our standpoint in Florida is that it requires that seedling selection be done in the ratoon crop and that all clones in the breeding program would potentially be infected with RSD. In all probability very high yielding susceptible clones would be dropped with this selection scheme. Growers in Florida now manage RSD with a combination of genetic resistance and clean seed cane. Therefore, our industry is not willing to lose those potentially high yielding clones that are susceptible but could be profitable when grown without RSD.

Progress in the Development of Transgenic Disease-Resistant Sugarcane

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Efforts are underway to develop sugarcane with transgenic resistance to the sugarcane yellow leaf luteovirus (SCYLV), leaf scald disease (LSD), and ratoon stunting disease (RSD). Genetic constructs containing the SCYLV coat protein in the sense (pFM395) and antisense (pFM396) orientations were obtain from T. E. Mirkov (Texas A&M, Weslaco). A genetic construct (pMBP39-22) containing a modified cecropin gene (MB39) was obtained from Lowell

Owens (USDA, Beltsville, MD). In vitro growth inhibition assays indicated that MB39 should be highly active against the RSD and LSD pathogens, *Clavibacter xyli* subsp. xyli and *Xanthomonas albilineans*, respectively. A number of other DNA constructs were made including those with the cecropin gene under control of the maize ubiquitan promoter (pZY-C), and the antisense SCYLV gene fused with the cecropin gene both under control of the ubiquitan promoter (pZY-CSA). Sugarcane callus cultures were co-bombarded with the individual constructs and another construct containing the NPT II gene as a selectable marker. Genetically transformed plants were regenerated from these materials and are being tested further.

Potential Impact of DNA Marker Technology on Sugarcane Breeding

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At the turn of the new millennium, breeders have begun to realize how DNA marker technology may potentially impact traditional sugarcane breeding programs. Sugarcane is a tropical grass with both male and female organs within each tiny flower. Self-pollination may occur even after a male-sterility treatment such as the immersion of tassels in hot water or alcohol. The use of DNA marker technology may allow breeders to eliminate progeny from unwanted selfs early in the basic and commercial programs. At least five classes of DNA markers are available to use, each having its strong and weak points. These are restriction fragment length polymorphism (RFLP), random amplified polymorphic DNA (RAPD), polymerase chain reaction (PCR), simple sequence repeat (SSR) or microsatellites, and amplified fragment length polymorphism (AFLP). Unlike the morphological traits, DNA fingerprints constructed with these classes of markers are quite reliable and not influenced by the environment. A few PCR (*Eri3/Eri4* and *GigI/PII*), RAPD (*OPA11-366*), and SSR (*SMC334BS*, *SMC336BS* and *MCSA068G08*) markers, that prove to be species-specific, have been developed to assist in the basic selection program at the Sugarcane Research Unit at Houma, Louisiana. Multi-disciplinary studies are underway to identify and clone RAPD or AFLP markers that are tightly linked to genes contributing to important agronomic traits. Multi-institutional collaborations are also being sought to construct microsatellite linkage maps from several genetic populations (F1, F2, BC1) of sugarcane.

In Vivo Viability Assay of Sugarcane Pollen Stored at Ultra Low Temperature Following Preservation Treatments

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Storage of sugarcane pollen is desirable for enhancing germplasm because of the different flowering time. The viability of *Saccharum spontaneum* pollen can be significantly prolonged under low temperature after being properly air dried to reduce its moisture content.

The information on pollen viability of commercial cultivars (CP 70-1133, CP 98-1301, and CP 98-1654) were used to examine their viability after being stored at low temperature. Pollen samples were collected in the early morning after anthesis and divided into two sets: the first was dried in a cool dehumidified room for three hours and the second set was treated with cryoprotectants. Both sets of pollen were stored immediately at –80°C for 1 to 4 months. Cryoprotectants included 0.25 – 0.5 M solutions in various combinations of dimenthyl sulfoxide, glycerol, sorbitol, and sucrose. An in vivo assay was used to measure the pollen viability. Pollen was applied onto the tassels of green canes, CP 65-357 and Green German (*S.* officinarum), in the morning during the flowering season. Fuzz was harvested about 30 days after pollination for germination test. Seedlings were transplanted to field. Seedlings from crosses derived from stored *S.* officinarum pollen were classified based on the gross plant morphology at 4-month-old while seedlings derived from crosses with stored pollen of commercial cultivars were classified based on stalk colors. Stalk color was determined by one internode from each of 12-month-old seedlings that was cut and dipped vertically in 5% sulfurous acid solution for 3-4 days to eliminate chlorophyll pigment. Loss of pollen viability (%) due to preservation treatments was estimated by [1 – (seed set from stored pollen)/(seed set from fresh pollen)]100. Results showed that pollen of neither *S. spontaneum* nor commercial cultivars produced viable seedlings when they were stored at –80°C after being treated with cryoprotectants. After being exposed to air drying, pollen of both *S. spontaneum* and commercial cultivars produced viable seedlings ranging from poor to good seed set when the stored pollen was used to cross with CP 65-357 or Green German. Average losses of pollen viability were 50% (1997/98) and 88% (1999/00) for CP 98-1654. In addition to the use of the pollen storage for germplasm enhancement, this study suggests that stored pollen with genetic marker may be used to help identify hybrids for genetic and breeding investigations.

MANUFACTURING ABSTRACTS

The Freeze of 2001-A "New Book is Written"

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Atlantic Sugar Associations, Inc. developed an organizational plan, which involved pooling its R&D/Harvesting, Operations/Mill, and Cane Bank, to handle the freeze in 2001. Atlantic Sugar Associations, Inc. had successful and record-breaking results across the board.

The Breakage in Sugarcane Mill Rolls

Jorge Okhuysen
Mexico

The causes of failure involving the design, materials selection, methods of manufacturing, and the influence of operating conditions in sugarcane mill rolls will be discussed.

Material Balance and Equipment Requirements of a Typical Sugar Mill

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Traditionally, to reduce production costs or for other reasons, most sugar mills have increased their grinding rate over the years, after they were designed and built for certain capacity, and conditions. When an expansion project is conceived in a sugar mill, the focus generally is, on cane grinding capacity and steam production. Even though these are extremely important factors, a proper evaluation of the rest of the equipment in the factory is often neglected. This, bring about unnecessary bottlenecks that will defeat the purpose of the expansion, or even worse, a reduction of efficiency. With a properly conducted survey of equipment capacities, an engineer can determine, with the new operating conditions, the proper capacity required in each station of the process.

This paper describes, calculations of material and steam balance performed for a typical sugar mill. It is based on a grinding rate of 1000 tons of cane per day, using the double magma system, and quadruple effect evaporation, with first effect vapor bleeding for secondary heaters and clarified juice heaters and second effect vapor bleeding for primary heaters and vacuum pans.

The results are presented in various charts. These were developed, to illustrate different volumes of materials that can be expected in the boiling house, under different cane quality conditions. Other charts are also presented such as: heating surface required for Juice heaters on the various stages, evaporation rates necessary to satisfy the demands of vacuum pans, and heaters. These figures are useful for sizing the proper equipment required under different conditions and grinding rate.

Properly planning an expansion project, after evaluating all the areas of the mill, will help mill managers spend their investment dollars in the areas were equipment is most needed. A properly balanced factory, provides a smooth operation that enable the mill engineers to focus their attention on increasing efficiency, rather than coping with the added material they have to process.

Reducing Equipment Cost/Best Equipment Management Practices

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The owning and operating cost of mobile equipment can have an adverse effect on a mill's profitability. Cost control is important. The core business of the mill is grinding cane, rather than mobile equipment management. Many managers do not take the time to consider this key area of operation. The productivity of equipment is directly proportional to the effectiveness of an equipment management strategy. Equipment that stays idle during productive times is a substantial cost to the mill. Utilization tracking can be used to determine if added equipment is required. Downtime can be an indicator both of equipment and maintenance problems. A good program of maintenance for high-tech equipment must include oil sampling, repair option management, preventative maintenance, and life cycle planning. A good record keeping system should also include an effort to make historical comparisons of cost per hour. The equipment division of each mill should also have a Standard Operating Procedures guide, which would address the key areas of equipment operation and maintenance. This paper will provide ideas on better equipment management and review specific examples key to lowering the operating cost of equipment.

What You Should Learn from Your Chemical Supplier

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This paper surveys the issues of selection, use and fate of chemicals used as processing aids in sugar production and in equipment cleaning. The chemical sales business is extremely competitive and it is essential that the sugar technologist (chemical user) be aware of the benefits, costs, and possible unforeseen consequences of each chemical used. The chemical supplier who should be familiar with the scientific basis for the application must provide this information – there is no magic in this business. Chemical use should be minimal but is

unavoidable, and factory personnel must have the information required to avoid unnecessary use. Examples of cases where problems and new consumer issues have arisen will be presented, along with some suggestions of new chemical applications.

The Effect of Two Louisiana Soils on Cane Juice Quality

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As part of a large-scale investigation on the effect of various field practices on the quality of cane juice in Louisiana, it was noted that when soil was added to the cane juice to assess the effect of soil on cane juice quality, the juice color lightened. In a study during the 1998/99 crop in Louisiana, with addition of 5% and 10% soil, it was noted that polysaccharide was also removed, the first time this had been reported. These observations run contrary to expectations that soil would degrade the quality of cane juice. Two soils from the Louisiana cane growing area, Sharkey clay and Norwood silty clay loam from Bunkie, were tested on raw juice from green cane, topped, with side leaves, at a 10% add-on to juice. The juice was treated for 30 minutes in a shaker either at room temperature (25°C) or heated (80°C). Changes in pH, color, and total polysaccharide, ash and filtration rate were noted. Both soils caused significant decreases in color and total polysaccharide and increased the filtration rate. Ash and pH were not significantly changed.

Mill House Operation: Composition of Juice from Individual Mills

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Although a lot of work has been done to study and improve sucrose extraction by individual mills in the factory, little information is available about the nature and composition of the juice exiting each mill. The type and concentration of the impurities entering into the process with the extra sucrose may affect processing and the quality of sugar, a subject that has not been addressed to the fullest extent. From a processing point of view, it is useful to have detailed knowledge of every sugar-bearing stream within a sugar factory. Samples of individual mill juices were collected from mills at a local factory during the 2000 grinding season. Juice

samples were analyzed for purity, invert, color, total polysaccharides, conductivity ash, cations, anions, and nitrogen content. The level of extraction of non-sucrose components generally increased across the mills, while the sucrose content decreased. Purity drop was in the range of 3 to 10 degrees while color, total polysaccharides and nitrogen content increased 2 to 4 times from mill #1 to #6. Among cations, sodium and potassium increased, phosphate plateaued at mill #3 or #4, and chloride did not change very much. Potential application of this information will be discussed.

A New Polarimetric Method for the Analysis of Dextran and Sucrose

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A new method for dextran quantification has been developed and field-trialled in Jamaica, in association with the Sugar Industry Research Institute. The method uses a near infrared (NIR) polarimeter and a specific dextranase. The dextranase selectively breaks-down the dextran into sugars of lesser specific rotations without affecting any other substance present in the juice. The initial dextran concentration is derived from the calibration curve of the change in observed optical rotation (OR) due to enzymatic hydrolysis and outputted automatically by the polarimeter. Readings are not affected by the molecular weight of the dextrans, the entire procedure takes less than 10 minutes to perform and it is semi-automated. Use of a NIR polarimeter negates the need for lead clarification. The method is suitable for both juice and raw sugar samples.

Comparative Performance of Hot, Cold, and Intermediate Lime Clarification at Cora Texas Factory

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Since 1996, Cora Texas factory in Louisiana has been operating intermediate lime clarification and was, therefore, one of the few U.S. factories that did not operate cold lime clarification. In an attempt to further improve clarification performance, the factory made the decision to convert to hot lime clarification during the 2000-grinding season. This comparative investigation of hot versus intermediate and cold lime clarification was undertaken to quantitative performance. In cold liming, mixed juice (MJ) was incubated and then limed in a lime tank (4min), both at ambient temperature (~105°F). For intermediate liming, 50% of the

MJ was heated (180-200°F) before incubation, then limed in a lime tank (4min) at ~150°F. Hot liming was configured very similar to intermediate liming except that lime was added immediately after flash heating (215°F; 30sec). Hourly samples across each of the three processes were collected over a six-hour sampling period, on three consecutive days respectively, and these were repeated three times across the 2000-grinding season. For most clarification parameters investigated, both hot and intermediate liming performed much better than cold liming, and hot liming offered some extra advantages over intermediate liming. Markedly less sucrose was lost to inversion reactions across both hot (season av. 0.79%) and intermediate (0.97%) lime processes than across cold liming (1.48%). Increasing the factory target pH of the final evaporator syrup (FES) from ~6.0 to 6.3, in sampling period 3, caused a marked reduction in sucrose inversion losses in both hot and intermediate liming. Less lime was added in hot liming compared to either cold or intermediate liming, with the factory consuming, on season average, only 1.01 lbs lime/ton cane compared to 1.28 for the 1999-grinding season when intermediate rather than hot liming was operated. Pre-heating 50% of the MJ in both intermediate and hot liming markedly removed color, dextran, and starch. Approximately 2.1% (season av.) more turbidity removal (MJ to CJ) occurred in intermediate and hot liming compared to cold liming, with better CJ turbidity control. Subsequent FES turbidity values and control were better in hot liming. Significantly less color (~2.5%) formed on hot liming because of the alkaline degradation of invert compared to ~17% color formation in cold and intermediate lime clarification. Dextran removal was best across hot liming and, as expected, dextran formed in the cold lime tanks.

Advanced Report on the Use of Lime Saccharate in the Alkalinization of Sugarcane Juices

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A factory scale trail on the use of lime "Saccharate" at Atlantic Sugar Association in Florida is described. The methods of application, using existing equipment and facilities, are shown, and some modifications proposed. Results obtained are discussed, within possibilities, and proposals formulated for a continuance of the study.

The Re-introduction of Formal Sugar Engineering Courses at LSU

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The need for adequately trained people in the sugar industry is discussed. In response to the need for better-qualified people in the Louisiana sugar mills, it has been decided to introduce formal courses in Sugar Process Engineering and Sugar Factory Design, in the Department of Biological Engineering. These courses will form part of the curriculum of students studying Chemical, Mechanical or Biological Engineering who wish to earn a Minor in Sugar

Engineering. In addition, options for Masters students in engineering to take the sugar courses exist, aimed at producing graduate students with a comprehensive knowledge of sugar. The benefits to the industry, to Audubon Sugar Institute, and the University are highlighted.

SAT Process for Production of White Sugar from Sugar Mills

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Due to the uncertainty in the government's sugar program and the threat of global competition, the US domestic sugar industry is under pressure to develop a new strategy for the new millennium. One of the potential solution is to produce white sugar directly from sugar mills with minimal / nominal capital cost. With this vision in mind, the SAT process was developed at Sugar Processing Research Institute under the direction of its former managing director, Dr. Chung Chi Chou and is the subject of this paper.

For the cane sugar industry, sugar is extracted from sugar cane, processed to produce raw sugar in a sugar factory and then further purified to refined white sugar in a sugar refinery. However, beet sugar does not require a two-stage process to achieve white sugar in a beet sugar factory. By studying the basic differences in the nature of colorants and various composition of sugar streams from both sugar cane and sugar beet, the SAT process is developed successfully to produce white sugar using clarified juice from sugar mills with color ranging from 80 to 150 ICUMSA. In this paper, the SAT process itself and its benefit to sugar mills will be presented.

The Biorefinery Concept

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In response to the present energy problems, global warming and the lack of a national energy policy, US Government agencies as USDA, EPA, DOE and others are presently preparing a strategic plan entitled: "Fostering The Biology Revolution...In Biobased Products and Biobased Energy". The national goal is to triple the U.S. use of biobased products and bioenergy by 2010. The biorefinery concept is based upon (cheap) sugars from which a diverse and flexible mix of energy, fuel, chemical and material products from biomass resources is produced; sugarcane should play a major role.

R&D to reduce the cost of the sugar cane crop has to be part of this effort. It already has been demonstrated that betaine can improve the sucrose yield in Louisiana. Most of the blackstrap molasses produced in Louisiana is leaving the state. With a large biorefinery we can produce from molasses and waste sugars (as an example): bioethanol, carbon dioxide, inositol, glycerine, itaconic acid and succinic acid. Other value-added or co-products such as lactic acid

and thetins could be recovered as well. An example of a biorefinery with a modern waste treatment system based upon incineration and heat recovery is presented. These biorefineries can have much higher Return On Investments then (raw) sugar factories.

Evaporator Scale-Minimization with Electro-Coagulation and Improved Cleaning with Chelates

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Electro-coagulation of clarified juice resulted in the removal of essentially all the silicon dioxide & silicates plus from 10 to 40% of calcium, magnesium and (inorganic) phosphate. This may reduce scaling by up to 50%. Preliminary work on mixed juice indicates that it is likely that electro-coagulation can be effective before clarification also.

The removal of scale is typically accomplished by boiling with an alkaline solution, a water wash and an acid solution. A new acid is being tested, which shows promise as a cleaning agent. However, in testing several BASF-chelate solutions we have identified two types of chelate solutions that show much improved cleaning over the standard method(s) and in a matter of two hours of boiling time. These chelates most likely can replace both the alkaline and acid boils, will be cost effective and save on downtime.

Evaporator Performance During Crop 2000-2001 at Cajun Sugar Factory

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During the crop 2000-2001 we tried at Cajun Sugar Cooperative a scale inhibitor. We could extend our grinding between the clean outs from 50,000 TC to 110,000 TC. We also used products in the cleaning solutions. To our caustic soda of 25 Be we added 5% of soda ash together with an activator and a dispersant. We observed that the juice heaters after the crop where cleaner then before we started the crop. In our acid boiling we used 1.5% HCl together with 3% ammonium bifloride % diluted muriatic acid. We also used a new inhibitor, which allows us to boil the acid for 1.5 hours. The total cleaning cycle was done in approximately 10 hours including a calandria test in 3 evaporators. The cleaning solutions we used helped us to obtain perfectly cleaned heating surfaces. In the original paper I will include more detailed facts and analysis from the scaling we could remove or not.

Mixed Juice Clarifier Distribution at Clewiston

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For the 2000/2001 crushing season, it was necessary to install a new mixed juice flash tank at the Clewiston milling facility. Along with the flash tank installation, a new mixed juice distribution system, feeding the clarifiers, was also commissioned. The distribution system is fully automatic and has several novel features that enhance the operation.

This paper discusses the installation and its benefits as well as limitations after one season of operation. Overall the project was very successful and will lead the way to a reduction in the high retention times currently being experienced in the mixed juice clarifiers. Plans for the future are also listed.

Goats, Mice, and Dextran, the Road to a Monoclonal Antibody Test Kit

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For several years we have been pursuing the development and commercialization of a rapid antibody-based kit for the quantitation of dextran in a diverse range of sugar streams. The report will detail the development process that finally resulted in the a rapid test for dextran.

Comparing the Effects of Sulphur Dioxide on Model Sucrose and Cane Juice Systems

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Sulphur dioxide (SO_2) has been used for centuries to minimize color in food processing and fruit and vegetable storage. In the sugar industry, sugar beet processors to reduce and prevent color formation in white refined sugar use it routinely. Sugarcane processors throughout the world use SO_2 to produce plantation white sugars. This study was undertaken to determine the effect of SO_2 on pure sucrose solutions in comparison to real factory sugarcane juice streams. Sugar systems included 15 brix pure sucrose, clarified juice and mixed juice from a Louisiana sugarcane mill. A pH of 8.0 was obtained by adding milk of lime then lowered to

approximately pH 5.0 with either SO_2 or HCl as the control. Several samples ranging from pH 5 to 8 were processed at 0-120 min at 85^0 C. Analyses included pH, SO_2, color, calcium, and invert (as a measure of sucrose loss). Results indicated that the model system was much more sensitive to small levels of SO_2 than real juice samples. The pH levels dropped rapidly and invert levels increased with time. There was 1.6 % loss of sucrose in the SO_2 trial as compared with no sucrose loss with HCl. Clarified juice resisted changes in pH with both SO_2 and HCl. Sucrose loss at 120 min of processing and a pH of 5.0 was only 0.88 %. There was a maximum color reduction of 10-15 % in the SO_2 trial, whereas no color reduction or sucrose loss was observed in the HCl trial. The mixed juice was very resistant to pH changes, and a minimum pH of 6.0 was achieved with 4800 ppm SO_2. No sucrose loss was observed in either trial with mixed juice, and color reduction was the same in both the SO_2 and HCl trials. In real juice streams, SO_2 reduced color by 10-15 % more than clarification alone but also induced some sucrose loss (0.88%) after a lengthy time.

Advances in Technology of Boiler Treatment in Louisiana Sugarcane Mills

Brent Weber, Brian Cochran, and Brian Kitchen
ONDEO Nalco

During the 2000 crop, two new technologies were introduced to improve boiler water treatment and control at a number of Louisiana sugar cane mills. This paper discusses these technologies, their application and overall improvements documented at these mills. Also reviewed are possible opportunities to utilize these technologies to improve overall mill operations and efficiencies in the future.

The basis of these technologies is the adaptation of fluorescing bodies, detected via a fluorometer, and read as distinct wavelengths of light. These identifiable wavelengths of light are the core of our ability to control chemical feed and perform diagnostic control studies, which can dramatically improve the performance and reliability of mill steam generating equipment.

Technology #1 is the introduction of a new internal treatment program for steam generating equipment. It is the first new product for this purpose introduced by the industry in over 15 years. It incorporates the fluorescing technology described previously and has been successfully utilized by several Louisiana mills during the 2000 grind.

Technology #2 builds upon our knowledge of fluorescence by identifying the presence of sugar in return bodies such as pan and evaporative condensate. This is made possible by the detection of fluorescing bodies associated with the sucrose molecule. This technology was successfully evaluated during the 2000 grind at mills in both Florida and Louisiana for boiler, cooling water and once through waters.

Journal American Society of Sugarcane Technologists, Vol. 22, 2002

Heat Transfer Devices

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Alfa Laval Inc.
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Richmond, Virginia

In the past 2 decades, great advances have been made in the use of lower cost and more efficient heat transfer devices. In the presentation, we will look at how the sugarcane industry in the USA can best take advantage of this technology. We will examine the origins of the plate heat exchanger and the latest developments up to the present day where we have plate evaporators playing an ever-larger role in sugar processing. We will cover the 4 major areas in which plates can be beneficial, namely raw juice heaters, clarified juice heaters, evaporators, and molasses coolers.

Special attention will be paid to the installation and operation of plates with regard to the sugarcane process and its particular fouling issues. We will discuss key design points that should be taken into account before a plate heater or evaporator is installed and the importance of venting non condensable gases and maintaining minimum flows. All of these factors need to be taken into account by the plant engineer or designer when he/she is looking to use plate heat exchanger technology.

IN MEMORIAM

In Memoriam
ENRIQUE R. ARIAS
September 13, 1918 - January 1, 2002

The sugar industry was deeply saddened by the loss of Enrique R. Arias on January 1, 2002.

Mr. Arias was the Executive Vice President of the Sugar Cane Growers Cooperative of Florida before his retirement in June 1994.

Born in Havana, Cuba in 1918, his expertise in the sugar business goes back to his roots. Following in his father's footsteps, Mr. Arias attended the University of Notre Dame where he earned a Bachelor of Science degree in 1940 and later returned to Cuba where he studied sugar chemistry and sugar engineering at the University of Havana. His first work in the sugar industry was with the Arechabala group which owned and operated a sugar based industrial complex and two sugar mills in the Province of Matanzas, Cuba.

In 1957, he founded the Industrial Service and Construction Company and led the field in the conversion of raw sugar handling from bags to bulk.

Mr. Arias moved his family to the United States in October 1960. In 1961 he joined Farrel Birmingham Company of Ansonia, Connecticut and was moved to Florida to become the Resident Manager for the construction of Glades Sugar House owned by the Sugar Cane Growers Cooperative of Florida.

Upon completion of the project he joined the National Sugar Refining Company as Director of Project Engineering and successively held the positions of Director of Planning, Vice President Planning and Vice President Operations.

In 1970, Mr. Arias joined the staff of Sugar Cane Growers Cooperative of Florida as Vice President Planning and later became Executive Vice President. He managed the feasibility studies, engineering and construction functions to increase the capacity of Glades Sugar House in several steps from 10,000 tons per day to 13,000, 18,000 and 21,000 tons per day.

At the Port of Palm Beach, Mr. Arias directed the design, construction and operation of the bulk sugar shipment facilities of the Florida Sugar Marketing and Terminal Association and the expansion of the molasses shipping facilities of the Florida Molasses Exchange.

He was active in many professional and sugar-related organizations including chairing the Florida Sugar Cane League's Environmental Quality Technical Sub-Committee and the technical committee of the Florida Sugar Marketing & Terminal Association. He was past-president of the

Cuban Association of Sugar Technologists and of the Florida Division of the American Society of Sugar Cane Technologists and past chairman of the Finance Committee of the Sugar Industry Technologists (SIT) and of the Industrial Development Research Council, Inc. He was a member of the Board of Directors and sat on the Executive and Nominating Committees for the Sugar Association Inc. and was a member of the Cuban Association of Agronomical and Sugar Engineers, the International Society of Sugar Cane Technologists, and the U.S. National Committee of the International Commission for the Uniform Methods of Sugar Analysis. He was also the past-president of Sugar Processing Research Institute Inc. (SPRI).

Mr. Arias received the Sugar Industry Technologists' Crystal Award for achievements in sugar technology in 1991. He was awarded an honorary lifetime membership of the American Society of Sugar Cane Technologists in 1988.

The members of the American Society of Sugar Cane Technologists will long remember Mr. Arias with admiration for his contributions to the sugar industry.

In Memoriam
S.J.P. CHILTON
February 3, 1909-April 2, 2001

Dr. St. John Poindexter Chilton passed away on April 2, 2001 in Rapides Regional Medical Center in Alexandria, Louisiana. Probably very few of today's growers and processors in the Louisiana industry remember Dr. Chilton, although there are a few of us who remember him quite well. Dr. Chilton was 92 when he passed away and is survived by his wife, Alice Hunter Chilton of Bayou Rapides. The official notice of his death states that he was retired as a plant pathology professor and department head at Louisiana State University in Baton Rouge. He was also a former consultant for the Nicaragua Sugar Estates, director of LaPlace Enterprises, president of the local chapter of SAR, past president of the Louisiana Historical and Genealogical Society, president of the Historical Association of Central Louisiana, a Rotarian and was listed in Who's Who in the World.

From a personal recollection, Dr. Chilton was bigger than all those things. He was most instrumental in establishing the sugarcane crossing and selection program at LSU. During the 1950s, 60s and early 70s, he and Elias Paliatseas were the individuals who led the crossing and selection program at LSU. Preston Dunckelman was also part of that team in the early years. It was demonstrated that sugarcane could be forced to flower in Louisiana using a photoperiod regime and that viable seed could be produced from these crosses. This work was done in the early 1950s. The Grand Isle crossing facility was established, although it was used for flowering and crossing for only a couple of years and seed were planted in Baton Rouge for selection. The "L" selection program was established and high sugar content was a major objective in their selection effort. In fact, L60-25 was the first variety to come from that initiative and set a new high water mark in terms of sugar content in the industry. The variety lasted only a few years because of mosaic and RSD susceptibility, but definitely brought this industry into the era of high sugar varieties.

Dr. Chilton, while known for his determination, aggressiveness and dedication toward the sugar industry, was also sometimes regarded as a "tough individual" and someone who could be quite combative. Those who crossed him soon learned how powerful he could be. He served on many a graduate student's committee, and from a personal standpoint, lived up to his reputation as "tough and spirited". He often kept the "fire lit" under people making sure they were always moving and he was always eager to share his sugarcane breeding philosophies with those interested in listening. He will always be remembered for his dedication, determination and the direction he brought to the LSU selection program. He will be sadly missed by his relatives and friends throughout the international sugar community.

In Memoriam
Jack L. Dean
March 15, 1925-August 4, 2001

Dr. Jack L. Dean, a retired USDA-ARS research plant pathologist, died on August 4, 2001. Dr. Dean was born in Keota, Oklahoma on March 15, 1925. He served in the U. S. Navy during World War II and after the war, he obtained his BS in botany in 1949 and his MS degree in plant pathology in 1951 from Oklahoma State University. From 1951 to 1966, he was a USDA-ARS plant pathologist and then a research plant pathologist at Meridian, Mississippi. During this time he completed his PhD in plant pathology at Louisiana State University. In 1966, Dr. Dean moved to the Sugarcane Field Station at Canal Point, Florida where he served as a Research Sugarcane Pathologist until he retired for the first time in 1987. Dr. Dean then became one of the oldest if not the most experienced of research associates at the University of Florida working with Dr. Mike Davis until he retired again in 1993. During his career he authored and/or co-authored 100 research papers. He developed inoculation techniques for sugarcane mosaic and leaf scald to select resistant cultivars that are still used at Canal Point. During the 1970's and 1980's he addressed the threat of sugarcane rust and smut that were introduced on the US mainland. Dr. Dean understood the theoretical bases of statistics and stressed their practical impact on the selection of CP cultivars. During the last phase of Dr. Dean's career he helped determine the importance of ratoon stunting disease in Florida and helped develop techniques to screen for resistance. Dr. Dean was an Honorary member of the Joint Division of the American Society of Sugar Cane Technologists.

Jack Dean was born to be a scientist. He may never have come across a biological problem that did not intrigue him. This quality, combined with his experience and knowledge, made him both a mentor and a youthful inspiration to his fellow scientists in his final years at Canal Point. Many will remember Dr. Dean's contributions to sugarcane pathology. Those of us who knew him personally will also remember him for his humor and his intense thought which at times could override the more trivial aspects on a person's mind. Jack probably entered more than one colleague's office forgetting why he was there. This was not a fault, it was how he was when he was thinking about research. For those fortunate enough to know him, we consider ourselves lucky. He was a good man.

AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS
EDITORIAL POLICY

Nature of papers to be published:

Papers submitted must represent a significant technological or scientific contribution. Papers will be limited to the production and processing of sugarcane, or to subjects logically related. Authors may submit papers that represent a review, a new approach to field or factory problems, or new knowledge gained through experimentation. Papers promoting machinery or commercial products will not be acceptable.

Frequency of publication:

The Journal will appear at least once a year. At the direction of the Joint Executive Committee, the Journal may appear more frequently. Contributed papers not presented at a meeting may be reviewed, edited, and published if the editorial criteria are met.

Editorial Committee:

The Editorial Committee shall be composed of the Managing Editor, Technical Editor for the Agricultural Section, and Technical Editor for the Manufacturing Section. The Editorial Committee shall regulate the Journal content and assure its quality. It is charged with the authority necessary to achieve these goals. The Editorial Committee shall determine broad policy. Each editor will serve for three years; and may at the Joint Executive Committee's discretion, serve beyond the expiration of his or her term.

Handling of manuscripts:

Four copies of each manuscript are initially submitted to the Managing Editor. Manuscripts received by the Managing Editor will be assigned a registration number determined serially by the date of receipt. The Managing Editor writes to the one who submitted the paper to inform the author of the receipt of the paper and the registration number which must be used in all correspondence regarding it.

The Technical Editors obtain at least two reviews for each paper from qualified persons. The identities of reviewers must not be revealed to each other nor to the author during the review process. Instructions sent with the papers emphasize the necessity for promptness as well as thoroughness in making the review. Page charges will be assessed for the entire manuscript for non-members. Members will be assessed for those pages in excess of ten (10) double spaced Times New Roman (TT) 12 pt typed pages of 8 1/2" x 11" dimension with one (1) inch margins.

When a paper is returned by reviewers, the Technical Editor evaluates the paper and the recommendations of the reviewers. If major revisions are recommended, the Technical Editor sends the paper to the author for this purpose, along with anonymous copies of reviewers' recommendations. When the paper is returned to the Technical Editor, he/she will judge the adequacy of the revision and may send the paper back to any reviewer for further review. When the

paper has been revised satisfactorily, it is sent to the Managing Editor for publishing. A paper sent to its author for revision and held more than 6 months will be given a new date of receipt when returned. This date will determine the priority of publication of the paper.

A paper rejected by one reviewer may be sent to additional reviewers until two reviewers either accept or reject the paper. If a paper is judged by two or more reviewers as not acceptable for the Journal, the Technical Editor returns it to the author along with a summary of the reasons given by the reviewers for the rejection. The registration form for the paper is filled out and returned to the Managing Editor along with copies of the reviewers' statements and a copy of the Technical Editor's transmittal letter to the author. The names of all reviewers must be shown on the registration form transmitted to the Managing Editor.

If the paper as received is recommended by two reviewers for publication in the Journal, it is read by the Technical Editor to correct typographical, grammatical, and style errors and to improve the writing where this seems possible and appropriate, with special care not to change the meaning. The paper is then sent by the Technical Editor to the Managing Editor who notifies the authors of the acceptance of the paper and of the probable dates of publication. At this time, the Managing Editor will request a final version in hardcopy and on diskette in WordPerfect format from the corresponding author.

Preparation of papers for publication:

Papers sent by the Technical Editor to the Managing Editor are prepared for printing according to their dates of original submittal and final approval and according to the space available in the next issue of the Journal.

The paper is printed in the proper form for reproduction, and proofs are sent to the authors for final review. When the proofs are returned, all necessary corrections are made prior to reproduction. The author will be notified at the appropriate time to order reprints at cost.

Any drawings and photographs for the figures in the paper are "scaled" according to their dimensions, the size of lettering, and other factors. They are then sent to the printer for camera work. Proofs of the illustrations are sent to the authors. Any changes requested at this stage would be expensive and authors will be expected to pay the cost of such changes.

Reprinting in trade journals has the approval of the Editorial Committee provided: a) no article is reprinted before being accepted by the Journal; b) credit is given all authors, the author's institutions, and the ASSCT; and c) permission of all authors has been obtained. Summaries, condensations, or portions may be printed in advance of Journal publication provided the approval of the Editorial Committee has been obtained.

RULES FOR PREPARING PAPERS TO BE PRINTED IN THE JOURNAL OF THE AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS

Format

Unless the nature of the manuscript prevents, it should include the following sections in the order listed: ABSTRACT, INTRODUCTION, MATERIALS and METHODS, RESULTS, DISCUSSION (OR RESULTS AND DISCUSSION), CONCLUSIONS, ACKNOWLEDGMENTS, and REFERENCES. Not all the sections listed above will be included in each paper, but each section should have an appropriate heading that is centered on the page with all letters capitalized. Scientific names shall be italicized.

All material (including tables and figures) shall be submitted on 8½ X 11 inch paper with one inch margins on all sides. If using WordPerfect, set the bottom margin at 0.5 inches. This will set the page number at 0.5 inches and the final line of text at 1 inch from the bottom margin. Exactness in reproduction can be insured if electronic copies of the final versions of manuscripts are submitted. Authors are encouraged to contact the managing editor for specifics regarding software and formatting software to achieve ease of electronic transfer.

Authorship

Name of the authors, institution or organization with which they are associated, and their locations should follow the title of the paper.

Abstract

The abstract should be placed at the beginning of the manuscript, immediately following the author's name, organization and location. The abstract should be limited to a single self-contained paragraph of about 250 words. State your rationale, objectives, methods, results, and their meaning or scope of application. Be specific. Identify the crops or organisms involved, as well as soil type, chemicals, or other details that figure in interpretation of the results. Do not cite tables, figures, or references. Avoid equations unless they are the focus of the paper.

Tables

Number the tables consecutively and refer to them in the text as Table 1, Table 2, etc. Each table must have a heading or caption. Capitalize only the initial word and proper names in table headings. Headings and text of tables should be single spaced. Use TAB function rather than SPACE BAR to separate columns of a table.

Figures

Number the figures consecutively and refer to them in the text as Figure 1, Figure 2, etc. Each figure must have a legend. Figures must be of sufficient quality to reproduce legibly.

Drawings & Photographs

Drawings and photographs must be provided separately from the text of the manuscript and identified on the back of each. Type figure numbers and legends on separate pieces of paper with proper identification. Drawings and photographs should be of sufficient quality that they will reproduce legibly.

Reference Citations

The heading for the literature cited should be REFERENCES. References should be arranged such that the literature cited will be numbered consecutively and placed in alphabetical order according to the surname of the senior author. In the text, references to literature cited should be made by name of author(s) and year of publication from list of references. Do not use capital letters in the titles of such articles except in initial words and proper names, but capitalize words in the titles of the periodicals or books.

Format Example

ITCHGRASS *(ROTTBOELLIA COCHINCHINENSIS) CONTROL* IN SUGARCANE WITH POSTEMERGENCE HERBICIDES

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and

Edward P. Richard, Jr.
Sugarcane Research Unit, USDA-ARS, Houma, LA 70361

ABSTRACT

INTRODUCTION

MATERIALS AND METHODS

RESULTS AND DISCUSSION

Table 1. Visual itchgrass control and sugarcane injury as influenced by over-the-top herbicide application at Maringouin and Thibodaux, LA, 1989.

CONCLUSIONS

ACKNOWLEDGMENTS

REFERENCES

GUIDELINES FOR PREPARING PAPERS FOR JOURNAL OF ASSCT

The following guidelines for WordPerfect software are intended to facilitate the production of this journal. Authors are strongly encouraged to prepare their final manuscripts with WordPerfect 6.0 or a later version for Windows. Please contact the Managing Editor if you will not use one of those software packages.

Paper & Margins: All material (including tables and figures) shall be submitted on 8½ X 11 inch paper with one inch margins on all sides. To achieve this with WordPerfect, set the top, left, and right margins at one inch. However, set the bottom margin at 0.5 inches. This will place the page number at 0.5 inches and the final line of text at one inch.

Fonts: Submit your document in the Times New Roman (TT) 12pt font. If you do not have this font, contact the Managing Editor.

Alignment: Choose the full alignment option to prepare your manuscript. The use of SPACE BAR for alignment is not acceptable. As a general rule SPACE BAR should only be used for space between words and limited other uses. Do not use space bar to indent paragraphs, align and indent columns, or create tables.

Do not use hard returns at the end of sentences within a paragraph. Hard returns are to be used when ending paragraphs or producing a short line.

Place tables and figures within the text where you wish them to appear. Otherwise, all tables and figures will appear after your References section.

Styles: ***Italicize*** scientific names. Do not use underline.

Tables: Use Tab stops and the **Graphics** line draw option when constructing tables. Avoid the space bar to separate columns (see alignment). All lines should begin with the left most symbol in their left most column and should end with the right most symbol in their right most column.

Citations: When producing Literature Citations, use the indent feature to produce text as below.

1. Smith, I. M., H. P. Jones, C. W. Doe, 1991. The use of multidiscipline approaches to control rodent populations in plants. Journal of American Society of Plant Management. 10:383-394.

CONSTITUTION OF THE AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS

As Revised and Approved on June 21, 1991
As Amended on June 23, 1994
As Amended on June 15, 1995

ARTICLE I

Name, Object and Domicile

Section 1. The name of this Society shall be the American Society of Sugar Cane Technolo-gists.

Section 2. The object of this society shall be the general study of the sugar industry in all its various branches and the dissemination of information to the members of the organization through meetings and publications.

Section 3. The domicile of the Society shall be at the office of the General Secretary-Treasurer (as described in Article IV, Section 1).

ARTICLE II

Divisions

The Society shall be composed of two divisions, the Louisiana Division and the Florida Division. Each division shall have its separate membership roster and separate officers and committees. Voting rights of active and honorary members shall be restricted to their respective divisions, except at the general annual and special meetings of the entire Society, hereinafter provided for, at which general meetings active and honorary members of both divisions shall have the right to vote. Officers and committee members shall be members of and serve the respective divisions from which elected or selected, except the General Secretary-Treasurer who shall serve the entire Society.

ARTICLE III

Membership and Dues

Section 1. There shall be five classes of members: Active, Associate, Honorary, Off-shore or Foreign, and Supporting.

Section 2. Active members shall be individuals residing in the continental United States actually engaged in the production of sugar cane or the manufacture of cane sugar, or research or education pertaining to the industry, including employees of any corporation, firm or other organization which is so engaged.

Section 3. Associate members shall be individuals not actively engaged in the production of sugar cane or the manufacture of cane sugar or research pertaining to the industry, but who may be interested in the objects of the Society.

Section 4. Honorary membership shall be conferred on any individual who has distinguished himself or herself in the sugar industry, and has been elected by a majority vote of the Joint Executive Committee. Honorary membership shall be exempt from dues and entitled to all the privileges of active membership. Each Division may have up to 15 living Honorary Members. In addition, there may be up to 5 living Honorary members assigned to the two Divisions jointly.

Section 5. Off-shore or foreign members shall be individuals not residing in the continental United States who may be interested in the objects of the Society.

Section 6. Supporting members shall be persons engaged in the manufacturing, production or distribution of equipment or supplies used in conjunction with production of sugar cane or cane sugar, or any corporation, firm or other organization engaged in the production of sugar cane or the manufacture of cane sugar, who may be interested in the objects of the Society.

Section 7. Applicants for new membership shall make written application to the Secretary-Treasurer of the respective divisions, endorsed by two members of the division, and such applications shall be acted upon by the division membership committee.

Section 8. Minimum charge for annual dues shall be as follows:

Active Membership	$10.00
Associate Membership	$25.00
Honorary Membership	NONE
Off-shore or Foreign Membership	$20.00
Supporting Membership	$50.00

Each Division can assess charges for dues more than the above schedule as determined by the Division officers or by the membership at the discretion of the officers of each Division.

Dues for each calendar year shall be paid not later than 3 months prior to the annual meeting of the member's division. New members shall pay the full amount of dues, irrespective of when they join. Any changes in dues will become effective in the subsequent calendar year.

Section 9. Dues shall be collected by each of the Division's Secretary-Treasurer from the members in their respective divisions. Unless and until changed by action of the Joint Executive Committee, 50 percent of the minimum charge for annual dues, as described in Section 8 for each membership class, shall be transmitted to the office of the General Secretary-Treasurer.

Section 10. Members in arrears for dues for more than a year will be dropped from membership after thirty days notice to this effect from the Secretary-Treasurer. Members thus dropped may be reinstated only after payment of back dues and assessments.

Section 11. Only active members of the Society whose dues are not in arrears and honorary members shall have the privilege of voting and holding office. Only members (all classes) shall have the privilege of speaking at meetings of the Society.

ARTICLE IV

General Secretary-Treasurer and Joint Executive Committee

Section 1. The General Secretary-Treasurer shall serve as Chief Administrative Officer of the Society and shall coordinate the activities of the divisions and the sections. He or she will serve as ex-officio Chairperson of the Joint Executive Committee and as General Chairperson of the General Society Meetings, and shall have such other duties as may be delegated to him or her by the Joint Executive Committee. The office of the General Secretary-Treasurer shall be the domicile of the Society.

Section 2. The Joint Executive Committee shall be composed of the elected members of the two division Executive Committees, and is vested with full authority to conduct the business and affairs of the Society.

ARTICLE V

Division Officers and Executive Committee

Section 1. The officers of each division of the Society shall be: a President, a First Vice-President, a Second Vice-President, a Secretary-Treasurer or a Secretary and a Treasurer, and an Executive Committee composed of these officers and four other members, one from each section of the Division (as described in Section 3 of Article VII), one elected at large, and the President of the previous Executive Committee who shall serve as an Ex-Officio member of the Division Executive Committee. The office of the Secretary-Treasurer in this constitution indicates either the Secretary-Treasurer, or the Secretary and the Treasurer.

Section 2. These officers, except Secretary-Treasurer, shall be nominated by a nominating committee and voted upon before the annual division meeting. Notices of such nominations shall be mailed to each member at least one month before such meeting. Ballots not received before the annually specified date will not be counted.

Section 3. The Secretary-Treasurer shall be appointed by and serve as a non-voting member at the pleasure of the Division Executive Committee. The Secretary-Treasurer may not hold an elected office on the Executive Committee.

Section 4. The duties of these officers shall be such as usually pertain to such officers in similar societies.

Section 5. Each section as described in Article VII shall be represented in the offices of the President and Vice-President.

Section 6. The President, First Vice-President, and Second Vice-President of each Division shall not hold the same office for two consecutive years. Either Section Chairperson (as described in Section 3 of Article VII) may hold the same office for up to two consecutive years. The terms of the other officers shall be unlimited.

Section 7. The President shall be elected each year alternately from the two sections hereinafter provided for. In any given year, the Presidents of the two Divisions shall be nominated and elected from different sections. The President from the Louisiana Division for the year beginning February, 1970, shall be nominated and elected from the Agricultural Section. The president from the Florida Division for the year beginning February,

1970, shall be nominated and elected from the Manufacturing Section.

Section 8. Vacancies occurring between meetings shall be filled by the Division Executive Committee.

Section 9. The terms "year" and "consecutive year" as used in Articles V and VI shall be considered to be comprised of the elapsed time between one annual division meeting of the Society and the following annual division meeting of the Society.

ARTICLE VI

Division Committees

Section 1. The President of each division shall appoint a committee of three to serve as a Membership Committee. It will be the duty of this committee to pass upon applications for membership in the division and report to the Secretary-Treasurer.

Section 2. The President of each division shall appoint each year a committee of three to serve as a Nominating Committee. It will be the duty of the Secretary-Treasurer of the Division to notify all active and honorary members of the Division as to the personnel of this committee. It will be the duty of this committee to receive nominations and to prepare a list of nominees and mail this to each member of the Division at least a month before the annual meeting.

ARTICLE VII

Sections

Section 1. There shall be two sections of each Division, to be designated as:

1. Agricultural
2. Manufacturing

Section 2. Each active member shall designate whether he or she desires to be enrolled in the Agricultural Section or the Manufacturing Section.

Section 3. There shall be a Chairperson for each section of each Division who will be the member from that Section elected to the Executive Committee. It will be the duty of the Chairperson of a section to arrange the program for the annual Division meeting.

Section 4. The Executive Committee of each Division is empowered to elect one of their own number or to appoint another person to handle the details of printing, proof reading, etc., in connection with these programs and to authorize the Secretary-Treasurer to make whatever payments may be necessary for same.

ARTICLE VIII

Meetings

Section 1. The annual General Meeting of the members of the Society shall be held in June each year on a date and at a place to be determined, from time to time, by the Joint Executive Committee. At all meetings of the two Divisions of the Society, five percent of the active members shall constitute a quorum. The program for the annual meeting

of the Society shall be arranged by the General Secretary-Treasurer in collaboration with the Joint Executive Committee.

Section 2. The annual meeting of the Louisiana Division shall be held in February of each year, at such time as the Executive Committee of the Division shall decide. The annual meeting of the Florida Division shall be held in September or October of each year, at such time as the Executive Committee of that Division shall decide. Special meetings of a Division may be called by the Executive Committee of such Division.

Section 3. Special meetings of a Section for the discussion of matters of particular interest to that Section may be called by the President upon request from the respective Chairperson of a Section.

Section 4. At Division meetings, 10 percent of the active division members and the President or a Vice-President shall constitute a quorum.

ARTICLE IX

Management

Section 1. The conduct and management of the affairs of the Society and of the Divisions including the direction of work of its special committees, shall be in the hands of the Joint Executive Committee and Division Executive Committees, respectively.

Section 2. The Joint Executive Committee shall represent this Society in conferences with the American Sugar Cane League, the Florida Sugar Cane League, or any other association, and may make any rules or conduct any business not in conflict with this Constitution.

Section 3. Four members of the Division Executive Committee shall constitute a quorum. The President, or in his or her absence one of the Vice-Presidents, shall chair this committee.

Section 4. Two members of each Division Executive Committee shall constitute a quorum of all members of the Joint Executive Committee. Each member of the Joint Executive Committee, except the General Secretary-Treasurer, shall be entitled to one vote on all matters voted upon by the Joint Executive Committee. In case of a tie vote, the General Secretary-Treasurer shall cast the deciding vote.

ARTICLE X

Publications

Section 1. The name of the official journal of the Society shall be the "Journal of the American Society of Sugar Cane Technologists." This Journal shall be published at least once per calendar year. All articles, whether volunteered or invited, shall be subject to review as described in Section 4 of Article X.

Section 2. The Managing Editor of the Journal of the American Society of Sugar Cane Technologists shall be a member of either the Florida or Louisiana Divisions; however, he or she shall not be a member of both Divisions. The Division affiliation of Managing Editors shall alternate between the Divisions from term to term with the normal term being three years, unless the Division responsible for nominating the new Managing Editor reports that it has no suitable candidate. The Managing Editor shall

be appointed by the Joint Executive Committee no later than 6 months prior to the beginning of his or her term. A term will coincide with the date of the annual Joint Meeting of the Society. No one shall serve two consecutive terms unless there is no suitable candidate from either Division willing to replace the current Managing Editor. If the Managing Editor serves less than one year of his or her three-year term, another candidate is nominated by the same Division, approved by the other Division, and appointed by the General Secretary-Treasurer to a full three-year term. If the appointed Managing Editor serves more than one year but less than the full three-year term, the Technical Editor from the same Division will fill the unexpired term of the departed Managing Editor. In the event that the Technical Editor declines the nomination, the General Secretary-Treasurer will appoint a Managing Editor from the same Division to serve the unexpired term.

Section 3. The "Journal of the American Society of Sugar Cane Technologists" shall have two Technical Editors, which are an Agricultural Editor and a Manufacturing Editor. The Managing Editor shall appoint the Technical Editors for terms not to exceed his or her term of office. Any Technical Editor shall be a member of either the Louisiana or Florida Division. Each Division will be represented by one technical editor at all times unless the Executive Committee of one Division and the Managing Editor agree that there is no suitable candidate willing to serve from that Division.

Section 4. Any member or nonmember wishing to contribute to the Journal of the American Society of Sugar Cane Technologists shall submit his or her manuscript to the Managing Editor. The Managing Editor shall then assign the manuscript to the appropriate Technical Editor. The Technical Editor shall solicit peer reviews until, in the opinion of the Technical Editor, two responsible reviews have been obtained that either accept (with or without major or minor revision) or reject the manuscript. For articles accepted with major revision, it shall be the responsibility of the Technical Editor to decide if the authors have satisfactorily completed the major revision(s). The Technical Editor may solicit the opinion of the reviewers when making this decision. The Technical Editors shall not divulge the identity of any reviewer. The Managing Editor shall serve as Technical Editor of any manuscript which includes a Technical Editor as an author.

ARTICLE XI

Amendments

Section 1. Amendments to this Constitution may be made only at the annual meeting of the Society or at a special meeting of the Society. Written notices of such proposed amendments, accompanied by the signature of at least twenty (20) active or honorary members must be given to the General Secretary-Treasurer at least thirty (30) days before the date of the meeting, and he or she must notify each member of the proposed amendment before the date of the meeting.

ARTICLE XII

Dissolution

Section 1. All members must receive notification from the General Secretary-Treasurer of any meeting called for the purpose of terminating the Society at least thirty (30) days prior to the date of the meeting. After all members have been properly notified, this organization may be terminated at any time, at any regular or special meeting called for

that purpose, by an affirmative vote of two-thirds of the total honorary and active members in good standing present at the meeting. Thereupon, the organization shall be dissolved by such legal proceedings as are provided by law. Upon dissolution of the Joint Society, its assets will be divided equally between the two Divisions of the Society. Dissolution of the Joint Society will not be cause for automatic dissolution of either Division. Upon dissolution of either Division, its assets will be divided in accordance with the wishes of its members and in conformity with existing IRS regulations and other laws applicable at the time of dissolution.

ARTICLE XIII

Assets

Section 1. No member shall have any vested right, interest or privilege of, in, or to the assets, functions, affairs or franchises of the organization; nor any right, interest or privilege which may be transferable or inheritable.

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JOURNAL

American Society of Sugar Cane Technologists

Volume 23
Florida and Louisiana Divisions
June, 2003

ASSCT

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PRESIDENT'S MESSSAGE
LOUISIANA DIVISION

Chris Mattingly
Lula-Westfield, LLC
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On behalf of the membership of the Louisiana Division of the American Society of Sugar Cane Technologists, I would like to thank the Florida Division for hosting this year's annual joint meeting at Amelia Island Plantation. I look forward to this thirty-second annual meeting being as educational and enjoyable as the previous meetings have been.

Let me begin by reviewing the 2000 crop and harvest report. The crop began with tremendous promise and the second largest acreage planted to cane in the state's history. With 491,109 acres in cane and a mild winter and spring, growers and mills were excited as well as a little nervous about the potential for a record crop. Good weather during April and May allowed quality fieldwork to be done in a timely manner and at lay-by the crop looked encouraging. Then in early June, tropical storm Allison came through dumping twelve to thirty-six inches of rain on Louisiana. Although the sugarcane crop did not experience the devastation that some row crops did, the damage to the cane crop was still significant. Many fields had standing water on them for several days and in some cases for over a week. To compound the problem, cloudy overcast skies and above normal rainfall for the remainder of the month of June placed additional stress on the crop in many areas. By late summer, most growers and mills had lowered their estimates somewhat but remained hopeful that the crop could overcome this weather related damage. However, shortly after the harvest began our fears were confirmed and our optimism over what might have been turned into disappointment. The 2001 crop would not be the record crop that the Louisiana industry had hoped it would be. The 451,820 acres harvested for sugar were only slightly less than the record acreage harvested in 2000. A yield of just over 33.1 tons of cane per acre resulted in a crop of 14,977,000 tons of cane ground. Although this was only about 88.5% of the predicted yield, this stands as the third largest cane crop ever produced in Louisiana. With a yield of 207 pounds of sugar per ton, the crop produced the second largest yield of sugar ever with 1,580,000 short tons of raw value sugar. This crop also yielded 86,368,000 gallons of 79.5 degree brix molasses. It took 117 days to grind the Louisiana crop this past year. The first mills began on September 17, 2001, and the last mill to grind finished on January 11, 2002. The closing of the Evan Hall mill after the 2000 crop left only seventeen mills in the state to grind this crop. The concerns of grinding a potential record crop with one less mill were unwarranted as ideal weather during harvest, good mill performance at most mills, and lower than expected tonnage allowed grinding to be completed earlier than expected. Most of the mills in the Bayou Lafourche and Mississippi River areas finished grinding before the end of December with a few mills in the northern and western parts of the belt running into January.

All things considered, 2001 was a good year for the Louisiana sugar industry with many positive events taking place. The rebounding of the sugar price was one of the more significant changes of the past year. Although the increase was short-lived, the impact on last year's crop should be a little more than a one-cent per pound increase over the 2000 sugar price. Molasses prices were also up this year with an increase of about twenty cents per ton of cane. These price increases

represent a very positive economic impact on our industry. Dry weather during harvest allowed both growers and mills a chance to reduce costs and to maximize efficiency. One such example was that many mills were able to reduce or eliminate cane washing during good weather allowing more sugar recovery per ton of cane.

The Louisiana sugar industry has the opportunity to use a special harvest permit, which allows cane haulers up to 100,000 pound gross vehicle weight. This privilege means a substantial cost savings to the whole industry, and it is important that we maintain this ability in spite of opposition from other groups. In an effort to combat abuse of this privilege, the industry made the decision to self-regulate its cane hauling this past harvest. With the State Legislature passing an industry-sponsored concurrent resolution that mandates all sugar mill scales be locked out at 100,000 pounds, the incentive for overloading is removed since there is no payment for cane over the 100,000 pound level. Complaints have been greatly reduced about overloaded trucks spilling cane and tearing up the highways. A similar success has been achieved with the cane burning issue by implementing a voluntary smoke and ash management program for the 2000 crop. There are numerous environmental and public issues associated with cane burning; therefore the state and the sugar industry have implemented this program to assist growers in addressing these types of issues. The significant reduction in the number of smoke- and ash-related complaints this past year attest to the success of this program. In both of these cases the industry has been praised for taking positive steps to solve its own problems.

Another high point of the 2001 crop has been a record setting performance by a Louisiana mill grinding two million tons of cane in a single season. On January 8, the Enterprise mill of M.A. Patout & Son, Ltd. made Louisiana history by being the only mill in the state to ever grind two million tons of cane. Congratulations to M.A. Patout & Son, Ltd. along with all of the growers and employees of the Enterprise mill.

No agricultural industry or commodity can bank on being successful or profitable every year. There are just too many variables and no guarantees. A couple of things such as hard work, dedication, and the willingness and ability to do what it takes will certainly improve chances for success. The Louisiana sugar industry has always realized the value of this philosophy and embraced it. It is no secret that increased production and improved efficiency of our factories and our farms are the best way to combat rising costs and depressed sugar prices. Dedicated scientists doing research and developing the technologies to keep our industry competitive and progressive accomplish these objectives.

One of the most basic and important types of research work is the variety development program. This work is a cooperative effort by the USDA-ARS in Houma, the Sugar Research Station of the LSU Ag Center, and the American Sugar Cane League. Together they are responsible for the breeding, selection, and advancement of new varieties in Louisiana. The LSU Ag Center and USDA-ARS also provide valuable information to growers from research they conduct on all cultural practices from planting to harvest, crop protection, pest management, and economics. In addition, they team-up with the American Sugar Cane League and Audubon Sugar Institute to study cane quality issues affecting both growers and processors. Sugar mills in Louisiana look to Audubon Sugar Institute for new mill research along with help with processing problems and training of factory personnel. The American Sugar Cane League works with both growers and processors on

a wide variety of issues. The League handles most of the political issues and the lobbying efforts for the industry. Through its network of local, state, and national committees, the Farm Bureau often assists the sugar industry on commodity and political issues.

The information generated by the research and work of these groups is of vital importance to our industry. Various meetings, conferences, field days and our own society plays an integral part in disseminating this information. The American Society of Sugar Cane Technologists joint meeting as well as our respective division meetings provide excellent mediums for reporting results of research, new technologies, and product development.

With the invaluable assistance of these support groups and the continued hard work and dedication of the growers and processors, our industry demonstrates its willingness and ability to succeed. Because the future holds no guarantees, we are poised to face its challenges. Our most immediate challenge is to assure the industry of a favorable sugar provision in the upcoming Farm Bill. Much hard work has gone into this effort and at this time (May 1) things look favorable. The problems with Mexico over NAFTA are ongoing, but it appears that the problem with importation of stuffed molasses from Canada is heading towards a permanent resolution thanks to the work of Senator Breaux. The industry faces a constant battle to market sugar at a fair price. Will the growers and mills in Louisiana own a refinery in the future? Less mills grinding more cane means longer grindings. Our researchers are challenged to develop varieties that mature earlier and have better cold tolerance and post freeze deterioration. Can we develop a cane ripener that works quickly and has no adverse affect on subsequent stubble crops? Will an equitable cane payment formula be developed that rewards growers for delivering quality cane and rewards mills for recovering more sugar from this cane?

These and many other challenges will face our industry in the future, and we will be prepared to face them if we work together. No individual or group can do it alone. It has taken many people working together to make the Louisiana Sugar Industry the success that it is today, and it will take this continued cooperation to ensure our future.

PRESIDENT'S MESSAGE
FLORIDA DIVISION

John A. Fanjul
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This past crop for Florida, in spite of freezes on January 1 and 6, 2001, the drought during the spring growth period, followed by flooding in late summer, early fall, managed to be very good. Looking back five years, this year was the third largest crop and had the second best yield to date. I think that the 2001-02 crop year presented a real revolution in the mainland cane sugar industry, especially in Florida. As of November, 2001, more than 80%, if not all of the Florida industry can be said to have become "vertically integrated," with the purchase of the Domino Sugar Refineries by The American Sugar Refining Company, formed by the growers of the Sugar Cane Growers Cooperative, Florida Crystals Corporation, and Atlantic Sugar Association.

This venture brings together Okeelanta's refinery, R.S.I. Yonkers refinery, and Domino's Baltimore, New York, and New Orleans refineries, into one corporation, which together with U.S. Sugar's Clewiston refinery, means that for the first time in history, one can say that almost 50 percent of all the refined sugar made from sugar cane is truly "From the Field to the Table."

All of this presents and will present new challenges and opportunities for all of us. I think we will be more demanding of ourselves in every aspect of our industry, becoming a truly agri-industrial business. We are now responsible for our product way beyond our traditional boundaries; therefore, we have to be more conscientious of our bottom line, all the way up from agriculture research and development to quality control at the mill/sugar house, through our own refineries, to the ultimate consumer.

The motto of the ASSCT is: "Organized for the Advancement of the Mainland Cane Sugar Industry." Never before has this ever been so important. I believe that to survive in the near and long term, we must be aware that on an ascending scale in our vertically integrated industry, all of us are responsible for improving efficiencies, which will increase productivity with cost effectiveness through positive accountability, in order to achieve maximum profitability.

Today we are tied together into four major sections or divisions, each of which has their own subdivisions:
I. Agriculture: with it's research and development working on developing new cane varieties through traditional genetic development, and using transengenics and bio-technology, must maintain this ever important work that helps us increase our sugar per acre production, which in my opinion, is, at our level, the true "bottom line" goal. We need optimum soil fertility working hand in hand with cane varieties to maintain high yields through recycling mill muds and preventing erosion. Soil conservation is of the highest priority, especially in Florida. Agronomy together with best farming practices, within our own ecosystem is everyone's concern.

Farming and land preparation are of the utmost importance, and rotation guided by research

and development, hold the key to our economic future. Corn, rice and vegetables, all help farm profitability and soil conservation. Planting, cultivation, fertilization, and pest control are equally important to maintain productivity. Today with the advent of precision agriculture, farming can be very precise and cost effective, implementing all of the above, through G.P.S. cultivation and practices.

II. Harvesting, in most cases in Florida, is a function of the mills, but in some cases, and in most of Louisiana, I understand, is a function of farming. Harvesting and hauling have their own important contributions. Burning, while thought to be on it's way out, is a function of harvesting. Cane freshness is essential to provide good juice quality to the mill. We at FCC try to keep it under 13 hours, burn to scale. Advances in cane harvesting machines have improved billeted cane to a level of efficiency and cost that has surpassed all expectations. Infield hauling with the implementation of high dumps, can save money and time. We that use the transfer stations need to maintain efficient operations and quick turnarounds. Keeping good road conditions and proper trailer loading is especially important in feeding the mills.

III. Mill: It is very important that field harvesting and hauling be coordinated and maintain good communications during the crop. Good yard management, including weighing and storing is of the utmost importance. Time in the yards should be held to a minimum and we strive to keep the cane no more that six to eight hours and feed the mill at a uniform rate. A mill is only as good as its cane quality, it cannot produce more than what it receives from the field. Grinding and extraction are two functions very important in holding down crop costs and increase profitability. You all know how much one crop day costs, and how much in earnings, one point in extraction can mean. Another factor is bagasse quality. The better the bagasse, the less fossil fuel is needed and the better the sugar house works. Proper mill settings to equal the grinding rate is essential. Fabrication has four functions that have to work in perfect coordination: clarification, evaporation, sugar boiling/crystallization, and sugar production. High standards of sugar quality, high Pol and low humidity, gives us a higher return. Keeping a good safety factor will help guarantee sugar quality at the refinery, and final molasses exhaustion helps to increase sugar output. the better we do our job, the easier and more profitable the refining of sugar should be.
More and more pressure will be put upon us by the federal and state EPA's to keep us as environmentally friendly as possible. Up to now, it has been my experience that many environmental obligations have increased our efficiency.

IV. At the top end of our scale is refined sugar production sales and marketing, from which the money flows down again in most cases in Florida, right back to the farmer/agriculture.
Not only do we have to be efficient, we need to be "profitable" in each basic step of the scale by our own merits. In the case of the first three basic steps; milling, harvesting, and agriculture, we presently have to make this happen between 0.18/0.19.5 a pound of raw sugar, or between $360.00 – $390.00 FOB mill per ton of raw sugar. Sometimes we get lucky and it's more, but for the sake of present day economics, lets leave it at that. Within these parameters, all of our functions have to be paid for and provide for a healthy corporate profit.

These days, the refinery does not have that much of a spread, and depending on whether it is bulk, commercial, or retail, I believe it oscillates anywhere between 3 and 9 cents a pound of refined sugar over the raw C.I.F. sugar price. The bottom line is that we need to be ever conscious

of our goals in order to survive. The refining sector will, in all probability, demand a better quality of raw sugar from us and we have to get ready to do so on a consistent basis, in the near future.

There are many other outside pressures that come and will come to bear on us in the future; NAFTA, federal, state and local politics, as well as environmental issues. We as technologists must become more pro-active in our industry in all aspects, especially in increasing productivity and efficiency, which at the end of the day, is our obligation. Also in the political and public relations area, I believe that if any of us have good scientific data that can be useful to our public relations department, we should let them know it.

There are many misconceptions continuously expounded in the press against sugar, for example, the calorie count in a teaspoon of sugar is only 15, hardly an alarming number by any means. The press however, would like you to believe that sugar is one of the evils of life.

Another is that we are a huge industry when the reality is this: Let's say in Texas, Louisiana, and Florida, we produce 4,000,000 tons of raw cane sugar a year, at $390.00 a ton. That's $1,560,000,000.00 total sales in one year. To put that in perspective, this is equal to two weeks sales of Albertsons Supermarkets or four days of General Motors sales!

As you can see, in our country's economy, we are a very small fish in a huge pond, yet the perception is that we are exploiting the U.S. taxpayer. We aren't, and by the same token, we provide jobs and are responsible for over 40,000 families, pay taxes, and diligently cooperate with the state and federal agencies to protect our environment, feed our citizens and care for our nation.

The message I want to get across today, is that we need to work together within and without each sector of our industry, in order to increase our efficiency, productivity, and profitability so our children and our children's children can continue this wonderful agri-industry, with over 200 years of tradition in the United States.

This is our challenge; let's make it our opportunity!

PEER

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LABORATORY SCREENING OF INSECTICIDES FOR PREVENTING INJURY BY THE WIREWORM *MELANOTUS COMMUNIS* (COLEOPTERA: ELATERIDAE) TO GERMINATING SUGARCANE

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ABSTRACT

A laboratory bioassay was investigated for screening insecticides for preventing stand losses by the wireworm *Melanotus communis* (Gyllenhal) to germinating plant cane. For liquid materials, single-eye billets were dipped into different concentrations of a candidate insecticide and then planted in plastic containers of organic soil; wireworms were then introduced, airtight lids were placed onto the containers, and wireworm survival and damage were assessed 4 wk later. Tests with granular materials were similar except the containers were partially filled with untreated soil; 30 cc of soil treated with granular material were then added to the container; an untreated single-eye billet was placed onto this treated soil; an additional 30 cc of treated soil was then placed on and around the billet; and finally untreated soil was added to fill the container. Conditions inside the bioassay containers were suitable for germination and early growth of most cultivars. The airtight lids were advantageous from the standpoint of maintaining soil moisture.

Among six candidate insecticides studied, bifenthrin 2EC, thiamethoxam 25WG, thiamethoxam 2G, and tefluthrin 3G each reduced damage by wireworms to germinating eyes of seed cane planted in organic soils. Wireworms frequently survived in containers of seed-pieces treated with these materials yet did not damage eyes before germination, indicating the materials repelled wireworms. However, germinated shoots of billets treated with these materials were sometimes injured by the surviving wireworms.

INTRODUCTION

The wireworm *Melanotus communis* (Gyllenhal) (Coleoptera: Elateridae) is currently the single-most important insect pest of sugarcane in Florida based on economic damage potential, frequency of infestations, and money spent to prevent damage (Hall 2001). Preventing economic losses to *M. communis* using cultural tactics has historically been difficult particularly in a successive-plant situation, and biological control has offered little promise as a management tactic (Hall 2001). Two insecticides, ethoprop and phorate, are currently labeled and effective for reducing wireworm damage to newly-planted sugarcane. Additional insecticides for wireworm control in Florida sugarcane would be desirable, particularly since there is some concern that the sugarcane labels for ethoprop and phorate may eventually be cancelled.

To find new wireworm insecticides, candidate materials can be initially screened for efficacy under a laboratory setting and the most promising materials can later be field-tested.

Initial laboratory screenings of insecticides have traditionally involved topically applying technical grade materials directly to insects with subsequent assessments of mortality, the goal being to measure the relative toxicity of test compounds (e.g., Hall and Cherry 1985). Commercial pesticides available in liquid formulations can be substituted for technical grade materials in topical application assays on toxicity. A drawback to topical applications as an initial screening bioassay for wireworm pesticides is that such assays give no insight into how a material may perform in soil.

As an alternative to topical applications for initial screening of materials, wireworms can be introduced into soil treated with candidate materials (e.g., Cherry 2001). This treated-soil approach to screening materials gives insight into the relative toxicity of materials in soil. A disadvantage to both topical application and treated-soil assays is that they are biased toward finding toxic materials. Some materials might have little or no toxicity to wireworms but could still have value as a tool for wireworm control if they repel wireworms or stop wireworms from feeding. For example, Villani and Gould (1985) found that extracts from some plant species provided significant levels of feeding deterrency by *M. communis* in tests with treated potatoes. To simultaneously study both toxicity and repellency, single-eye sugarcane billets could be treated with candidate materials (liquids) and planted into containers of soil, wireworms would then be introduced into the containers, and the efficacy of the materials for killing wireworms or preventing damage would later be assessed. To screen granular materials, single-eye sugarcane billets could be planted in a small pocket of soil treated with a material within a container of untreated soil.

Presented here are the results of laboratory screenings on the efficacy of candidate materials for *M. communis* control in sugarcane using bioassays with single-eye billets planted in soil.

METHODS AND MATERIALS

The basic assay used to screen candidate materials for preventing wireworm injury to germinating cane was as follows. For bioassays involving liquid materials, single-eye billets were dipped into different parts-per-million (ppm) concentrations of a material in distilled water; allowed to air dry under a fume hood for aproximately 30 minutes; and then planted individually into 475 ml plastic containers (Fisherbrand #02-544-126, natural) partially filled with organic soil. Additional soil was then added to nearly fill each container; 2 – 3 ml of distilled water were pipetted onto the soil; and then an airtight lid was fitted onto each container. Bioassays with granular materials were similar except for the following. A bulk quantity (cc) of soil equal to 60 cc times the number of containers to receive a specific rate of material was calculated; the specific rate of material per container was multiplied by the number of containers to receive the rate, and the total amount of material needed for all of the containers was mixed into the bulk soil sample. Containers were then partially filled with untreated soil; 30cc of treated soil was placed into each container; a single-eye billet was placed onto this treated soil; 30cc of additional treated soil was placed on and around the billet; and then additional untreated soil was added to nearly fill each container. The specific per-container rate of a granular material was therefore applied in a total of 60 cc of treated soil per container. Test rates of granular materials were based on mg ai (active ingredient) per m^2 and were calculated based on the surface area of soil in

a container (9 cm diameter, 63.7 cm^2 surface area).

After setting up containers for a trial, three field-collected *M. communis* wireworms were introduced onto the soil surface of each container. The lidded containers were then placed either into an environmental chamber or onto a lab bench and checked every 1-2 days to determine when shoots emerged. When a shoot emerged, the contents of the container were emptied to assess wireworm survival and damage to the shoot. The bioassays were terminated after 4 wk, at which time each of the remaining containers was emptied to assess wireworm survival, damage to non-germinated buds and damage to germinated shoots. A wireworm was considered dead if it displayed no movement when prodded.

Most of the bioassays were conducted using sugarcane cultivar CL77-797, but other cultivars were utilized in some assays. Organic soil (55 to 80% organic matter, silica <5%, pH 7.5-7.9) obtained from sugarcane fields infested by wireworms was used in all trials. The soil was stored in sealed plastic bags in an air-conditioned lab until employed for the assays. By storing the fresh soil in sealed plastic bags, percentage moisture of the field-collected organic soil was maintained (50 to 55% by weight for the soil used in these trials). Prior to using the soil in an assay, it was forced through a 4.75 mm sieve to destroy clods and remove unwanted material. Wireworms used in the bioassays were collected from sugarcane fields during November-January and maintained in plastic boxes containing organic soil and pieces of carrots. Lids were placed onto these boxes, but the lidded boxes were not airtight. New carrots were placed into the boxes every 2-3 weeks and water was periodically added. The individual wireworms used in the assays were mid- to late-instar larvae generally weighing around 50 to 80 mg. *M. communis* wireworms in Florida sugarcane during December average 67.7 mg in weight (SEM 2.03, n=210) (Hall, unpublished). The bioassays were conducted at 20° to 24°C, as this range was representative of temperatures at planting during the fall in Florida.

Bioassays Without Insecticides

Two trials were conducted in which no wireworm control materials were tested. One of these was conducted during 2000 to evaluate germination of eight different sugarcane cultivars planted in the bioassay container (airtight lids, 55 day trial, no wireworms, 22°C, 9/12-11/6). Ten single-eye billets of each cultivar were studied, with 5 billets planted with the eye in an up position and 5 with the eye in a down position. The number of days from planting until emergence was recorded. At the end of the trial, all containers without emerged shoots were emptied and whether or not eyes had germinated was determined. Among plants which emerged, the average number of days from planting to emergence and percent emergence were determined for each cultivar. Also for each cultivar, the percentage of eyes which germinated was calculated. ANOVA was conducted to compare cultivars with respect to percent emergence and percent germination (percentages log-transformed); the ANOVA was based on two quasi replications, one for billets in an up position and one for billets in a down position, and mean comparisons were made using Duncan's multiple range test. In the second trial without insecticides, damage by wireworms newly-collected from a sugarcane field was compared to damage by wireworms which had been maintained in a laboratory for 50-54 wk (airtight lids, 61-620, billets planted with the eye in a side position, 30 replications per wireworm type, 4 wk test, 1 wireworm per container, 22°C).

Bioassays with Candidate Insecticides for Preventing Damage by Wireworms

Seven trials were conducted in which six candidate wireworm control materials were tested: bifenthrin 2 EC (Capture, 240 g ai/l, FMC), ethipriole 10EC (RPA 107382, 100 g ai/l, Aventis), tefluthrin 3G (Force, 3% ai, Zeneca), thiamethoxam 25WG (CGA293343, 25% ai, Syngenta), thiamethoxam 2G (CGA293343, 2% ai, Syngenta), and zeta-cypermethrin 0.8 EC (Fury, 96 g ai/l, FMC). Several of these compounds were screened simultaneously in some trials while other trials involved screening a single compound. The seven trials were conducted as follows.

Trial 1 – Billets dipped in bifenthrin (24,000 ppm) or ethiprole (48,000 ppm), February 2001, wireworms collected 2-4 wk before the trial, CL61-620, 22°C.

Trial 2 – Billets dipped in ethiprole (24,000 or 48,000 ppm) or bifenthrin (12,000 or 24,000 ppm), February 2001, wireworms collected 6-10 wk before the trial, CL61-620, 22°C.

Trial 3 – Billets dipped in bifenthrin (1,500, 3,000 or 6,000 ppm), ethiprole (1,500 or 12,000 ppm), or thiamethoxam 25WG (12,000 or 24,000 ppm), April 2001, wireworms collected 11-18 wk before the trial, CP84-1198, 22°C.

Trial 4 – Billets dipped in ethiprole (12,000, 24,000 or 48,000 ppm) or thiamethoxam 25WG (12,000, 24,000 or 48,000 ppm), January 2002, wireworms collected 2-8 wk before the trial, CL77-797, 23.7°C (SEM 0.02°C).

Trial 5 – Billets dipped in zeta-cypermethrin (75, 100 or 125 ppm), March 2002, wireworms collected 8-12 wk before the trial, CL77-797, 23.2°C (SEM 0.01°C).

Trial 6 – Billets planted in a pocket of soil treated with tefluthrin 3G (2.75, 5.5 or 11.0 g/m^2; 83, 165 or 330 mg ai/m^2), January 2002, wireworms collected 4-6 wk before the trial, CL77-797, 23.6°C (SEM 0.01°C).

Trial 7 - Billets planted in a pocket of soil treated with thiamethoxam 2G (2.75, 5.5 or 11.0 g/m^2; 55, 110 or 220 mg ai/m^2), February 2002, wireworms collected 5-11 wk before the trial, CL77-797, 23.2°C (SEM 0.02°C).

Billets were planted with eyes positioned to the side in all trials. Twenty containers were tested for each rate of each test material except in trial two, where ten containers were tested for each rate of each material. For each trial, the containers of each treatment were randomly assigned to one of four replications (5 containers per replication) (exception, trial two consisted of only two replications). At the end of each trial, numbers of wireworms surviving, percentages of eyes germinated, eyes damaged before germination, and shoots damaged after germination were determined. The percentages of plants damaged before and after germination were added to obtain a total index of damage per container. ANOVA was conducted for each trial (log-transformed data for percentages), and means among treatments were compared using Duncan's new multiple range test.

RESULTS

Bioassays Without Insecticides

Among the eight cultivars tested, percent germination of single-eye billets planted in airtight containers ranged from 20 to 100% (Table 1). From 80 to 100% germination occurred for six of the cultivars, and 100% germination occurred for three cultivars. Percent germination of one cultivar (CP73-1547) was mediocre (60%) and of another (CL78-1600) poor (20%). With respect to speed of germination and emergence under the bioassay conditions, CL61-620, CP78-1628 and CP84-1198 developed the fastest; CL83-4266 and CP80-1743 were slower; and CL77-797 and CP73-1547 were slowest. CL78-1600 showed little development over the 55-day period. With eyes positioned down, plant emergence was delayed by more than 33 days for CL77-797 and by from 17 to 21 days for CL61-620, CL83-4266 and CP80-1743 (Table 2). Less of a delay was observed for CP73-1547 and CP79-1628 (with buds positioned down, plant emergence was delayed by only about 5 days). In the second trial, wireworms held for 2-3 wk before being used in the bioassay damaged 47% of the eyes while wireworms held for 50-54 wk damaged 20% of the eyes.

Bioassays with Candidate Insecticides for Preventing Damage by Wireworms

Ethiprole (48,000 ppm solution) and bifenthrin (24,000 ppm solution) appeared moderately toxic to wireworms in the first trial, each material causing a significant reduction in wireworm survival (Table 3). Low percent germination of CL61-620 billets dipped into the ethiprole treatment indicated the material may have been phytotoxic. Percent germination of billets dipped into the bifenthrin treatment was lower than expected but better than under the infested-check treatment. Wireworms caused considerable damage to seed under the infested-check treatment and some damage to eyes of billets treated with ethiprole, but no damage by wireworms occurred to the eyes of billets treated with bifenthrin. Although bifenthrin provided good protection of eyes from damage, the treatment did not prevent damage to some germinated shoots.

In the second trial, no significant reductions in numbers of live wireworms occurred in containers holding billets treated with 24,000 or 48,000 ppm solutions of ethiprole (Table 3). Billets of CL61-620 dipped into a 48,000 ppm solution of ethiprole had significantly poorer germination than billets dipped into a 24,000 ppm solution, but germination under the 48,000 ppm ethiprole treatment was generally better than in the first trial with this variety. A significant reduction in numbers of live wireworms occurred in containers holding billets treated with a 24,000 ppm solution of bifenthrin but not in containers holding billets treated with a 12,000 ppm solution. Good levels of germination occurred in containers holding billets treated with bifenthrin at each rate. No damage by wireworms was observed to eyes or germinated shoots under either bifenthrin treatment regardless of the presence of live wireworms.

Table 1. Germination of different cultivars in bioassay.[a]

Cultivar	Mean (SEM) days to emergence	Mean percent emergence	Mean percent germination
CL61-620	18.4 (4.57)	70a	90ab
CL77-797	33.3 (4.33)	30b	80ab
CL78-1600	-	0c	20c
CL83-4266	25.6 (4.32)	100a	100a
CP73-1547	29.8 (3.65)	50ab	60b
CP78-1628	15.6 (1.38)	90a	100a
CP80-1743	24.9 (3.72)	80a	100a
CP84-1198	18.0 (2.51)	90a	90ab

[a]Means in the same column followed by the same letter are not significantly different (α=0.05), Duncan's test.

Table 2. Germination of different cultivars in bioassay, billets planted with eyes in an up versus down position.

Cultivar	Eye position	Mean (SEM) days to emergence	Percent emergence	Percent germination
CL61-620	Down	29.3 (6.17)	60	80
	Up	10.3 (1.44)	80	100
CL77-797	Down	-	0	80
	Up	33.3 (4.33)	60	80
CL78-1600	Down	-	0	20
	Up	-	0	20
CL83-4266	Down	36.0 (5.39)	100	100
	Up	15.2 (0.97)	100	100
CP73-1547	Down	32.5 (8.50)	40	40
	Up	28.0 (4.04)	60	80
CP78-1628	Down	18.3 (1.31)	80	100
	Up	13.4 (1.78)	100	100
CP80-1743	Down	35.7 (3.76)	60	100
	Up	18.4 (2.54)	100	100
CP84-1198	Down	23.0 (2.53)	100	100
	Up	11.8 (1.89)	80	80
Overall	Down	28.5 (2.20)	55.0	77.5
	Up	17.5 (1.58)	72.5	82.5

Table 3. Efficacy of different liquid treatments for preventing wireworm damage under the assay conditions.[a]

Material	Rate (ppm)	Mean number wireworms surviving	Mean germ. (%)	Mean plants killed before germ (%)	Mean plants killed after germ (%)	Mean total stand loss (%)
Trial 1: cultivar CL61-620						
ethiprole	48,000	1.5b	5.0b	20.0b	0.0a	20.0ab
bifenthrin	24,000	1.3b	45.0a	0.0c	15.0a	15.0b
infested check	-	2.4a	10.0b	70.0a	5.0a	75.0a
Trial 2: cultivar CL61-620						
ethiprole	48,000	1.9ab	20.0b	30.0a	0.0a	30.0a
ethiprole	24,000	2.7a	80.0a	0.0b	0.0a	0.0b
bifenthrin	24,000	1.1b	90.0a	0.0b	0.0a	0.0b
bifenthrin	12,000	2.1a	80.0a	0.0b	0.0a	0.0b
infested check	-	2.7a	60.0a	30.0a	20.0a	50.0a
non-infested check	-	-	90.0a	0.0b	0.0a	0.0b
Trial 3: cultivar CP84-1198						
ethiprole	12,000	2.4a	35.0b	15.0ab	5.0b	20.0ab
ethiprole	1,500	2.3ab	65.0a	5.0ab	10.0ab	15.0ab
bifenthrin	6,000	1.5c	75.0a	0.0b	5.0b	5.0b
bifenthrin	3,000	1.9abc	55.0ab	0.0b	5.0b	5.0b
bifenthrin	1,500	1.8bc	80.0a	0.0b	5.0b	5.0b
thiamethoxam	24,000	2.0abc	70.0a	0.0b	0.0b	0.0b
thiamethoxam	12,000	2.3ab	65.0a	5.0ab	0.0b	5.0b
infested check	-	2.0abc	65.0a	20.0a	25.0a	45.0a
non-infested check	-	-	85.0a	0.0b	0.0b	0.0b
Trial 4: cultivar CL77-797						
thiamethoxam	48,000	2.5b	70.0a	0.0c	0.0a	0.0d
thiamethoxam	24,000	2.9a	85.0a	0.0c	0.0a	0.0d
thiamethoxam	12,000	2.8a	90.0a	0.0c	0.0a	0.0d
ethiprole	48,000	2.8a	0.0b	20.0b	0.0a	20.0c
ethiprole	24,000	2.8a	0.0b	35.0ab	0.0a	35.0bc
ethiprole	12,000	2.9a	0.0b	40.0a	0.0a	40.0ab
infested check	-	3.0a	5.0b	75.0a	5.0a	80.0a
non-infested check	-	-	80.0a	0.0c	0.0a	0.0d
non-infested ethiprole	24,000	-	0.0b	0.0c	0.0a	0.0d
Trial 5: cultivar CL77-797						
zeta-cypermethrin	125	2.9a	40.0a	55.0a	20.0ab	75.0a
zeta-cypermethrin	100	2.7a	35.0a	55.0a	15.0ab	70.0a
zeta-cypermethrin	75	2.7a	60.0a	30.0b	10.0ab	40.0b
infested check	-	2.8a	45.0a	50.0ab	30.0a	80.0a
non-infested check	-	-	90.0a	0.0c	0.0b	0.0c

[a]For each trial, means in the same column followed by the same letter are not significantly different (α=0.05), Duncan's test.

No significant wireworm mortality occurred in containers of billets treated with ethiprole at either 1,500 or 12,000 ppm in the third trial (Table 3). With respect to bifenthrin, significant wireworm mortality occurred in containers with billets dipped into a 6,000 ppm solution. No significant wireworm mortality occurred in containers with billets dipped into thiamethoxam 25WG at either 12,000 or 24,000 ppm. Respectable levels of CP84-1198 germination occurred under all treatments except 12,000 ppm solutions of ethiprole. A low level of damage to eyes was observed under the 12,000 ppm ethiprole treatment, but not enough to account for the reduced germination; this rate of ethiprole may have been phytotoxic to CP84-1198. No damage to eyes occurred under any of the three bifenthrin treatments, but some young shoots were killed. A low percentage of eyes were damaged among billets dipped into a 12,000 ppm solution of thiamethoxam 25WG but not a 24,000 ppm solution. No young shoots were injured under either of the thiamethoxam treatments.

A small but significant reduction in wireworm survival occurred in containers of billets dipped into a 48,000 ppm solution of thiamethoxam 25WG in the fourth trial (Table 3). No significant mortality of wireworms occurred in containers of billets dipped into 12,000 or 24,000 ppm solutions of thiamethoxam 25WG nor into 12,000, 24,000 or 48,000 ppm solutions of ethiprole (Table 3). In spite of wireworm survival under the thiamethoxam treatments, good levels of germination occurred with no damage to either eyes or young shoots. No germination of CL77-797 occurred among billets dipped into the ethiprole treatments. The ethiprole treatments did not prevent wireworms from attacking eyes, although the percentages attacked were lower than under the infested-check treatment.

In the fifth trial, no significant wireworm mortality occurred in containers with billets treated with zeta-cypermethrin (Table 3). Significant percentages of eyes were damaged by wireworms before germination among billets treated with this material, and significant percentages of germinated shoots were injured by wireworms in spite of the zeta-cypermethrin treatments. For unknown reasons, damage by wireworms in containers of billets treated with 75 ppm zeta-cypermethrin was generally less than when billets were treated with 100 or 125 ppm.

No significant wireworm mortality occurred among containers in which billets were protected with tefluthrin 3G in the sixth trial (Table 4). A rate of 330 mg ai/m^2 provided good protection from wireworm injury to eyes before germination, but rates of 165 or 83 mg ai/m^2 did not. Wireworms tended to cause less damage to young shoots in containers treated with these rates of tefluthrin than in containers not treated.

Treating the soil around billets with thiamethoxam 2G at rates of 55, 110 or 220 mg ai/m^2 resulted in no significant wireworm mortality during the seventh trial (Table 4). However, wireworms caused significantly less damage to eyes before germination under these treatments. The treatments did not prevent damage to shoots after germination.

Because ethiprole appeared phytotoxic in a number of trials, especially to CL77-797, a separate trial was conducted in which single-eye billets were dipped into five ethiprole solutions ranging from 100 to 40,000 ppm (two replications of five containers per ethiprole concentration, CL77-797, March 2002). These billets were planted in containers filled with organic soil and maintained with an airtight lid for 4 wk (no wireworms were introduced). Good germination of

Table 4. Efficacy of different granular treatments for preventing wireworm damage under the assay conditions.[a]

Material	Rate (mg ai/m^2)	Mean number wireworms surviving	Mean percent germ.	Mean percent plants killed before germ.	Mean percent plants killed after germ.	Mean total percent stand loss
Trial 6: cultivar CL77-797						
tefluthrin 3G	330	2.6a	30.0a	10.0b	0.0a	10.0b
tefluthrin 3G	165	2.9a	50.0a	25.0a	5.0a	30.0a
tefluthrin 3G	83	2.8a	20.0a	45.0a	0.0a	45.0a
infested check	-	2.9a	20.0a	65.0a	15.0a	80.0a
non-infested check	-	-	70.0a	0.0c	0.0a	0.0c
Trial 7: cultivar CL77-797						
thiamethoxam 2G	220	3.0a	75.0a	0.0b	15.0a	15.0bc
thiamethoxam 2G	110	3.0a	80.0a	15.0b	25.0a	40.0ab
thiamethoxam 2G	55	2.9a	70.0ab	20.0b	25.0a	45.0ab
infested check	-	2.8a	35.0b	65.0a	20.0a	85.0a
non-infested check	-	-	85.0a	0.0b	0.0a	0.0c

[a]For each trial, means in the same column followed by the same letter are not significantly different (α=0.05), Duncan's test.

root primordia and eyes occurred on billets dipped into solutions of 1,000 ppm or less but not at higher doses (Table 5).

Table 5. Germination of single-eye billets treated with ethiprole and planted in organic soil with airtight plastic containers, 23.2°C (SEM 0.01).[a]

Ethiprole concentration (ppm)	Seed pieces with germinated root primordia (%)	Germination of buds (%)
0	100.0a	100.0a
100	100.0a	100.0a
1,000	100.0a	90.0a
10,000	10.0b	0.0b
20,000	0.0b	0.0b
40,000	0.0b	0.0b

[a]Means in the same column followed by the same letter are not significantly different (α=0.05), Duncan's test.

DISCUSSION

The bioassay was a relatively easy approach for evaluating candidate materials for wireworm control. Airtight lids were advantageous from the standpoint of maintaining soil moisture. However, it remained possible that the efficacy of a material for wireworm control might appear different using an assay without airtight lids because air exchange could affect factors such as the persistence of insecticide odor. The assay could be conducted without lids, in which case water would have to periodically be added to each container. To determine how much water to add, a baseline initial weight could be determined for each container after it is set up, and then enough water to restore a container's weight back to the initial level could periodically be added to compensate for loss of soil moisture. A study comparing lidded versus non-lidded containers would be worthwhile. Soil moisture levels near 50% were suitable for wireworms in the particular organic soil used in the assays. In soils with lower than 50-60% organic matter, lower soil moisture levels by weight would be needed, with the particular moisture level being dependent upon suitability for wireworms.

The speed of germination of some cultivars is inherently slower than others. Most cultivars germinated normally under the bioassay conditions, but it is possible that some cultivars could perform better under the assay conditions than others. Based on the differences observed among the eight cultivars with respect to speed of germination and development, some cultivars may be better suited than others for a bioassay aimed at screening for materials to reduce stand losses by wireworms. For example, a cultivar intermediate or slow in germination rate may be advantageous with respect to giving wireworms ample time to attack a billet. As intuitively expected, plants emerged faster when billets were planted with eyes in an up position.

The data indicated it may be disadvantageous to hold *M. communis* for a long period of time before screening a material for wireworm control because a reduction in wireworm damage may be mistaken as control. If wireworms stored for a long time had to be used in an assay, greater numbers of wireworms could be introduced per billet. *M. communis* is thought to have one annual generation in southern Florida, with most wireworms pupating during early to mid spring (e.g., late March to early May). Wireworms are relatively easy to collect from cane stubble soon after harvest during late October – March. When wireworms are collected during the winter and maintained in containers of soil with carrots as a food source on a laboratory bench, few wireworms pupate even if they are held for more than a year. It is possible such wireworms may feed less because they have completed development and are simply waiting for environmental cues to pupate. If so, it may be disadvantageous to utilize wireworms collected during October-January after around the following March.

Relatively little wireworm mortality occurred in most of the trials regardless of which insecticide was tested, yet little damage to eyes prior to germination often occurred. Wireworms in containers with billets not treated with insecticides usually caused substantial injury. Therefore, wireworms in containers with treated billets may have simply avoided the billets due to repellency of the insecticides (e.g., odor or other characteristics which deterred feeding). Insecticides may vary in both toxicity and repellency (Silverman and Liang 1999). Working with *M. communis* in North Carolina, Villani and Gould (1985) found that five extracts from four plant families significantly reduced wireworm feeding damage to potato. It is possible that a

nontoxic material which repels wireworms from germinating eyes of sugarcane could be useful for reducing damage before germination, but developing shoots might still be subject to attack.

At the rates studied, bifenthrin, thiamethoxam 25WG, thiamethoxam 2G, and tefluthrin 3G each appeared to have value as materials for reducing damage by wireworms to germinating eyes of seed cane planted in organic soils. However, germinated shoots of billets treated with these materials were sometimes injured by wireworms, usually some distance away from the billet itself. Some seed-piece treatments may protect eyes from wireworm injury during germination but not young shoots. Overall, the most promising material based on these limited data appeared to be thiamethoxam 25WG with respect to reducing damage to both germinating eyes and young shoots. Ethiprole was phytotoxic to CL77-797, at least at concentrations above 1,000 ppm, and may have been somewhat phytotoxic to CL61-620 and CP84-1198. A granular formulation of ethiprole might be less toxic to cultivars such as CL77-797. Little wireworm mortality occurred in containers of billets treated with ethiprole at any rate, but surviving wireworms frequently caused injury to the billets. Zeta-cypermethrin appeared to have little value as a wireworm control material at the rates studied, which were comparatively much smaller than the rates tested of the other liquid materials. Higher rates of zeta-cypermethrin might be more effective.

Since the Florida sugar industry currently uses granular formulations of either ethoprop 20G or phorate 20G for wireworm control, alternative pesticides in granular formulations would be more convenient substitutes than liquid pesticides. The recommended application rate of phorate 20G, 1 kg per 300 row meters, equates to approximately 10.9 g product/m^2 or 2.2 g ai/m^2 when applied in a 30-cm band. The recommended application rate of ethoprop 20G, 0.6 to 1.3 kg per 300 row meters, equates to 6.8 to 13.7 g per m^2 or 1.4 to 2.7 g ai/m^2 when applied in a 30-cm band. With respect to g ai/m^2, my test rates of thiamethoxam 2G (0.055 to 0.220 g ai/m^2) and tefluthrin 3G (0.083 to 0.330 g ai/m^2) were much lower than the recommended rates of phorate 20G and ethoprop 20G; higher rates of the two candidate alternatives might have been more effective for killing wireworms in organic soil. Other granular pesticides which could be investigated for wireworm control include Deltagard 0.1%G, Talstar PL-GR (0.2%) and Aztec 2.1%G (Cherry 2001). The Florida industry could consider liquid alternatives to ethoprop 20G and phorate 20G. Ethoprop EC (6 lb per gal) was once registered for wireworm control in Florida sugarcane, with recommended application rates of 100 to 250 g ai/300 row meters (at spray volumes of 4 to 6 l per 300 row meters, solutions of around 15,000 to 60,000 ppm).

The bioassay could be standardized using initial screening rates of 100, 1,000, 10,000 and 50,000 ppm solutions of liquid materials, or rates of 100, 1,000, 2,000 and 4,000 mg ai/m^2 for granular materials, with 20 containers per rate and 3 wireworms per container. Larger numbers of containers per rate would be advantageous for statistical comparisons.

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REFERENCES

1. Cherry, R. H. 2001. Efficacy of soil insecticides for wireworm control in Florida sugarcane. J. American Soc. Sugar Cane Technol. 21: 151-152.

2. Hall, D. G. 2001. The wireworm problem in Florida sugarcane. Proc. Int. Soc. Sugar Cane Technol. 24 (2): 378-381.

3. Hall, D. G. and R. H. Cherry. 1985. Contact toxicities of eight insecticides to the wireworm *Melanotus communis* (Coleoptera: Elateridae). Fla. Entomol. 68: 350-352.

4. Silverman, J. and D. Liang. 1999. Effect of fipronil on bait formulation-based aversion in the German cockroach (Dictyoptera: Blattellidae). J. Econ. Entomol. 92: 886-889.

5. Villani, M. and F. Gould. 1985. Screening of crude plant extracts as feeding deterrents of the wireworm *Melanotus communis*. Entomol. Exp. Appl. 37: 69-75.

EARLY GENERATION SELECTION OF SUGARCANE FAMILIES AND CLONES IN AUSTRALIA: A REVIEW

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ABSTRACT

Sugarcane breeding programs typically commence by evaluating a large number of seedlings derived from true seed. Individual clone (mass) selection applied at this stage of the program has been shown to be inefficient because of lack of replication and the associated confounding effects of the environment. In Australia, the introduction of mobile weighing machines made it possible to implement family selection. Several research projects demonstrated that family selection, when followed by individual clone selection, was superior in terms of genetic gain and more cost effective than either family or individual clone selection alone. This combination of family and individual clone selection is now used routinely in all the Australian programs. Families are evaluated using replicated plots for cane yield (mechanically harvested and weighed) and sucrose content in the plant crop. Individual clones are selected, based mainly on visual appraisal for cane yield, from selected families in the first ratoon crop. Family selection is usually liberal with about 30 – 40 % of families selected. More clones are selected from the best families with progressively fewer clones being selected from the moderate to average families. The availability of objective family data makes it possible to estimate the breeding value of parents using the Best Linear Unbiased Predictors (BLUP). This information is used to retain or drop parents from the crossing program and to plan better cross combinations.

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INTRODUCTION

Although sugarcane is grown commercially as a clone, sugarcane breeding programs typically commence by evaluating large numbers of seedlings derived from true seed. Sugarcane breeders have traditionally employed intensive selection of individual seedlings or seedling bunches to select clones at this stage. Selection is usually subjective, based on visual appraisal for cane yield. Some programs also consider sucrose content, which is indirectly measured as

Brix (% soluble solids w/w in the juice) using a hand-held refractometer, in their selection criteria. Although satisfactory gains have been achieved using individual seedling selection, it is not efficient (Hogarth et al., 1997; Skinner, 1971). The lack of replications, competition effects among seedlings and, because individual clone selection is labor intensive and expensive, all contribute to reduce selection efficiency.

Research in Australia revealed that family selection would be superior to individual seedling selection at this stage (Hogarth, 1971). Family selection is particularly useful for traits with low heritability because, unlike clones, families can be replicated across years and sites, thereby improving estimates of family means as well as aiding in the identification of stable families (Jackson and McRae, 1998; Falconer and Mackay, 1996). Because sugarcane is exploited commercially as a clone, the rationale for family selection is not to produce superior families with commercial value but rather to identify families with a higher frequency of superior clones. Family selection makes it possible to focus selection for superior clones (individual clone selection) on the best families, because the probability of finding superior clones at later stages of the program is highest within these families (Cox and Hogarth, 1993). An added advantage of family selection in sugarcane is that family data can be used to infer the breeding value of parents based on progeny performance (Balzarini, 2000; Cox and Stringer, 1998; Stringer et al., 1996; Chang and Milligan, 1992a, b).

In the 1970s, families still had to be cut and weighed manually; therefore, the cost of implementing family selection was prohibitive at the time. With the development of mobile weighing machines in Australia, it became possible to investigate the advantages of family selection in more detailed experiments and under different geographical and environmental conditions (Hogarth and Mullins, 1989). Following results from these experiments, the Australian programs were redesigned to include family selection at this early (seedling) stage (Cox and Hogarth, 1993; Hogarth and Mullins, 1989). In this report, we share some of our experiences with family selection in Australia. We briefly review some of the experiments that led to the redesign of the Australian programs and further examine the impact of family selection on other aspects of the selection program. In particular, we reveal how family selection has contributed positively to the selection of parents and crosses and to population improvement. In this paper, as in other sugarcane breeding papers, the phrase family selection is used in some instances as an all encompassing one to describe the selection of families and clones within families.

Family selection in Australia

Sugarcane growing regions and family selection experiments

In Australia, sugarcane is cultivated over a 2100 km stretch from northern New South Wales (approximately 30°S) to northern Queensland (approximately 17°S), with the actual hectarage spread unevenly across this distance (Figure 1). Additional hectarage is emerging in the Ord river basin. The Bureau of Sugar Experiment Stations (BSES) operates five separate sugarcane selection programs in Australia, which are separated into regions by latitude (Hogarth and Mullins, 1989) and are strategically located in the major sugarcane-growing regions. Each selection program operates independently, but family selection is a common feature in the early

stages of all the programs (Table 1). The number of seedlings and clones planted and selected at each stage, varies in the different programs.

Several family selection experiments have been carried out under different geographical and environmental conditions in Australia (Jackson et al., 1995a, b; McRae and Jackson, 1995; McRae et al., 1993; Cox et al., 1996; Hogarth et al., 1990; Hogarth, 1971). But, the best set of experiments to use in illustrating the benefits of family selection was carried out in the Burdekin region (Ayr, Figure 1) where the growing conditions have been described as unfavorable to selection (Jackson et al., 1992; Pollock, 1982). In this region, sugarcane is grown under irrigation, which results in large and frequently lodged crops. Because individual clone selection is impractical under such conditions, the practice was to restrict crop growth by minimizing irrigation and fertilizers to prevent lodging and enable individual clone selection. However, because the crop growth potential was not realized under such conditions, this probably had a negative impact on selection response because visual estimation of cane yield was poorly correlated with actual cane yield in heavily lodged crops (Jackson et al., 1992; Pollock, 1982). Indeed, in an experiment conducted by Hogarth et al. (1990), neither family selection nor mass selection was effective under conditions that restricted crop growth. The selection conditions (environments) were probably atypical of the target environment. Furthermore, under conditions of restricted crop growth, misleading information on family performance would probably lead to inappropriate parents being selected for crossing, thereby, impeding future selection progress (Kimbeng et al., 2000).

An experiment was conducted in which lodging was experienced as a result of letting it grow to its full potential (Kimbeng et al., 2000). One hundred full-sib families were evaluated in single-row plots, replicated four times with 20 seedlings per family plot. Family plot data were collected in the lodged plant crop using mobile weighing machines as described for a Stage 1 trial (see Table 1). In the young first ratoon crop, prior to lodging, three clones were visually selected, and another three clones were taken at random from each family plot. These clones were each planted to a single-row, 10-m plot in a split-plot arrangement and replicated into four randomized complete blocks. Whole plots were assigned to families and sub-plots to selection methods (random vs. selected) for a total of six clones per plot. First clonal stage data were collected in the plant and first ratoon crops as described for a Stage 2 trial (Table 1).

Figure 2 shows the percentage of elite clones (clones with Net Merit Grades, NMG > 9.0; see Table 1 for description of NMG) in Stage 2 with respect to the selection strategy used in Stage 1 for the top 40% of families. Essentially, the results showed that family selection could be effective even under lodged conditions. This is evident from the performance among random clones, which was generally higher among the top NMG families and decreased progressively in the poorer NMG families. Visual selection in the young first ratoon crop was also effective in identifying elite clones within families, as evident from Figure 2 and the significant effect of selection method (random vs. selected, 1df) in the ANOVA (data not shown). Also, the effectiveness of visual selection was consistent across families as indicated by the lack of significant family by selection method interaction in the ANOVA (data not shown). Family selection in the plant crop followed by individual clone selection in the first ratoon crop was superior to either family or individual clone selection. Similar results were found in a simulation study that modeled family by environment interactions, genotypic correlations

between the selected trait and sugar yield, among family variance, total variance and cost of selection (Jackson et al., 1995b). The authors reported superior genetic gain and cost effectiveness for combined family and individual clone selection compared to either family or individual clone selection in most cases. Family selection was also superior to individual clone selection in most cases. Individual clone selection was superior only in cases where there was both a small proportion of among-family variance and a high genetic correlation between the selected trait and sugar yield.

Any form of family selection, however, would have to be liberal because some clones have been found to perform better than expected on the basis of their family performance in seedling trials (Kimbeng et al., 2000; Hogarth et al., 1990). Furthermore, although an overall increase in family mean is desirable, the ultimate goal for sugarcane breeders is to select the best-yielding clone(s). Cox et al. (1996) suggested that only the top 30 to 40% of families be targeted for routine individual clone selection. He contends that after intentionally selecting clones from the moderate NMG families (50 – 70 %) for a number of years, not a single clone from this category progressed to the advanced stages (Cox, Personal Communication). Kimbeng et al. (2000) also found the highest percentage of elite clones within the top 30 to 40% of families (and see Figure 2). Kimbeng et al. (2001a, b; 2000), however, found evidence that elite clones could be selected from the moderate to low NMG families. They found some outstanding clones among moderate NMG families, especially those that had high CCS but low TCH and vice versa. According to Kimbeng et al. (2001b), the time required to select individual clones from these relatively poor families should not be a limiting factor in a field operation, because these plots can be predetermined using the plant crop family data. In central Queensland, each row is harvested immediately after individual clone selection, giving the selecting crew equal access to all rows and clones during selection.

A major practical benefit of family selection is that it allows genetic material to be evaluated across locations and years, which aids in the identification of stable families (Jackson and McRae, 1998). This is particularly useful in situations where family by environment interaction is important. In the Burdekin region (Ayr, Figure 1), McRae and Jackson (1995) did not find significant interactions between family and any of the environmental factors, namely soil types, management practices and crop cycle that they evaluated. Based on these findings, in this region, families are evaluated only in the plant crop and at one location (the breeding station) as described in Table 1. Significant family by environment interactions were found in the Herbert region (Ingham, Figure 1) (Jackson et al., 1994). However, Jackson et al. (1995a) and Jackson and Galvez (1996) later found that soil nutrient status was the principal cause of the interactions. Soil nutrient status is a predictable and repeatable source of genotype by environment interaction (Allard and Bradshaw, 1964) that was easily corrected. In southern Queensland, Bull et al. (1992) reported significant family by location interaction. When resources are not a constraining factor, families are evaluated at more than one location in this region.

Competition among seedlings in a plot can affect selection response adversely if the appropriate intra-row spacing between seedlings is not used. Research under Louisiana growing conditions showed that genetic response was larger at a wider intra-row spacing of 82 cm compared to a narrower spacing of 41 cm (De Sousa-Vieira and Milligan, 1999). Intra-row

spacing varies among the Australian programs and is probably influenced by land availability and the size of the crop. For example, an intra-row spacing of 50 cm is used in central Queensland (Mackay, Figure 1), but in the Burdekin (Ayr, Figure 1), where they have access to irrigation and tend to grow bigger crops, the spacing is 60 cm.

Appraisal of family selection using data generated from routine selection activities

Any crop improvement program needs to be constantly monitored to ensure that the breeding and selection methods are operating at optimal levels. Retrospective analyses using data generated from routine selection activities can be particularly helpful in this effort because these data serve as footprints of the program's activities. Cox and Stringer (1998) analyzed the efficacy of early generation selection for the southern Queensland program (Bundaberg, Figure 1) using data from the selection database. In this analysis, all the clones that were advanced to Stage 3, based on their performance in Stage 2, were categorized according to the families from which they were derived in Stage 1 (see Table 1 for a detailed explanation of Stages). The results showed that selection rates for clones derived from Stage 1 families were low (3.8 %) for low NMG families (< 10), were similar for families with NMG 10 to < 13 (6.9% - 7.6%) and were quite high for the highest NMG category (13.6 %) (Table 2). It appears, during selection of clones in the first ratoon crop, selection intensity, which is normally higher for the poorer NMG families, more than compensated for the poor family performance. This explains the similar selection rates of clones from Stage 2 to Stage 3 for families with NMG 10 to < 13 (6.9% - 7.6%). Thus, selection intensity can be a major driving force to increase genetic gain. The authors suggested that genetic gain could be improved by planting larger numbers of clones (in extra plots) of the better families and increasing individual selection intensity for these families. In this case, the extra plots would be selected in the plant crop without having to wait for more data. This strategy combines the strengths of the family selection and proven cross methods.

An analysis similar to that of Cox and Stringer (1998) was performed for the central Queensland program (Mackay, Figure 1) using a much larger data set (Kimbeng et al., 2001a). The results, with respect to selection among families, were similar to those reported by Cox and Stringer (1998); selection rates were higher for the top NMG families and comparatively lower for the poor NMG families. However, a bias with this type of analysis is that the high NMG families were originally represented by more clones in Stage 2 compared to the poor NMG families. Therefore, no conclusion could be drawn with respect to the selection of clones within families. In an attempt to overcome this bias, Kimbeng et al. (2001a) divided the selection rate (Stage 2 to 3) by the percent of clones evaluated in Stage 2 for each NMG category. In this analysis, the selection rate was taken to represent the realized response and the percent of clones evaluated in Stage 2 represented the potential response. The results from this analysis revealed that although family selection was effective in identifying those families that harbor a greater proportion of elite clones, selection of clones within families was not efficient, especially for the high NMG families. Kimbeng et al. (2001a) observed that in central Queensland, the top NMG families did not undergo the strict appraisal process used for the lower NMG families and as a result more clones are advanced than is actually necessary. More clones are usually earmarked for selection from the high NMG families. Because the NMG formula awards a bonus for high sucrose content, there is a tendency not to Brix clones within the top NMG families because of the perception that most of the clones are high in sucrose content. The reverse is true for the low NMG families, where almost every clone is subjected to a Brix test before selecting a few. The

analysis, unfortunately, could not accurately account for what happened in the average to poor families. These families had either been discarded or had already undergone very stringent selection. The breeder could be discarding potential clones if the selection intensity applied to these families is more intense than necessary. Although differential selection rates are used within families, whereby more clones are selected out of the best families (top 10 %), with progressively fewer clones being selected from the 20 to 40% of families, the number of clones selected from these families is currently not based on any objective data. Based on the available resources, only a finite number of clones can be evaluated in Stage 2 trials and, for family selection to be efficient, selection of clones within families would have to be optimized. In central Queensland, the resources allocated to Stage 2 trials can accommodate only about 10% of clones from Stage 1.

Simulated selection to optimize family selection

An experiment was carried out in central Queensland (Mackay, Figure 1) to investigate optimum selection intensities for family and individual clone selection (Kimbeng et al., 2001b). In this experiment, families (replicated family plots) and random clones within each family plot were assessed for various characteristics, including cane yield, sucrose content, visual grade and Brix in the plant crop of a Stage 1 trial (see Table 1 for explanation of a Stage 1 trial). These clones were evaluated in Stage 2 (first clonal stage) in the plant and first ratoon crops. Response to selection in Stage 1 was judged on the performance of corresponding clones in Stage 2. The main objective was to simulate optimum rates of combined family and individual clone selection in Stage 1. The simulations to determine optimum rates of combined family and individual clone selection in Stage 1 were performed using Microsoft Access Relational Database.

The results confirmed that while family selection was effective in identifying families with a high proportion of elite clones, it was more efficient when combined with visual selection (Table 3). The efficiency improved further when clones with good visual grade were subjected to a Brix test. Most of the efficiency arose from the fact that inferior clones were rejected on the basis of visual grade and Brix, and considerably fewer clones were evaluated in Stage 2. Given that only 10% of clones from Stage 1 can be accommodated in Stage 2 trials, this would represent about 240 clones in this study (Table 3).

Enforcing a strict selection for Brix led to the loss of a considerable number of elite clones. But, when the cut-off point for Brix was allowed to vary, depending on the visual grade, (for example a clone with low Brix is accepted when the visual grade is high), the number of elite clones that would have been discarded dropped dramatically, but one would have had to increase the number of clones evaluated in Stage 2. In practice, the decision to accept or reject a clone based on visual grade is much easier to make since that decision always equals to a yes (acceptable) or no (unacceptable) answer. Based on the results from the simulations, individual clone selection rates of 40, 30, 25 and 10% were optimum for families selection rates of 10, 20, 30 and 40%, respectively, when selecting families (based on NMG) in the plant crop and clones (based on visual appraisal) in the first ratoon crop. Individual clone selection based on Brix was best determined by taking into consideration the visual grade of the clone. These selection rates should be applied with some caution because they probably depend on the germplasm base and, as such, may differ in other programs. In Louisiana, for example, the best outcome was achieved with 75% family and 13% within-family selection, and the author contends that this was only slightly more efficient than mass selection (Zaunbrecher, 1995). The author attributed this to the

narrow genetic diversity or low among-family variance (11%) in the Louisiana program. During the study period, only about 80 parents were used to make an average of about 300 biparental crosses in Louisiana, compared to 800 -1000 parents used to make about 2,500 crosses in Australia each year. The number of parents used in the Louisiana crossing program has increased to about 160, largely because of increased efficiency of floral initiation using the photoperiod facility.

Impact of family selection on other aspects of the breeding program

Selection of parents, crosses and population improvement

A selection cycle in sugarcane usually involves a sequence of about four to six stages (Skinner et al., 1987). A selection cycle typically takes about 12-15 years to complete. The first stage is the only stage, after hybridization, to be planted with true seed. Subsequent stages are planted using vegetative propagation, and progressively fewer clones are selected and evaluated in the more advanced stages. During this 12 to 15 year period, no opportunities exist for sexual recombination or the creation of new genetic variation that the breeder can exploit. The breeder has to rely on the initial variation created during hybridization. Research that can predict the outcome of a cross would help the breeder to concentrate effort on the most profitable crosses, which in turn would substantially increase the chances of selecting elite clones. The selection of genotypes to use as parents, or crosses to plant, is one of the most critical decisions the sugarcane breeder has to make.

At the BSES, Hogarth and Skinner (1986) developed an algorithm for assessing the breeding value of parental clones that combined breeding information, agronomic data and disease ratings into a single index. The breeding information relied heavily on the percent of clones from a cross that are advanced to later stages. Crosses with high advancement rates (proven crosses), were usually replanted to large numbers of progenies, unduly increasing their odds of producing advanced clones to the detriment of experimental crosses. Furthermore, although the agronomic data and disease ratings combined information from both the parent and progenies, the method required several years to reliably estimate breeding value, and it is now known that individual clone selection in the early stages was not efficient.

BSES breeders recognized the limitations of this empirical approach and sought more efficient methods of estimating breeding value. But this effort was hampered by the lack of objective data on family or clonal performance, as early stage data were based on indirect measurements; that is, visual assessment to estimate cane yield and Brix to estimate sucrose content. Therefore, the availability of objective family data on both cane yield and sucrose content presented a unique opportunity to apply statistical approaches to the problem. However, the highly unbalanced nature of data sets generated from routine progeny evaluation trials precluded the use of statistical methods such as factorial (or North Carolina design II) (Comstock et al., 1949, Comstock and Robinson, 1948) and Diallel (Griffing, 1956; Hayman, 1954) mating designs.

The Best Linear Unbiased Predictor (BLUP), which was developed to estimate breeding value in animal breeding (Henderson 1975), can handle large, highly unbalanced data sets such as those generated in routine sugarcane progeny evaluation trials. The BLUP allows data from a diverse range of mating designs, relatives, and precisions to be combined into a single breeding

value for each trait and genotype (Balzarini, 2000). Chang and Milligan (1992a, 1992b) were the first to report that the BLUP was reliable in predicting the potential of a cross to produce elite progeny in sugarcane. They also found that the potential of a cross to produce elite progeny could be accurately predicted from the cross mean of that trait, and the cross mean was more readily obtained than the BLUP (Chang and Milligan, 1992b). These latter results were obtained using a balanced data set and were restricted to one stage of the breeding program. The real advantage of the BLUP over other statistical methods arises when highly unbalanced data sets, such as those generated from routine sugarcane selection trials, are analyzed across different stages of the program and include information about relatives (Balzarini, 2000; Stringer et al., 1996).

Using routine family appraisal data from the southern Queensland (Bundaburg, Figure 1) breeding program, Stringer et al. (1996) and Cox and Stringer (1998) compared the utility of the BLUP with that of an empirical method (Hogarth and Skinner, 1986) in predicting cross performance. The predictions were made by correlating the mean BLUP values obtained using data accumulated over several years up to a certain year, with the actual family mean values obtained in the following year. In other words, family mean plant crop data, in say 1995, were correlated with the corresponding mean BLUP values estimated using family data accumulated from, say 1992-1994. The empirical values were derived from at least ten years of data. These results showed that the BLUP method was superior to the empirical method in predicting cross performance (Table 4). Generally, the BLUP method requires less information (at least 1 year) compared to the empirical method (at least 10 years) and its power to predict cross performance increases as more data become available and is expected to increase even further when information on relatives is included in the model (Stringer et al., 1996). The robustness of the BLUP estimates depends largely on the availability of objective family appraisal data, albeit highly unbalanced.

Encouraged by the high predictive power of the BLUP analytical method, BSES breeders began to change their philosophy with respect to choice of parents and crosses. The BLUP was increasingly used to select parents and crosses, and to design new crosses. This led to a gradual increase in crosses involving newer parents. Use of historical parents began to decline, even when they were involved in 'proven crosses' (Cox and Hogarth, 1993). The new philosophy sought to achieve a much-needed balance between the short-term goals of producing elite sugarcane clones with the long-term need to continuously improve the base population. These issues needed to be considered simultaneously, because the repetitious nature of breeding for short-term needs was unlikely to provide the best results to accomplish long-term goals. For example, the hitherto strong emphasis on proven crosses in the BSES breeding program served the short-term need of producing elite varieties. However, it hampered efforts to broaden the genetic base of the breeding population, because only limited chances were available to evaluate experimental parents and crosses. Furthermore, it is well known among sugarcane breeders that the genetic base of cultivated sugarcane is very narrow, so concerted efforts had to be made to broaden the base population (Berding and Roach, 1987; Mangelsdorf, 1983).

Population improvement and base broadening efforts at the BSES encompass the rapid introduction of superior clones from advanced stages of the selection program as well as superior germplasm from exotic crosses, and international and national programs (inter-station exchange),

into the crossing program (Cox and Hogarth, 1993). In other instances, population improvement involved recurrent selection for specific traits, for example high early sucrose content (Cox et al., 1994; Cox et al., 1990) to provide suitable parents for the variety development crossing program. The availability of sound, objective data on family performance coupled with robust estimates of the BLUP, are crucial to the success of population improvement efforts.

The implementation of this new effort was assessed for the southern BSES program by evaluating the relative performance of families derived from crossing new versus old parents. The analysis used four years of routine family appraisal data in which parents were arbitrarily categorized as old (O), medium (M), or new (N) if the seedling parent had a year prefix < 65, 65-74, or > 74, respectively (Cox and Hogarth, 1993). The crosses were designated OxO, OxM, OxN, MxM, MxN, or NxN (Table 5). Although the small sample size of the NxN crosses precluded a reasonable assessment of this group of crosses, the overall results point to the inferior performance of old parents compared to the relatively new ones. Old parents performed poorly even when used in combination with relatively new parents, compared to crosses between relatively new parents. These results justify the continuous use and rapid recycling of parents in the breeding program. Again, data accumulated from family evaluation trials are crucial to the successful implementation of this policy.

Apart from evaluating parental performance, the population from which families and clones are selected (Stage 1, see Table 1) and the population of clones immediately following family and clonal selection (Stage 2, see Table 2) are also constantly monitored. This is to ensure that these populations are not adversely affected as a result of adopting family selection measures (for example, the BLUPs to select parents; the rapid recycling of newer parents including overseas clones). The performance of seedling populations (Stage 1) from 1993 to 2000 in southern Queensland depicts an overall gradual improvement in NMG at the rate of 0.02 units per year. Cane yield was a major driving force of this improvement [TCH = 0.02Year + 0.58; R^2 = 0.70], compared to sucrose content [CCS = -0.002Year + 0.93; R^2 = 0.03]. Heritability, estimated on an entry-mean basis using replicated family plots (Stage1), was higher for cane yield, 64%, compared to sucrose content, 48% (Kimbeng and McRae, 1999). Cane yield may, therefore, be more influential in determining among-family differences in seedling populations (Stage 1 trials) compared to sucrose content.

Within the same period, the NMG of clones (Stage 2) immediately following family and clonal selection improved on average by 1.58 units per year (Figure 4). The NMG of the top 10% of the mean, which constitutes most of the clones advanced to the next stage, improved on average by 2.02 units per year. Contrary to the seedlings, population improvement in the clones was driven more by improvements in sucrose content [CCS = 1.0Year + 89.92; R^2 = 0.63] than by cane yield [TCH = 0.11Year + 81.73; R^2 = 0.005], which is consistent with well-established expectations. In Stage 2 trials, large numbers of clones are evaluated in unreplicated, single-row plots. Cane yield is more adversely affected by the lack of replication and competition effects among clones in small plots compared to sucrose content (Jackson and McRae, 2001; McRae and Jackson, 1998; Hogarth, 1977). Kimbeng et al. (2001a) reported correlation coefficients that were always higher in magnitude for sucrose content compared to cane yield between clones in Stage 2 (single-row, unreplicated) and Stage 3 (2 replicates, multiple locations, 4-row plots) trials. Even in replicated clonal plots, the degree of genetic determination was five fold higher

for Brix compared to cane yield (Hogarth, 1977). Sucrose content is a more influential trait than cane yield in determining among clone differences in Stage 2 trials. The BSES is now routinely using spatial analysis, with the model also adjusting for intergenotypic competition, to improve estimates of cane yield in Stage 2 trials (Stringer and Cullis, 2002a, b). Research is underway to test the selection system proposed by Jackson and McRae (2001) in which, clones are evaluated in replicated 5-m plots with selections geared more towards sucrose content (measured objectively) and liberal for cane yield (measured as visual yield).

CONCLUSIONS

Several research and simulation studies have shown that combined family and individual clone selection is a practical and cost-efficient method of selection in early stage sugarcane trials. Family selection is very practical under lodged conditions and is especially suited to mechanical harvesting. Family selection, based on the plant crop data, is useful in identifying those families that harbor the highest proportion of elite clones. This makes it possible to focus selection for superior clones (individual clone selection) on the best families. Adopting family selection in early stage trials has positively affected other aspects of the selection program. For example, the availability of objective data on progeny performance presented the opportunity to generate robust estimates of the breeding value of parents involved in crosses. This allowed for a more rapid recycling of elite parents into the crossing program than was previously possible with the proven cross method. The population from which families and clones are selected and the population of clones immediately following family and clonal selection showed an overall gradual improvement indicating that these populations were not adversely affected by the adoption of family selection. Taken together, this can only lead to an improvement in the overall efficiency of the selection programs.

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REFERENCES

1. Allard R. W., and A. D. Bradshaw. 1964. Implications of genotype-environmental interactions in plant breeding. Crop Science 4: 503-508.

2. Balzarini, M. G. 2000. Biometrical models for predicting future performance in plant breeding. PhD Dissertation, Louisiana State University. (Dissertation Abstracts: 99-79242.)

3. Berding N., and E.T. Roach. 1987. Germplasm collection, maintenance and use. In: D.J. Heinz(ed), Sugarcane improvement through breeding Elsevier, New York, pp 143-210.

4. BSES. 1984. The Standard Laboratory Manual for Australian Sugar Mills. Volume 1. Principles and Practices. Bureau of Sugar Experiment Stations: Brisbane, Australia.

5. Bull, J. K., D. M. Hogarth, and K. E. Basford. 1992. Impact of genotype x environment interaction on response to selection in sugarcane. Australian Journal of Agricultural Research 32:731-737.

6. Chang, Y. S., and S. B. Milligan. 1992a. Estimating the potential of sugarcane families to produce elite genotypes using bivariate methods. Theoretical and Applied Genetics 84:633-639.

7. Chang, Y. S., and S. B. Milligan. 1992b. Estimating the potential of sugarcane families to produce elite genotypes using univariate cross prediction methods. Theoretical and Applied Genetics 84:662-671.

8. Comstock, R. E., and H. F. Robinson. 1948. The components of genetic variance in populations of biparental progenies and their use in estimating the average degree of dominance. Biometrics 4:254-266

9. Comstock, R. E., H. F. Robinson, and P. H. Harvey. 1949. A breeding procedure designed to make maximum use of both general and specific combining ability. Agronomy Journal 41:360-367.

10. Cox, M. C., and J. K. Stringer. 1998. Efficacy of early generation selection in a sugarcane improvement program. Proceedings Australian Society Sugarcane Technologists 20: 148-153.

11. Cox, M. C., T. A. McRae, J. K. Bull, and D. M. Hogarth. 1996. Family selection improves the efficiency and effectiveness of a sugarcane improvement program. *In* Wilson, J. R., Hogarth, D. M., Campbell, J. A. and Garside, A. L. (eds). Sugarcane: Research towards Efficient and Sustainable Production, Pp 42-43. CSIRO Div. Tropical Crops and Pastures, Brisbane.

12. Cox, M. C., Hogarth, D.M., and P. B. Hansen. 1994. Breeding and selection for high early season sugar content in a sugarcane (*Saccharum spp.* hybrids) improvement program. Australian Journal Agricultural Research 45:1569-1575.

13. Cox, M. C., and D. M. Hogarth. 1993. Progress and changes in the South Queensland Variety Development Program. Proceedings International Society Sugarcane Technologists 15:251-255.

14. Cox, M. C., D. M. Hogarth, and R. T. Mullins. 1990. Clonal evaluation of early sugar content. Proceedings Australian Society Sugarcane Technologists 12: 90-98.

15. De Sousa-Vieira, O., and S. B. Milligan. 1999. Intrarow spacings and family x environment effects on sugarcane family evaluation. Crop Science 39:358-364.

16. Falconer, D. S., and T. F. C. Mackay. 1996. Introduction to quantitative genetics. Fourth Edition. Longman Group Ltd., UK.

17. Griffing, B. 1956. Concept of general and specific combining ability in relation to diallel crossing systems. Australian Journal Biological Science 9:463-493.

18. Hayman, B. I. 1954. The theory and analysis of diallel crosses. Genetics 39:789-809.

19. Henderson, C. R. 1975. Best linear unbiased estimation and prediction under a selection model. Biometric 31:423-477.

20. Hogarth, D. M., M. C. Cox, and J. K. Bull. 1997. Sugarcane improvement: Past achievements and future prospects. In: Kang, M.S. (ed.) Crop Improvement for the 21st century, pp 29-56.

21. Hogarth, D. M., M. J. Braithwaite, and T. C. Skinner. 1990. Selection of sugarcane families in the Burdekin district. Proceedings Australian Society Sugarcane Technologists 12:99-104.

22. Hogarth, D. M., and R. T. Mullins. 1989. Changes in the BSES plant improvement program. Proceedings International Society Sugarcane Technologists 20: 956-961.

23. Hogarth, D. M., and J. C. Skinner. 1986. Computerisation of cane breeding records. Proceedings International Society Sugarcane Technologists 19:478-491.

24. Hogarth, D. M. 1977. Quantitative inheritance studies in sugarcane. III. The effect of competition and violation of genetic assumptions on estimation of genetic variance components. Australian Journal Agricultural Research 28: 257-268.

25. Hogarth, D. M. 1971. Quantitative inheritance studies in sugarcane. II. Correlations and predicted responses to selection. Australian Journal Agricultural Research 22: 103-109.

26. Jackson, P. A., and T. A. McRae. 2001. Selection of sugarcane clones in small plots: effects of plot size and selection criteria. Crop Science 41: 315-322.

27. Jackson, P. A., and T. A. McRae. 1998. Gains from selection of broadly adapted and specifically adapted sugarcane families. Field Crops Research 59: 151-162.

28. Jackson, P. A., and G. Galvez. 1996. Role of variable soil nutrient levels in causing genotype x environment interaction in sugarcane. *In* Wilson, J. R., Hogarth, D. M., Campbell, J. A. and Garside, A. L. (ed). Sugarcane: Research towards Efficient and Sustainable Production, Pp 52-54. CSIRO Div. Tropical Crops and Pastures, Brisbane.

29. Jackson, P. A., T. A. McRae, and D. M. Hogarth. 1995a. Selection of sugarcane families across variable environments. II. Patterns of response and association with environmental factors. Field Crop Research 43:109-118.

30. Jackson, P. A., T. A. McRae, and J. K. Bull. 1995b. The role of family selection in sugarcane breeding programs and the effect of genotype x environment interactions. Proceedings International Society of Sugarcane Technologists 22:261-269.

31. Jackson, P. A., W. M. Symington, T. E. Morgan, and A. W. Wood. 1992. The CSR sugarcane breeding program – Future direction and strategies. Proceedings Australian Society of Sugarcane Technologists 14:123-129.

32. Jackson, P. A., T. A. McRae, and D. M. Hogarth. 1994. Selecting superior sugarcane crosses for the Herbert River district. Proceedings Australian Society Sugarcane Technologists 16:47-54.

33. Kimbeng, C. A., D. Froyland, D. Appo, A. Corcoran, and M. Hetherington. 2001a. An appraisal of early generation selection in the central Queensland sugarcane improvement program. Proceedings Australian Society Sugarcane Technologists 23:129-135.

34. Kimbeng, C. A., T. A. McRae, and M. C. Cox. 2001b. Optimising early generation selection in sugarcane breeding. Proceedings International Society Sugarcane Technologists 24 (2): 488-493.

35. Kimbeng, C. A., T. A. McRae, and J. K. Stringer. 2000. Gains from family and visual selection in sugarcane, particularly for heavily lodged crops in the Burdekin region. Proceedings Australian Society Sugarcane Technologists 22: 163-169.

36. Kimbeng, C. A., and T. A. McRae. 1999. Optimum selection strategies in original seedlings particularly for heavily lodged crops. Sugar Research and Development Final Report. Bureau of Sugar Experiment Stations: Brisbane, Australia.

37. Mangelsdorf, A. J. 1983. Cytoplasmic diversity in relation to pests and pathogens. International Society of Sugarcane Technologists Newsletter 45:45-49

38. McRae, T. A., and P. A. Jackson. 1998. Competition effects in selection trials. Proceedings Australian Society Sugarcane Technologists 20:154-161.

39. McRae, T. A., and P. A. Jackson. 1995. Selection of sugarcane families for the Burdekin river irrigation area. Proceedings Australian Society of Sugarcane Technologists 17:134-141.

40. McRae, T. A., D. M. Hogarth, J. W. Foreman, and M. J. Braithwaite. 1993. Selection of sugarcane seedling families in the Burdekin district. In 'Focused Plant Improvement' Proceedings of the Tenth Australian Plant Breeding Conference. 77-82.

41. Pollock, J. S. 1982. Variety selection in the Burdekin. Proceedings Australian Society of Sugar Cane Technologists 4: 121-129.

42. Skinner, J. C., D. M. Hogart, and K. K. Wu. 1987. Selection methods, criteria, and indices. Developments in crop science 11: Sugarcane improvement through breeding DJ Heinz (ed.) Elsevier Amsterdam.

43. Skinner, J. C. 1971. Selection in sugarcane: a review. Proceedings International Society Sugarcane Technologists 14:149-162.

44. Skinner, J. C. 1967. Grading cultivars for selection. Proceedings International Society of Sugarcane Technologists 12: 938-949.

45. Stringer, J. K., and B. R. Cullis. 2002a. Application of spatial analysis techniques to adjust for fertility trends and identify interplot competition in early stage sugarcane selection trials Australian Journal of Agricultural Research 53: 911-918

46. Stringer, J. K., and B. R. Cullis. 2002b. Joint modeling of spatial variability and interplot competition. *In* McComb, J. A. (Ed) 'Plant Breeding for the 11th Millennium'. Proceedings of the 12th Australasian Plant Breeding Conference, Perth, W. Australia, 15-20 September 2002, pp 614-619.

47. Stringer, J. K., T. A. McRae, and M. C. Cox. 1996. Best linear unbiased prediction as a method of estimating breeding value in sugarcane. *In* Wilson, J. R., Hogarth, D. M., Campbell, J. A. and Garside, A. L. (eds). Sugarcane: Research towards Efficient and Sustainable Production, Pp 39-41. CSIRO Div. Tropical Crops and Pastures, Brisbane.

48. Zaunbrecher, R. 1995. Improving selection procedures in sugarcane using cross appraisal methods. Masters Thesis, Louisiana State University.

Table 1. The activities of the first two stages of a typical BSES sugarcane selection program

Year	Stage/ Crop	Operation[†]
1	Stage 1	**Seedling stage planted:** Full-sib families x 5 replicates x 20 seedlings/ replicate.
2	P	**Family performance data collected:** Sucrose content (CCS) is estimated using eight stalks, one from each of eight randomly chosen stools in a plot. Cane yield (TCH) is estimated on a family-plot basis using mechanical harvester and mobile weighing tipper. The selection index, net merit grade (NMG), is calculated using CCS, and TCH data. NMG expresses family performance relative to that of standard families or proven crosses, which are adjusted to a mean of ten. The NMG formula penalizes families with poor appearance grade and awards a bonus for high sucrose content.
3	1R	**Clones selected from best families:** Individual clone selection is based on visual appraisal for yield and appearance grade and on Brix (% soluble solids w / w in the juice) measured using hand held refractometers.
	Stage 2	**First clonal stage planted:** Single-row, single replicate, 10-m plots.
4	P	**First clonal stage data collected and top 30% of clones selected as "tentatives":** CCS is estimated using two random stalks in a plot. TCH is estimated for each clone using mechanical harvester and mobile weighing tipper. The selection index, NMG, is calculated using CCS and TCH data.
5	1R	**Data collected on "tentatives" and the top 20% selected:** CCS estimated using two random stalks in a plot. TCH is estimated for each clone using mechanical harvester and mobile weighing tipper. NMG is calculated using CCS and TCH.

[†] See Skinner (1967) for a more detailed explanation and calculation of NMG; the procedure to estimate CCS is outlined in a BSES (1984) publication.

Table 2. Selection rates, from Stage 2 to 3, of clones derived from different net merit grade (NMG) classes in Stage 1.[†]

Stage 1 NMG	No. of families selected in Stage 1	No. of clones selected Stage 1 to 2	% of clones selected Stage 1 to 2	No. of clones selected Stage 2 to 3	% of clones selected Stage 2 to 3	% of Stage 1 clones selected to Stage 3
9.0-9.9	19	53	2.7	2	3.8	0.11
10.0-10.9	54	379	7.0	26	6.9	0.48
11.0-11.9	36	486	13.5	36	7.4	1.00
12.0-12.9	18	304	16.9	23	7.6	1.28
≥ 13.0	11	191	17.4	26	13.6	2.36
Total	138	1413	10.2	113	8.0	0.82

[†] See Table 1 for a description of NMG and selection Stages.

Table 3. Gain from different selection strategies in Stage 1 as measured by performance in Stage 2. [†]

Selection strategy [‡]	Appraised Stage 1	Evaluated Stage 2	With NMG > 9.0 Stage 2 [§]	Gain, %
	.....No of clones.....			
Individual clone	2444	340	51	15.0
Family (F)	944	944	88	9.3
F + Visual grade	944	360	54	15.0
F + Visual grade + Brix	944	240	43	17.9

[†] See Table 1 for explanation on Stages of selection and NMG.
[‡] Only the top 40% of families are shown here.
[§] Clones with NMG > 9.0 are considered to be elite clones and are selected to the next stage.

Table 4. Correlation coefficients (r) between net merit grade (NMG) and Best Linear Unbiased Predictor (BLUP), and between NMG and empirical method among crosses in sugarcane. †

No. of families	Year(s) of data used to estimate BLUP values	Year of data used to estimate NMG values	$r_{(NMG\ vs\ BLUP)}$	$r_{(NMG\ vs\ Empirical\ method)}$ ‡
81	1992-93 (2)	1994	0.62	0.45
97	1992-94 (3)	1995	0.63	0.50
173	1992-95 (4)	1996	0.65	NA

† See Table 1 for explanation on NMG.

‡ At least 10 years of data used to estimate empirical mean values.

Table 5. Mean net merit grade and standard deviation for families derived from parents arbitrarily categorized as old (O), medium (M), or new (N). †

Family category	No. of families	Net merit grade‡
OxO	21	5.31 ± 1.30 c
OxM	135	6.38 ± 1.47 b
OxN	22	6.17 ± 1.47 b
MxM	83	7.07 ± 1.74 a
MxN	30	7.05 ± 1.55 a
NxN	2	5.91 ± 1.42 abc

† Parents were arbitrarily categorized as old (O), medium (M), or new (N) if the seedling parent had a year prefix < 65, 65-74, or > 74, respectively; data averaged over four years.

‡ See Table 1 for explanation on NMG. NMG was calculated relative to standard clones in the trial. Usually, proven crosses are used as standard families.

§ Means followed by different letters are significantly different ($P > 0.05$); the NxN group had too few families to permit any reasonable comparison.

Figure 1. The shaded portions show areas where sugarcane is cultivated in Australia. The breeding stations operated by the BSES are located at Meringa (south of Cairns), Ingham, Ayr, Mackay and Bundaberg.

Figure 2. Percentage of elite Stage 2 clones resulting from different selection strategies in Stage 1. See Table 1 for explanation of selection stages and NMG.

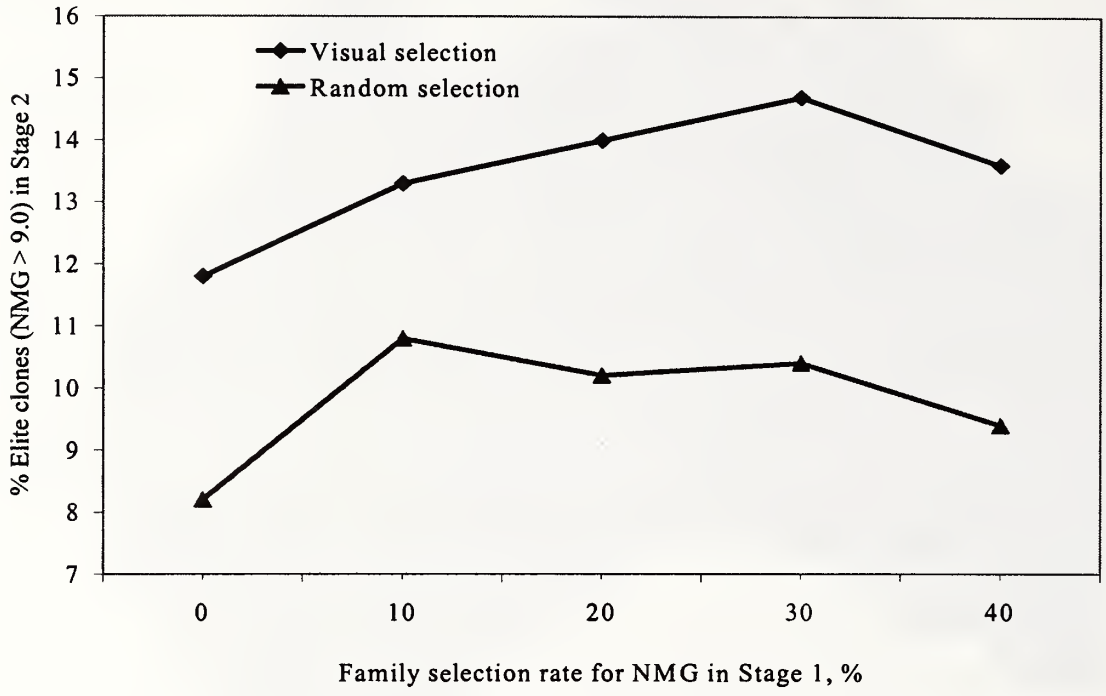


Figure 3. Population improvement in sugarcane: performance (NMG) of seedlings (Stage 1) relative to the cultivar Q151 from 1993 to 2000. See Table 1 for explanation of Stage 1 trials and NMG.

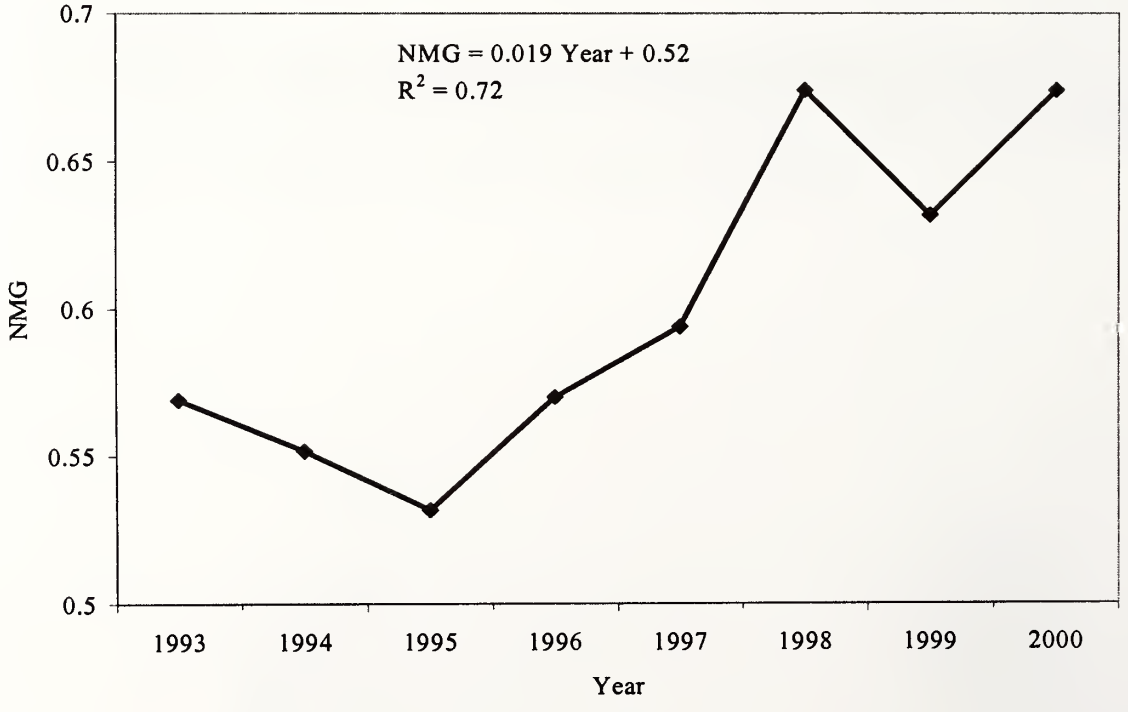
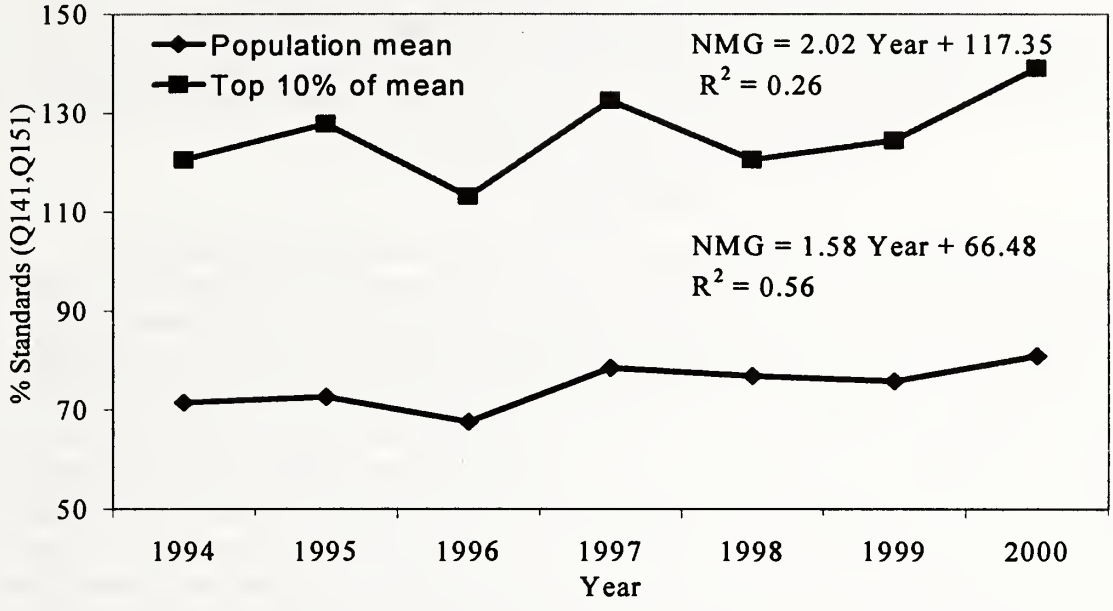


Figure 4. Population improvement in sugarcane: performance (NMG) of clones in Stage 2 relative to the cultivars Q141 and Q151 from 1994 to 2000. See Table 1 for explanation of Stage 2 trials and NMG.



REPEATABILITY WITHIN AND BETWEEN SELECTION STAGES IN A SUGARCANE BREEDING PROGRAM

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ABSTRACT

Aiming to obtain repeatability estimates ($r_{p(x)}$) to help in the identification of superior clones, six full-sib sugarcane families were evaluated in the first three of six clonal selection stages. The traits evaluated were: stalk length and diameter, stalk weight and number and Brix % cane juice. Results showed that, for stalk length and Brix, $r_{p(x)}$ estimates weren't significantly different between stages I and III and between II and III. For stalk diameter, stalk number and weight of stalks, there was a clear difference of $r_{p(x)}$ values between stages I and III and between II and III. These results indicate that, for phenotypic selection in stage I, priority should be given to Brix % cane juice and to stalk length in the first place, whereas from stage II forward, additional emphasis should be given to stalk diameter, number of stalks and weight of stalks. When the same selection stage is considered, repeatability estimates for each trait were also similar from plant to first ratoon, which indicates that selection for ratooning ability is not effective in the first two selection stages.

Keywords: sugarcane, repeatability, early selection

INTRODUCTION

New sugarcane cultivars are obtained through the selection of vegetatively propagated genotypes obtained from true seed, which is derived from the hybridization of superior parents. Selection is applied in all breeding stages: the choice of parents, cross combinations and the plant population originating from the crosses made (Skinner et al., 1987). Individual seedling selection during the initial stage is of low efficiency given the low broad sense heritability for the majority of traits (Skinner, 1982). It has been common practice in breeding programs to obtain phenotypic estimates for the traits under selection during the initial breeding stages. (Dudley and Moll, 1969; Skinner et al., 1987).

Repeatability estimates are utilized to measure the association of the same trait between different initial selection stages and crop cycles (plant cane and ratoons). Knowing these estimates helps to set up selection criteria for visual evaluation, which increases selection efficiency and reduces the risk of losing superior genotypes.

Studies with estimates of repeatability have been reported by Mariotti (1973) in Argentina, Miller and James (1975) and Milligan et al. (1996) in USA, Nageswara and Ethirajan

(1985) in India, Rodrigues (1986) in Colombia, Randoyal (1999) in Mauritius, and Bakshi Ram and Chaudhary (2000) in the West Indies, among others. Great variation in repeatability is observed among these studies, which indicates not only the influence of the environment on selection, but also a strong interaction between genotypes x environments and between genotypes x selection criteria.

The purpose of this work was to determine the estimates of repeatability for the more important traits in sugarcane, during the initial stages of selection and under the conditions of the breeding program in Braz

MATERIALS AND METHODS

The population utilized in this work was represented by the progenies of six bi-parental crosses (full-sibs), obtained at random from the Copersucar Breeding program, involving 12 different parents from the germplasm bank at Camamu, Bahia, Brazil. Seedlings obtained from each of the six crosses were planted in three experiments, one each year, in order to represent the first three selection stages of a total of six in the COPERSUCAR selection program. All experiments were planted in a randomized block design, with four replicates, and k genotypes (seedling or clone) within plots according to Steel and Torrie (1980), with k equal to 70 seedlings in experiment 1, 20 in experiment 2, and 10 in experiment 3. Sub-plot size varied from one stool spaced 0.5 m in the row in experiment 1, to one furrow two meters long in experiment 2, and then to two furrows six meters long in experiment 3. In all three experiments, rows were 1.4 m apart and the subplot sizes were the same as those used in the first three stages of selection in the Copersucar breeding program.

Twelve months after planting in the plant-cane stage, and 12 months after harvesting of the plant cane for the first-ratoon stage, we measured the following traits in the whole plot of each individual plant (sub-plot): stalk height (cm), stalk diameter (1 to 9 grade obtained with a cm-scaled rule, with 1 being the thickest diameter and 9, the thinnest one), stalk number, weight of stalks, and Brix % juice.

The repeatability estimates ($r_{p(x)}$) were obtained between crops and between selection stages. According to Falconer and Mackay (1996), $r_{p(x)}$ determines the upper boundary of the broad-sense heritability (h^2_a), and was estimated using the following expression:

$$r_{P(x)} = \frac{V_G + V_{EP}}{V_P}$$

where $r_{P(x)}$ represents the repeatability of trait x, V_G represents the genetic variance, V_{EP} is the permanent environmental variance and V_P is the phenotypic variance.

If V_{EP} is zero, $r_{P(x)} = h^2_a$. The permanent environmental variance occurs when data is collected and replicated over time in the same experiment, as is normal in sugarcane crops harvested over several ratoons. In vegetatively propagated crops like sugarcane, there is also the possibility of transmission of non-genetic effects (V_{EP}) with propagation. These effects

would appear in the next stage among the clones (Skinner, 1962). In this situation, repeatability among stages of selection has been used in sugarcane breeding.

The estimates of repeatability in each of the experiments, from the analysis of variance (Steel and Torrie, 1980), considered that seedlings or clones gave rise to two data sets (plant and ratoon stages) and was calculated as follows:

$$r_{P(x)} = \frac{\hat{\sigma}_P}{\hat{\sigma}_P^2 + \hat{\sigma}^2}$$

where $\hat{\sigma}_P^2$ is the estimate of the variance among seedlings or clones and contains the genetic variance among them plus the variance due to permanent environmental effects expressed in the two crop cycles (plant and ratoon). The term $\hat{\sigma}^2$ measures the environmental variance, at the sub-plot level, due to interaction between seedlings or clones with the crop cycles.

Estimates of repeatability between the experiments 1 to 3 (stage I to III) were obtained through covariance analysis (Steel and Torrie, 1980), as it involved data from different experiments, as opposed to the case with crop cycles. Thus, these repeatabilities correspond to the phenotypic correlation of trait (x) on a given stage and this same trait (x'), in other selection stages and cycles and were estimated as follows:

$$\bar{r}_{P(x)} = \bar{r}_{P(xx')} = \left(\frac{C\bar{\hat{o}}v_{P(xx')}}{\sqrt{\bar{\hat{\sigma}}^2_{P(x)} \bar{\hat{\sigma}}^2_{P(x')}}} \right)$$

where $C\bar{\hat{o}}v_{P(xx')}$ is the phenotypic covariance of trait x between experiments(stages), $\bar{\hat{\sigma}}^2_{P(x)}$ is the mean phenotypic variance of trait x and $\bar{\hat{\sigma}}^2_{P(x')}$ is the mean phenotypic variance of trait x'.

These analyses were first calculated for each cross and then after pooling for all crosses. For pooled data, a test for homogeneity among the estimates of repeatability between crosses was made and a χ^2 test was used to accept or reject it (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Estimates of repeatability in sugarcane are presented in Tables 1 to 5. Individual estimates for each cross are not presented separately since the differences for this group of crosses were not significant ($p>0.05$) based on χ^2 test for homogeneity. Table 1 shows that the highest values for repeatability of stalk length were observed between stage III-plant and stage I-ratoon and also between stage II-ratoon and stage I-ratoon. These estimates are similar to those presented by Mariotti (1973) in Argentina, who found $r_{p(x)} = 0.36$ for mean stalk length between stages I and II on first ratoon crop. On the other hand, Bakshi Ram and Chaudhary (2000) found estimates that varied from 0.15 to 0.21 between stage I and II plant cane for three open crosses.

Under these same conditions, Rodrigues (1986) observed estimates between 0.5 and 0.6 for $r_{p(x)}$ in the plant crop, while Randoyal (1999), using family means, found values of 0.59 and 0.60 for repeatability among plant cane and ratoon in stage I.

Table 1. Repeatability estimates for stalk length.

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.39**	0.37*	0.42**	0.43**
	Ratoon		0.32**	0.54**	0.56**
Stage II	Plant			0.38**	0.49**
	Ratoon				0.52**

** significant at the 0.01 level

The absence of significant differences of repeatability between plant-cane and first-ratoon crops in stages I and II indicates that selecting for stalk length could be done in the plant cane crop, which results in a higher selection gain per unit of time, given that the genotypes under selection will reach stage III two years after planting stage I. However, selecting for stalk length must be liberal, given that the correlation values between stages I and III and between stages II and III did not exceed 0.5.

Table 2 presents repeatability values observed for stalk diameter. Repeatabilities were slightly higher than those obtained for stalk length, with no difference between plant and first-ratoon crops. The repeatability observed between stages I and III were inferior to those observed between stages II and III, indicating that selection for this trait on stage I has low efficiency, particularly on ratoon crops. Our recommendation is that selection for stalk diameter on stage I should be very liberal, and more intense on stage II, where repeatability is higher. The repeatability values obtained in this study are close to those obtained by Rodrigues (1986) but inferior to those reported by Bakshi Ram and Chaudhary (2000), who found estimates between 0.84 and 0.90. We recommend that selection for stalk diameter should be made on plant cane in stages I and II..

Table 2. Repeatability estimates for stalk diameter

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.52**	0.58**	0.45**	0.45**
	Ratoon		0.47**	0.42**	0.37**
Stage II	Plant			0.53**	0.62**
	Ratoon				0.55**

** significant at the 0.01 level

For stalk number (Table 3), the highest repeatability occurred in stage II between plant cane and first ratoon, with $r_{p(x)} = 0.69$. Repeatabilities between stage I and II were low, close to those obtained for stalk length and inferior to those obtained for stalk diameter. However, between stages I and III and between stages II and III, repeatability values were higher than those obtained for stalk length and close to those obtained for stalk diameter. In this case our results are different from those of Rodrigues (1986) and Bakshi Ram and Chaudhary (2000), but similar to those of Miller and James (1975), who found repeatability values between stages I, II and III similar to those for stalk diameter (0.5).

Table 3. Repeatability estimates for stalk number

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.63**	0.34**	0.36**	0.41**
	Ratoon		0.39**	0.44**	0.46**
Stage II	Plant			0.69**	0.60**
	Ratoon				0.55**

** significant at the 0.01 level

Table 4 shows repeatabilities for Brix % cane juice. Here the $r_{p(x)}$ values obtained among all stages and crosses were uniform and high, with values greater than 0.60 in most cases, which indicates that Brix % cane juice is the character with highest repeatability in the initial stages of selection. The plant-cane crop had the most uniform results when compared to those obtained for the ratoon crop, with the highest values occurring between stages I and II, in plant cane. These values are higher than those reported in the literature (Mariotti, 1973; Miller and James, 1975; Nageswara and Ethirajan, 1985; Rodrigues, 1986; Bakshi Ram and Chaudhary, 2000).

Table 4. Repeatability estimates for Brix % cane juice.

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.45**	0.78**	0.72**	0.67**
	Ratoon		0.71**	0.68**	0.62**
Stage II	Plant			0.59**	0.70**
	Ratoon				0.67**

** significant at the 0.01 level

As a quantitative trait, resulting from other yield components (stalk length, stalk diameter and number of stalks), the weight of stalks had low repeatability values (Table 5). These values were small between stages I and II and between stages I and III, both for plant and ratoon crops.

Repeatability values between stages II and III were higher, however, indicating that weight of stalks in stage I should not be used as a direct selection criterion. Its components – stalk length, stalk diameter and number of stalks – should instead be preferred for selection in this stage.

Table 5. Repeatability estimates for stalk weight.

Stage	Crop Cycle	Stage I	Stage II		Stage III
		Ratoon	Plant	Ratoon	Plant
Stage I	Plant	0.48**	0.35**	0.36**	0.29**
	Ratoon		0.33**	0.42**	0.30**
Stage II	Plant			0.60**	0.57**
	Ratoon				0.53**

** significant at the 0.01 level

Based on the results obtained in stage III (which is the stage with the largest plot, lowest genotype x environment interaction and lowest competition between plots compared to previous stages) the following observations were made: (a) for stalk length and Brix, $r_{p(x)}$ values weren't significantly different between stages I and III and between stages II and III; (b) for stalk diameter, stalk number and weight of stalks, there was a clear difference of $r_{p(x)}$ values between stages I and III and between stages II and III. These results indicate that, for phenotypic selection in stage I, priority should be given to Brix % cane juice and to stalk length, whereas from stage II forward, additional emphasis should be given to stalk diameter, number of stalks and weight of stalks.

CONCLUSIONS

Brix % cane juice presented high repeatability values between stages I and III and also between plant-cane and first-ratoon crops. Particularly for this trait, individual selection can be intensified in stage I.

Stalk length showed low repeatability between stages I and II and intermediate repeatability between stages I and III and stages II and III, in both plant and ratoon crops. Given the similar values for $r_{p(x)}$ between stages I and III and stages II and III, we reached the conclusion that the same criterion utilized for selection on stage I can be applied on stage II.

The traits stalk diameter and number of stalks showed moderate repeatability among all stages and crops studied, with $r_{p(x)}$ values between stages II and III slightly higher than those between stages I and III, for both crops. In this scenario, selection for these traits in stage I should be less intense than in stage II, and it can be applied on plant cane.

Weight of stalks had low repeatability in stage I, and intermediate repeatability in stage II. Repeatability values were lower than those found for the number of stalks, stalk length and

stalk diameter in this study. As a recommendation, individual selection based on weight of stalks should be avoided in stage I, being applied only from stage II forward.

Regarding the plant and ratoon crop cycles, the values found for repeatability indicated that the individual selection could be applied on plant cane for both stages I and II, since the $r_{p(x)}$ values obtained were similar for plant cane and ratoon cane.

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REFERENCES

1. Bakshi Ram and B. S. Chaudhary. 2000. Individual and simultaneous selection for Brix yield in seedling populations of sugarcane. Sugar Cane International, Jun, 12-19.

2. Dudley, J. W. and R. H. Moll. 1969. Interpretation and use of estimates of heritability and genetic variances in plant breeding. Crop Science, Madison, 9:257-262.

3. Falconer, D.S and T. F. C. Mackay. 1996. Introduction to Quantitative Genetics. 4th ed. London: Longman, 464p.

4. Mariotti, J. A. 1973. Experiencias de seleccion clonal en cana de azúcar en la provincia de Jujuy. II – Repetibilidad y Heredabilidad de caracteres de interese agronómico. Revista Agronómica Norte Argentina, 10 (1-2):61-73.

5. Miller, J. D. And N. I. James. 1975. Selection in six crops of sugarcane. I – Repeatability of three characters. Crop Science, 15:23-25.

6. Milligan, S.B., K. A. Gravois, and F. A. Martin. 1996. Inheritance of sugarcane ratooning ability and the relationship of younger crop traits to older crop traits. Crop Science, 36:45-50.

7. Nageswara, R. A. O. and A. S. Ethirajan. 1985. Repeatability and predictability in progenies of crosses of high and low sugar cultivars of sugarcane. Indian Journal of Agricultural Science, 55(4):246-250.

8. Randoyal, K. 1999. Genetic correlation and repeatability for agronomic characters in sugar cane populations in contrasting environments and different crop years. Sugar Cane, Apr, 4-12.

9. Rodrigues, I. A. 1986. Influencia del sistema de cruzamiento en las poblaciones obtenidas de cana-azúcar. II – Repetibilidad de los principales caracteres. Boletín INICA, 2:1-10.

10. Skinner, J. C. 1962. Sugarcane selection experiments. *In*: International Society of Sugar Cane Technologists Congress, 11. Jakarta. Proceedings. Jakarta: The Organizing Committee, p. 561-567.

11. Skinner, J. C. 1982. Efficiency of bunch planted and single planted "seedlings" for selection of superior families in sugarcane. Euphytica, 31:523-37.

12. Skinner, J. C., D. M. Hogarth, and K. K. Wu. 1987. Selection methods, criteria and indices. *In*: Heinz, D.J. Sugarcane Improvement through Breeding. Amsterdam: Elsevier, p. 409-453.

13. Steel, R. G. D. And J. H. Torrie. 1980. Principles and Procedures of Statistics. A Biometric Approach. 2nd Ed. McGraw Hill. USA, 633p.

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ENHANCED SUGARCANE ESTABLISHMENT USING PLANT GROWTH REGULATORS

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ABSTRACT

Since sugarcane is vegetatively propagated, large amounts of seed cane are used in order to insure a good stand. Plant growth regulator compounds, often used as ripening agents, can cause sprouting at lower nodes. This response to growth regulators could lead to better stands at planting while possibly using less seed. Field studies were conducted over three years to determine the effectiveness of different plant growth regulator compounds and methods of application on emergence enhancement for several different sugarcane cultivars. In the first test, application of ethephon [(2-chloroethyl) phosphonic acid] or glyphosate [isopropylamine salt of N-(phosphonomethyl) glycine] to standing cane three weeks prior to cutting as seed had no effect, or decreased shoot counts in the sugarcane stand planted with this seed source. Ethephon application to the seed pieces in-furrow at planting at the standard seed cane planting rate tended to increase shoot counts in the new planting for the first four months, and stalk heights for five months after planting on some cultivars. In the second test, ethephon application in-furrow at planting at reduced seed cane planting rates increased shoot counts for up to nine months following planting but had very little effect on stalk heights, again only on some cultivars. In the third test in two commercial plantings, ethephon application had very little effect on shoot counts or stalk heights, but seed cane planting rates used by planting crews turned out to exceed recommended levels. Also, the two cultivars in these plantings may have been less responsive to ethephon than others used in the earlier tests. Even when seed cane planting rates in the commercial plantings were reduced by 32%, no differences in final shoot populations were found indicating that the planting rates used were much higher than necessary. Ethephon application to seed cane in-furrow at planting was effective in increasing tillering, but natural declines in shoot population when stalk growth rates were highest eliminated any benefit except where very low seed cane planting rates were used.

INTRODUCTION

Sugarcane is vegetatively propagated, therefore large amounts of seed cane are required for a new planting. The recommended planting rate is around 9 to 10 Mg ha^{-1}, but higher rates are often used. Fields used as a source of seed cane are lost for production that year, which takes out about 3% of all fields each year in Texas. While some sugarcane is planted mechanically, most is still planted by hand in Texas. Since a sugarcane crop will generally be grown for several years, it is important to insure a good stand. Therefore growers often plant very high rates of seed cane to make sure they have enough viable seed pieces for good field establishment.

Plant growth regulators (PGRs) act on sugarcane by modifying or retarding some aspect of cane growth (Alexander, 1973). PGRs are used to stimulate sugar accumulation in the stalk on

mature cane. Ripening using various growth regulating compounds is a common practice on sugarcane around the world (Eastwood and Davis, 1997), but only glyphosate [isopropylamine salt of–(phosphonomethyl) glycine] is used in the United States for this purpose. A common side effect of PGR application has been the formation of sideshoots from lower nodes. Sprouting of additional buds would result in more shoots and a better stand from the seed cane planted. Studies have indicated that certain plant growth regulator compounds increase tillering in newly planted sugarcane in greenhouse tests, but responses varied with cultivar (Bischoff and Martin, 1986; Eiland and Dean, 1985; Wong-Chong and Martin, 1983). In South Texas, dipping of seed pieces in a solution of ethephon [(2-chloroethyl) phosphonic acid) enhanced tillering of cultivar NCo 310 (Wiedenfeld, 1988). While dipping seed pieces may be effective, a more practical and economical application method would be desirable.

The objective of this study was to determine the effectiveness of different plant growth regulator compounds and methods of application on sugarcane emergence enhancement for several different cultivars.

MATERIALS AND METHODS

Field studies were conducted over a three year period in the Lower Rio Grande Valley of Texas, an area with a subtropical, semiarid climate (average annual rainfall - 500 mm). Soils are alluvial, medium textured (typically sandy clay loam) and calcareous.

During the first two years, tests were conducted on a Raymondville clay loam soil (Fine, mixed, hyperthermic Vertic Calciustolls) with a pH of 8.2. Treatments were applied to 5 sugarcane cultivars: CP70-321, CP71-1240, CP72-1210, CP80-1827 and TCP87-3388; and were applied in plots 6.1 m wide (4 rows spaced 1.5 m apart) by 9.1 m in length in randomized block designs with 6 replications. Treatments in the first year consisted of an untreated check, application of ethephon [(2-chloroethyl) phosphonic acid, Ethrel®, Rhone-Poulenc] or glyphosate [isoropylamine salt of N-(phosphonomethyl) glycine, Roundup®, Monsanto] to standing cane 3 weeks prior to cutting for seed cane, or application of ethephon in-furrow to the seed cane at planting (Table 1). Ethephon was applied at the rate of 119 g a.i./ha, and glyphosate was applied at the rate of 301 g a.i./ha. Seed cane planting rate was double stalk overlap plus about 25%, or approximately 3900 pieces 1.5 m long per ha, which is the recommended rate for South Texas (Rozeff, 1998).

Treatments the second year consisted of an untreated check or application of ethephon in-furrow to the seed cane at planting at the above rate, with seed cane planted at 2 different densities - single and double stalk overlap (Table 1). Cultivar CP80-1827, used the first year, was replaced with cultivar CP81-1405 the second year due to lack of response to treatments and because CP80-1827 is not widely grown while CP81-1405 was thought to have potential for use in the Lower Rio Grande Valley of Texas. The amount of seed cane planted was measured in the second year by weighing all cane planted in each plot.

The third year tests were conducted in two commercial plantings. The Hiler location was on a Hidalgo sandy clay loam soil (Fine-loamy, mixed, hyperthermic Typic Calciustolls, pH 8.3) using cultivar TCP87-3388, and the Beckwith location was on a Harlingen clay soil (Very-fine, montmorillonitic, hyperthermic Entic Chromusterts, pH 8.1) using cultivar CP70-1133. Treatments

consisted of an untreated check or ethephon application at the above rate applied to the normal rate of seed cane being planted by the commercial crews, or to a reduced cane planting rate (Table 1). The reduced rate was achieved by asking the commercial planting crews to plant at half of the normal rate. Treatments were applied in plots 1.5 m wide (1 row) by 30.5 m in length in randomized block designs with 3 replications at both locations. The third year, all seed cane planted was weighed in two 3 m sections of row in each plot.

Tests were furrow irrigated as required, and received herbicide application and mechanical cultivation for weed control each year. Shoot population counts were made by counting all shoots in two 3 m sections of row in each plot. Counts were initiated about 8 weeks following planting and continued periodically for a total of 10 to 16 counts until mid-August each year. Stalk height was measured on 3 stalks per plot in the first and second years, and on 2 stalks per plot in the two commercial tests the 3rd year. Stalk measurements were taken between 5 and 13 times in each study depending on the year. All data were analyzed statistically by cultivar using Analysis of Variance and Duncan's multiple range test.

RESULTS AND DISCUSSION

During each growing season shoot counts generally increased until a peak was reached, typically when maximum stalk growth rates were occurring, then tended to decline thereafter (Figs. 1-3). Highest average stalk growth rates approached 3.9 cm per day. Some differences in shoot counts and growth rates between cultivars were observed.

Ethephon application in-furrow tended to be the most effective at increasing shoot counts and heights in 1998 (Fig. 1). When a significant treatment effect occurred on shoot counts (20 out of 65 cultivar x date combinations) and plant heights (6 out of 25 cultivar x date combinations, Table 2), in-furrow ethephon application increased shoot counts 25% of the time, and increased stalk heights 67% of the time. Glyphosate application to standing cane appeared to have a detrimental effect on shoot counts at some dates. Where statistically significant treatment effects are indicated in Table 2, glyphosate application caused a reduction in shoot counts 95% of the time, and a reduction in stalk heights 50% of the time. Ethephon application to standing cane appeared to have very little effect. Treatment effects on shoot counts tended to disappear after about 4 months following planting. Treatments effects in this first test were most pronounced on cultivars CP70-321, CP70-1240 and CP72-1210; and were less evident or nonexistent on CP80-1827 and TCP87-3388. Amount of seed cane used in the first experiment was not measured, but planting rate was based on the "standard" recommendation which results in about 9 Mg/ha being planted. It was concluded that ethephon application in-furrow at planting was the treatment that showed the most promise based on the results obtained this first year. It was also observed that shoot numbers rose and then declined to an equilibrium level later in the season, indicating that the beneficial effects of ethephon on shoot emergence might be maximized at reduced planting rates.

Therefore, a standard double stalk overlap and a reduced single stalk overlap planting rate were used in the second test (Table 3) with and without in-furrow ethephon application. The beneficial effects of ethephon application occurred most dramatically at the reduced planting rate, increasing shoot counts in some cases up to the levels obtained at the higher planting rate without ethephon application in this study (Fig. 2). Where treatment effects were statistically significant on

shoot population (32 of 50 cultivar x date combinations, Table 4), 41% of those were due to ethephon application. Stalk heights were affected by treatment on only 6 of the possible 35 cultivar x date combinations, but on 5 of those 6 occasions the effect was due to ethephon application. Where significant treatment effects occurred on the parameters measured not attributable to ethephon application, the effect was due to differences in the amount of seed cane planted. Also, treatment effects on shoot counts persisted for 9 months after planting (Table 4). Cultivars CP71-1240 and CP72-1210 showed the greatest response to the ethephon treatment, as in the previous trial. TCP87-3388 shoot counts were affected by treatments applied in the second experiment, but the effect was almost entirely due to amount of seed cane planted. Differences between sugarcane cultivars in responses to PGR's has been routinely observed, making it necessary to calibrate PGR applications based on the response desired for each cultivar.

The rate of seed cane planted turned out to be higher than "recommended rates" in both commercial fields used in the 3rd experiment (Table 3). Some treatment effects on shoot counts were observed (Fig. 3) at one of the two locations up to almost 4 months after planting, but none were observed thereafter (Table 5). The cultivar TCP87-3388 used at the Hiler location showed little response to ethephon application in the prior tests while cultivar CP70-1133 used at the Beckwith location had not been tested in the first two years of this study.

CONCLUSIONS

This study indicates that ethephon application in-furrow at planting on sugarcane seed pieces does increase shoot counts and stalk heights on some cultivars, in particular CP71-1240 and CP72-1210. However, since shoot numbers in sugarcane tend to increase rapidly early during growth but then decline to an equilibrium level later in the season when the most rapid growth rates occur, the beneficial effects of the increased shoot counts that were caused early in the season tend to disappear. Only where substantially reduced planting rates are used does the benefit of the increased shoot counts persist through the entire growing season.

Another possible benefit of increased early season shoot counts and stalk heights would be to cause quicker canopy cover providing better competition over weeds. While glyphosate would not work for this purpose, ethephon may be a viable candidate for this use, although it would be necessary to determine whether the magnitude of the response would be adequate to provide the desired benefit.

Where reduced planting rates were used in the commercial sugarcane fields, no reduction in final shoot counts were obtained compared to the growers' standard planting rates regardless of ethephon treatment, indicating that these growers were using substantially more seed cane than is necessary to obtain maximum stands.

REFERENCES

1. Alexander, A.G. 1973. Sugarcane Physiology. A comprehensive study of the *Saccharum* source-to-sink system. pp. 443-464. Elsevier Scientific Publishing Co., Amsterdam.

2. Bischoff, K.P. and F.A. Martin. 1986. The response of saccharum species to growth regulators used as tillering agents. LSU Sugarcane Research Annual Progress Report, p. 54.

3. Eastwood, D. and H. B. Davis. 1997. Chemical ripening in Guyana - progress and prospects. Sugar Cane. 1997(3):4-17.

4. Eiland, B. R. and J. L. Dean. 1985. Growth regulator effects on sugar cane germination and tillering. J. Amer Soc. Sugar Cane Tech. (abstract) 5:112.

5. Rozeff, N. 1998. Preplant fertilization, seed cane and planting of sugarcane. *In*: N. Rozeff, J. M. Amador and J .E. Irvine. South Texas Sugarcane Production Handbook. Texas A&M University Research & Extension Center at Weslaco and Rio Grande Valley Sugar Growers, Inc., Santa Rosa.

6. Wiedenfeld, R.P. 1988. Effects of growth regulators on tillering, flower control and ripening of sugarcane in the Lower Rio Grande Valley of Texas. J. Amer. Soc. Sugar Cane Tech. 8:67-74.

7. Wong-Chong, J. and F.A. Martin. 1983. Greenhouse studies on the interaction of genotype and plant growth regulators with regard to early tillering in sugar cane. J. Amer. Soc Sugar Cane Tech. (abstract) 2:87.

Table 1. Description of treatments, planting densities, and cultivars evaluated vs variables in 3 experiments.

Season	Treatments	Plant densities	Cultivars	Planting dates
1998	untreated control	n.a.	CP70-321	7,8 Jan 98
	ethephon @ 119 g/ha (3 wks prior to cutting seed)		CP71-1240	
	ethephon @ 119 g/ha (in-furrow to seed)		CP72-1210	
	glyphosate @ 301 g/ha (3 wks prior to cutting seed)		CP80-1827	
			TCP87-3388	
1999	untreated control	single overlap	CP70-321	14-17 Dec 98
	ethephon @ 119 g/ha (in-furrow to seed)	double overlap	CP71-1240	
			CP72-1210	
			CP81-1405	
			TCP87-3388	
2000-01	untreated control	commercial	TCP87-3388	12 Aug 00
	ethephon @ 119 g/ha (in-furrow to seed)	reduced	CP70-1133	24 Aug 00

Table 2. Statistical significance of treatment effects on mean shoot population (pop) and height (hgt) measured for 5 sugarcane cultivars on various days after planting (DAP) in the first year.

		CP70-321		CP71-1240		CP72-1210		CP80-1827		TCP87-3388	
Date	DAP	pop	hgt	pop	hgt	pop	hgt	pop	hgt	pop	hgt
Mar 2	55	***	-	***	-	*	-	***	-	ns	-
16	68	***	-	***	-	**	-	*	-	ns	-
30	82	***	-	**	-	*	-	ns	-	ns	-
Apr 14	97	*	-	*	-	s	-	ns	-	ns	-
27	110	s	-	*	-	*	-	ns	-	*	-
May 11	124	*	-	*	-	ns	-	ns	-	ns	-
25	138	ns	-	ns	-	ns	-	ns	-	ns	-
Jun 8	152	ns	*	ns	ns	ns	*	ns	ns	ns	ns
22	166	ns	ns	ns	ns	ns	*	ns	ns	ns	ns
Jul 8	182	ns	ns	ns	*	ns	ns	ns	ns	ns	ns
20	194	ns	ns	ns	*	ns	s	ns	ns	ns	ns
Aug 3	208	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
19	224	ns	-	ns	-	ns	-	ns	-	ns	-

Differences between treatments means were statistically significant at the 10% (s), 5% (*), 1% (**) or 0.1% (***) level; or were not significantly different (ns).

Table 3. Seed cane planting rate for the different planting densities in the 2nd and 3rd years of the study.

Season	Location	Sugarcane Cultivar	Seed piece density[1]	
			low	high
			------- Mg/ha -------	
1999		CP70-321	3.6	7.0
		CP71-1240	4.5	9.1
		CP72-1210	4.4	9.1
		CP81-1405	4.5	8.8
		TCP87-3388	3.8	8.2
2000-01	Hiler farm	CP70-1133	9.0	13.4
	Beckwith farm	TCP87-3388	9.4	13.8

[1]Planting densities used in the 1999 crop were single (low) and double (high) overlap; and in the 2000-01 crop were a reduced (low) and a commercial (high) rate.

Table 4. Statistical significance of treatment effects on mean shoot population (pop) and height (hgt) measured for 5 sugarcane cultivars on various days after planting (DAP) in the second year.

		CP70-321		CP71-1240		CP72-1210		CP81-1405		TCP87-3388	
Date	DAP	pop	hgt	pop	hgt	pop	hgt	pop	hgt	pop	hgt
Feb 9	54	**	-	***	-	s	-	ns	-	***	-
Apr 12	116	*	-	***	-	***	-	ns	-	***	-
27	131	ns	-	***	-	**	-	ns	-	***	-
May 13	147	ns	-	***	-	**	-	ns	-	***	-
24	158	-	ns	-	*	-	ns	-	ns	-	ns
Jun 9	174	ns	ns	***	ns	***	s	ns	ns	**	ns
23	188	ns	ns	***	ns	***	ns	ns	ns	**	ns
Jul 7	202	ns	ns	***	ns	***	s	s	ns	*	ns
22	217	ns	ns	***	*	***	ns	ns	ns	ns	ns
Aug 4	230	ns	ns	***	ns	***	ns	ns	ns	**	ns
28	285	ns	ns	***	ns	***	ns	ns	s	*	ns

Differences between treatments means were statistically significant at the 10% (s), 5% (*), 1% (**) or 0.1% (***) level; or were not significantly different (ns).

Table 5. Statistical significance of treatment effects on mean shoot population (pop) and height (hgt) measured at 2 locations on various days after planting (DAP)in the third year.

Hiler farm TCP87-3388				Beckwith farm CP70-1133			
Date	DAP	pop	hgt	Date	DAP	pop	hgt
Oct 24	73	ns	-	Oct 24	61	ns	-
Dec 7	117	*	-	Dec 11	109	ns	-
Jan 2	143	*	-	Jan 2	131	ns	-
23	164	ns	ns	23	152	ns	-
Feb 6	178	ns	s	Feb 6	166	ns	-
Mar 1	201	ns	ns	Mar 1	189	ns	-
15	215	ns	ns	15	203	ns	-
26	226	ns	ns	Apr 2	221	ns	-
Apr 2	233	ns	ns	May 1	250	ns	ns
May 1	262	ns	ns	16	265	ns	ns
16	277	ns	ns	Jun 1	281	ns	ns
Jun 1	293	ns	ns	12	292	ns	ns
12	304	ns	ns	27	307	-	ns
27	319	ns	ns	28	308	ns	-
Jul 18	340	ns	ns	Jul 18	328	ns	ns
27	349	ns	ns	27	337	ns	ns
Aug 9	362	ns	ns	Aug 9	350	ns	ns

Differences between treatments means were statistically significant at the 10% (s) or 5% (*) level, or were not significantly different (ns).

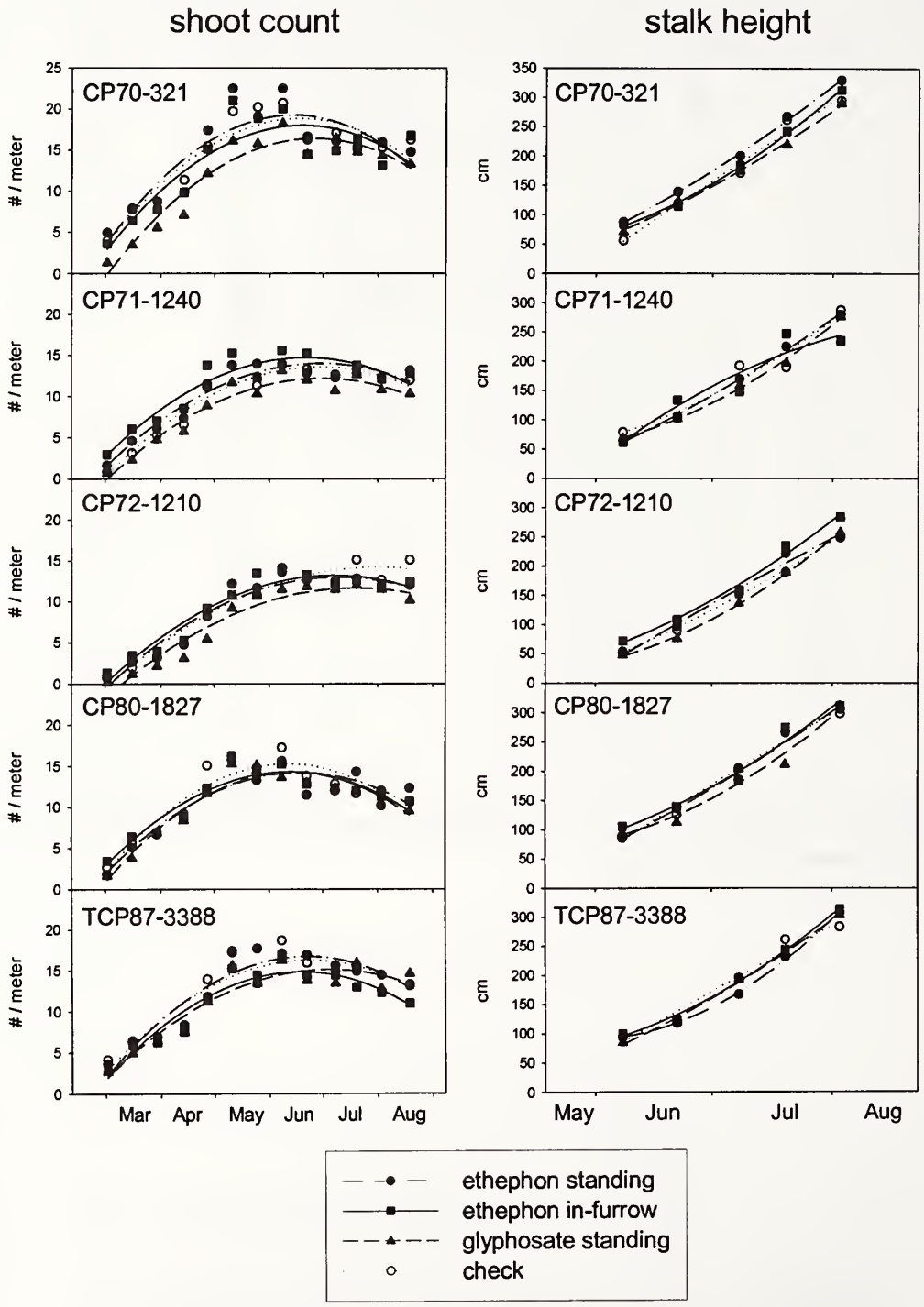

Figure 1. Sugarcane shoot counts and heights over time for different cultivars showing the effect of ethephon and glyphosate on standing cane and ethephon application in-furrow vs. a check in the 1st year of the study.

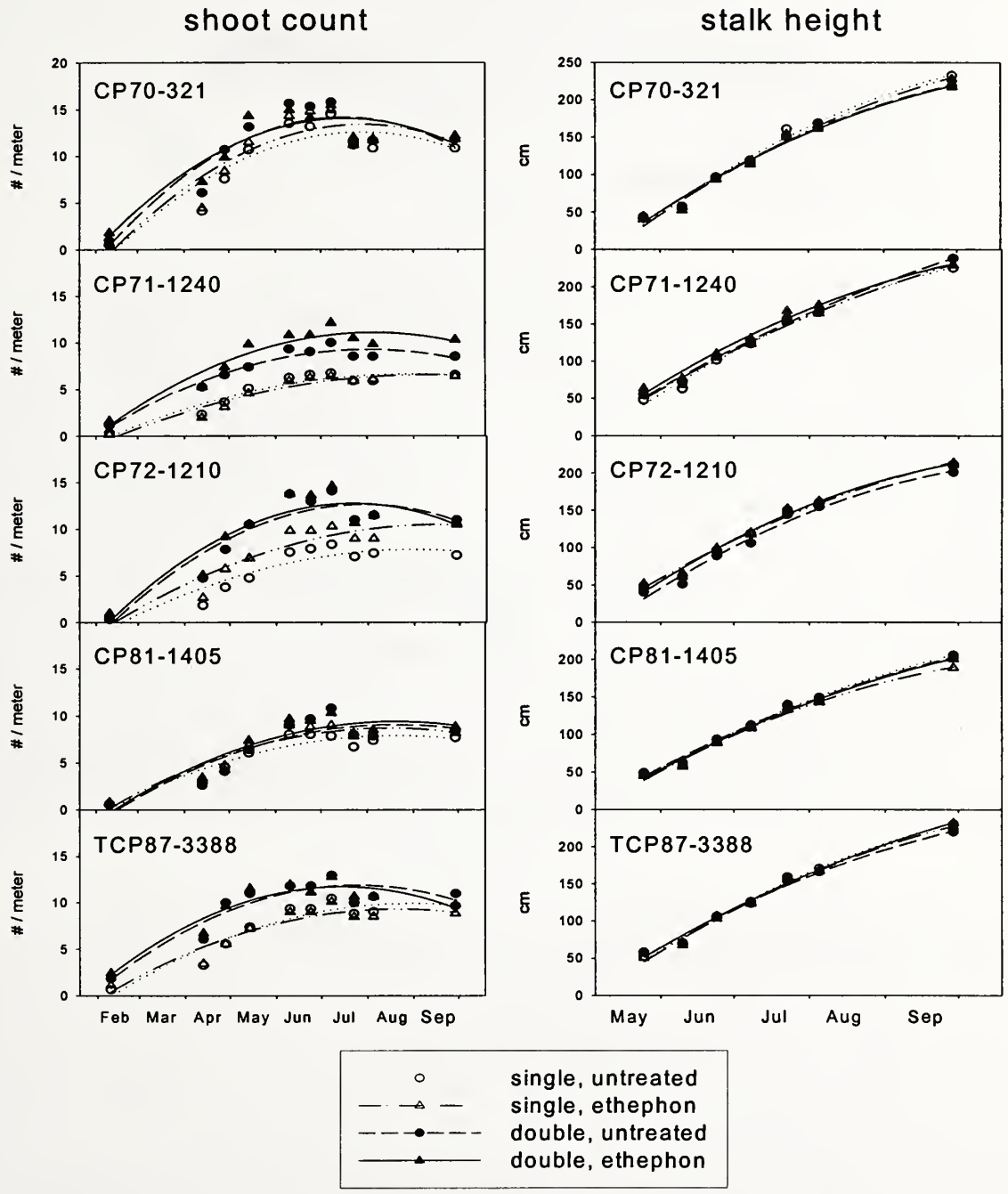

Figure 2. Sugarcane shoot counts and heights over time for different cultivars showing the effect of ethephon vs. untreated at single and double overlap planting rates in the 2nd year of the study.

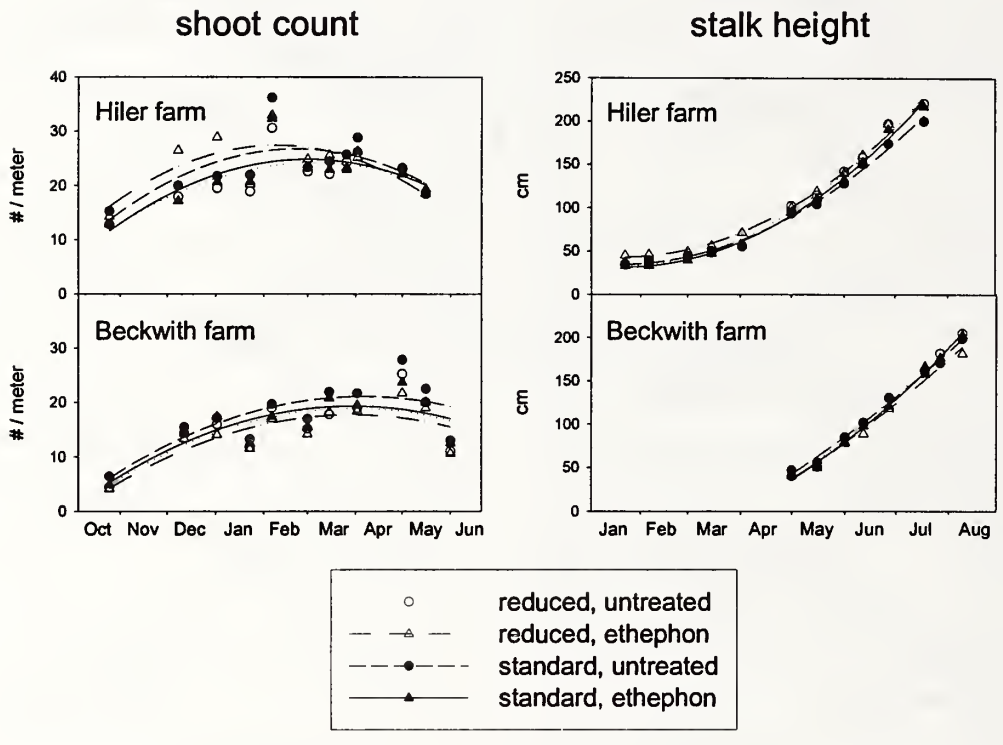

Figure 3. Sugarcane shoot counts and heights over time for two different locations and cultivars showing the effect of ethephon vs. untreated at reduced and standard planting rates in the 3rd year of the study.

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ESTIMATING THE FAMILY PERFORMANCE OF SUGARCANE CROSSES USING SMALL PROGENY TEST

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ABSTRACT

Improvement of sugarcane seedling populations by eliminating inferior progeny should increase the frequency of elite clones and increase the selection efficiency. The objective of this study was to evaluate the effectiveness of a progeny testing technique using a progeny performance test with a small number of seedlings per cross. Approximately seventy seedlings per cross from the seed germination tests of 1987, 1988, and 1989 cross series were transplanted to the field along with the regular seedling program. Selection rate and visual grade were assessed on each cross and forty seedlings were randomly selected for the measurement of stalk diameter, stalk number, stalk weight, and juice quality on each progeny. Selected Stage I clones were planted in Stage II tests for the measurement of juice quality. Multiple regression analyses were used to select the best predictive model for the progeny performance based on the selection rate. Results indicated that the frequency distribution of selection rates of all three cross series was markedly skewed toward higher performance in both small progeny tests and the regular seedling program. Stalk diameter was the best predictor of the selection rate within the regular seedling program. Information obtained from small progeny tests should help breeders select superior crosses to increase the incidence of elite clones for their regular seedling program.

INTRODUCTION

The Canal Point sugarcane variety development program (Tai and Miller, 1989) annually evaluates approximately 100,000 seedlings. Improvement of sugarcane seedling populations by eliminating inferior progeny would increase the frequency of superior seedlings and increase selection efficiency. Selection in original seedlings is intended to obtain some superior varieties, and to improve the average value of the whole population (Hogarth, 1987). There are numerous difficulties during the early stages of selection including the large number of clones, performance differences to be expected from single stools, later from the necessarily small plots, and the subjective nature of selection at this stage (Arceneaux et al., 1986). Numerous experiments have been conducted to assess the effectiveness of selection for a particular character or set of characters, the correlations between such characters, and prediction of response to selection (Brown et al., 1968; Hogarth, 1971; Miller and James, 1975; Miller et al., 1978; Tai and Miller, 1989; Walker, 1965). Walker (1965) reported that Brix is a better selection criterion because of its high correlation between stages, and stalk number is also a reasonably good selection criterion, but cane weight is not very reliable. Sugar content is poorly correlated at the two ages and no attempt is made to select

for high sugar in these early ages. Tai et al. (1980) reported that stalk number, stalk weight, Brix, sucrose percent, and sugar per ton of cane were highly repeatable between selection stages (Stages II and III), but tons of cane per hectare, and tons of sugar per hectare, were not repeatable between these two selection stages. In addition to selection for a single character, the selection index can be used by combining many important characters into a single measure (Hogarth , 1987). Miller et al. (1978) used stalk length, stalk diameter, stalk number, and Brix to construct a selection index for tonnes of sugar per hectare. Direct measurement of many important characters of sugarcane is time consuming and expensive. Sugarcane breeders have used grading systems (visual rating) to evaluate the potential commercial value of clones (Skinner, 1967). Grading is less accurate but less expensive than the selection index.

Several methods have been proposed for estimating the potential of sugarcane families to produce superior seedlings (elite genotypes), including factors for superior performance (FSP) by Arceneaux et al. (1986), the probability of exceeding a target value (PROB) (Milligan and Legendre, 1991), and a univariate cross prediction method (Chang and Milligan, 1992). The factors for superior performance (FSP) method is easy to use, but a FSP value can only be obtained after the original seedlings have been carried through all stages of selections. The univariate cross prediction method described by Chang and Milligan (1992) requires extensive data collection.

The selection percentage is a measure of the overall merit of the cross which represents all the aspects of desirability considered in these stages and the weight given to each component character by the selector (Walker, 1963). A high selection percentage indicates that the population had a high mean and/or variance for some or all desirable characters. Tai and Miller (1989) reported that selection rate between early stages of selection was highly correlated.

A progeny test with small number of individuals is routinely used to estimate the selection rate for the evaluation of proven crosses in sugarcane breeding programs in Australia (Hogarth, 1987). The progeny assessment trials also have been routinely used to identify the best families and select the superior clones from these families (Cox et al. 2000). Wu et al. (1978) studied the minimum sample size as the minimum number of individual sugarcane seedlings or stools necessary to estimate, with reasonable precision, mean and variance of a trial in a population and found forty individuals from a population to be the minimum sample size required to estimate the mean and variance for refractometer solids (Brix), stalk number, stalk diameter, or stalk length.

The objective of this study was to evaluate the effectiveness of using small numbers of seedlings per cross to estimate the progeny performance of families based on the selection rate.

MATERIALS AND METHODS

Progeny tests were established in each May of 1988, 1989, and 1990 by planting 70 to 100 seedlings per cross from the regular seed germination tests for 1987 (33 entries), 1988 (44 entries), and 1989 (29 entries) cross series, respectively. Those seedlings were transplanted to the field in two rows 1.5 m apart with 0.3 m between seedlings within a row. A visual rating (R1) (poor = 1, fair = 3, and good = 5) was made on each cross in early December of the same year. Data on stalk diameter (D1) were collected from up to five stalks for each of those 40 seedlings picked at random

in late December. Stalk diameter was measured near the mid-internode at 0.30 m above ground level and the number of millable stalks for each seedling was recorded. Stool weight (K1) was calculated by multiplying the stalk weight (W1) by the stalk number (N1). Data on stool weight were obtained from both the 1988 and the 1989 cross series. One stalk was cut from each of 40 seedling stools. The resulting 40-stalk bundle per cross was weighed and divided at random into two sub-samples, 20 stalks each, for juice analysis. The average Brix or sucrose from the two sub-samples was used for all statistical analyses.

Selection using the same criteria as the regular seedling program (Tai and Miller, 1989) was conducted in early January. Selection rate from the progeny test (SR1) (%) was computed as: (selected seedlings/number of seedlings of each progeny sample) X 100. Approximately 600 to 1,000 seedlings for each of those same crosses used in the progeny test were planted in the regular seedling program in the following year (CP 90, CP 91 and CP 92 clones selected from 1987, 1988, and 1989 cross series, respectively) . Selection rates for the regular seedling stage (SR2) (%) were computed as: (selected seedlings/number of regular seedlings per cross) X 100. One stalk (approximately 1 m long) from each of those selected seedlings was cut in January each year and planted as Stage I in a single-row plot in 1.5 m between rows and 0.6 m apart between plots. Plant-cane selection of Stage I clones was conducted in September of each year. Selection rate for Stage I (SR3) (%) was computed as (selected Stage I clones/original seedlings per cross) X 100. Each selected Stage I clones was advanced to Stage II (Tai and Miller, 1989). An eight-stalk seed cane sample was cut from each selected clone in Stage I and used to establish a 2-row plot 4.6 m long and 1.5 m wide in Stage II in October each year. Juice quality data were based on the Stage II samples harvested the following October. Juice quality was not measured on selections made in Stage I, the average of juice quality measurements from Stage II clones in each cross was used for all statistical analyses.

Predicting the selection rate (%) for progeny sample (SR1), regular seedling (SR2), and Stage I (SR3) was made by regression analysis (SAS, 1988) using the progeny assessment data on stalk diameter, stalk weight, and visual rating. The multiple regression of dependent variables, selection rates (SR1, SR2, and SR3), on stalk diameter (D1), stalk weight (W1), stalk number (N1), stool weight (K1), and visual rating (R1) based on the progeny test for each cross series were analyzed. The GLM procedure (SAS, 1988) was used to select the best predictive models for SR1, SR2 or SR3.

RESULTS AND DISCUSSION

The seedlings of the regular Seedling Stage generally had lower stalk weight and juice quality than the selected Stage I clones tested in Stage II (Table 1). Visual rating of three cross series ranged from 3.48 to 4.0 and their selection rates exceeded 20%. The results also indicate that the plant measurements for stalk characters and juice quality factors in Seedling Stage were smaller than those in Stage II. Those differences could be due to the plant development stage and the growth environment. The seedlings were developed from the true seed with a limited food supply while Stage II clones developed from buds with adequate food supply from the cane stalks. DeSousa-Vieira and Milligan (1999) showed that the plant spacing greatly affects stalk number and its variances.

Progeny tests suggest that a visual rating (R1) was closely associated with stalk diameter (D1) ($r = 0.43^{**}$ for 1987 cross series, $r = 0.37^{**}$ for 1988 cross series, and $r = 0.65^{**}$ for 1989 cross series), while R1 was not consistently associated with stalk weight (W1) ($r = 0.83^{**}$ for 1987 cross series and $r = 0.41^{**}$ 1989 cross series were significant, but $r = 0.24$ for 1988 cross series was not significant, Table 2). D1 and W1 were positively correlated. Both the selection rate for progeny sample (SR1) and the selection rate for the regular seedling (SR2) were closely correlated with either D1 or W1 in both the 1987 and 1989 cross series. Both selection rates, SR1 and SR2, were strongly affected by both D1 and W1 as shown in both the 1988 and 1989 cross series, while the selection rate for the Stage I clones (SR3) was affected by neither trait. In most crosses, R1 was not significantly correlated with SR1, SR2, or SR3. SR2 was positively associated with SR3 in three cross series.

Correlations of juice quality between the progeny tests and selected Stage I clones were inconsistent. The 1987 crosses gave significant correlations while 1988 and 1989 cross series were not significant (Table 3). The inconsistency could be due to both plant growth stages and field environment (DeSousa-Vieira and Milligan, 1999). The seedlings and Stage II were planted at a very different intra-row spacing. This may explain why the selection rate from Seedling Stage to Stage I was not well correlated to stalk weight. The stalk diameter varied considerably among individual seedlings within a cross. Also the composite stalk sample, which consisted of one stalk per seedling stool, would not have an equal amount of cane juice or cane stalk weight representing each stool. The measurement may not closely represent the juice quality of seedlings. Maturity, which also varied considerably among seedlings and between crosses, would affect the quality of cane juice. Correlations between traits shows they were changing rather than static and would be affected by cane growth and maturity (Dodonov et al. 1987; Tai et al. 1996). Family selection based on the mean of some traits may not be very effective in the early stages of selection. The selection rate between Seedling Stage and Stage I was significantly correlated in all three series of crosses as reported earlier by Tai and Miller (1989). The results suggest that family selection based on the selection rate should be effective. The larger the number of superior families included in the Seedling Stage, the higher percentage of superior individual clones will be potentially selected for the Stage I and the subsequent selection stages.

The multiple regressions for SR1, SR2, and SR3 are summarized in Table 4. The best regression models varied among the progeny test, Seedling Stage, and Stage I. Results indicate that the selection rate would be heavily dependent on stalk diameter D1 and $(D1)^2$ in the Seedling Stage. Other predictor variables were not chosen for the model for SR2 in any of the three cross series. Both the 1987 and 1989 crosses had very similar regression models for SR2, but they differed from that of the 1988 crosses. The quadratic regression model suggests that seedlings with either very thin or very thick stalks would drastically reduce the selection rate (Fig. 1). Seedling populations with an average stalk diameter between 21 and 25 mm would produce the highest selection rate. Predictor variables, stalk diameter (D1) and stalk number (N1), were chosen for the model for SR3 in the 1988 cross series and (R1)(W1) was chosen for the model in the 1989 cross series, but no predictor variable was chosen for the model for SR3 in 1987 cross series. The difference in the prediction models for SR2 and SR3 could be due to many factors. Stalk size of Stage I clones is generally much larger than that of the Seedling Stage due to selection for larger stalk diameter in the Seedling Stage (Tai and Miller, 1989). The selection criteria in Stages I and II emphasize other characters, such as stalk number, stalk shape, growth habit, solidness, plant height, etc, versus stalk diameter.

Both stalk number (N1) and rating (R1) x stalk weight (W1) appeared to be more predictive of selection rate in Stage I than stalk diameter (D1) based on the progeny test. DeSousa-Vieira and Milligan (1999) pointed out that the predicted family gains for millable stalk number per plant, stalk length and stalk weight using widely spaced plants would be more accurate than using narrowly spaced plants.

A progeny test with a small number of seedlings per cross should eliminate some of the poor crosses before a large population of seedlings is planted for the selection program. Adjusted R-squares of some regression models were relatively small; therefore, the effectiveness of predicting the selection rate might be low. Further study is needed to improve the regression model to estimate the selection rate. Even though individual (mass) selection can be more effective in maintaining genetic diversity of the seedling population than family selection, individual selection may not be the most efficient way to manage a seedling program. The progeny test to assess the potential performance of seedling progeny should benefit the selection program by planting larger numbers of the best progenies in the regular seedling program.

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REFERENCES

1. Arceneaux, G., J. F. Van Breemen, and J. O. Despradel. 1986. A new approach in sugar cane breeding: comparative study of progenies for incidence of superior seedlings. Sugar Cane 1986 (1):7-10.

2. Brown, A. H. D., J. Daniel, and B. D. H. Latter. 1968. Quantitative genetics of sugarcane. II. Correlation analysis of continuous characters in relation to hybrid sugarcane breeding. Theor. Appl. Genet. 38:1-10.

3. Chang, Y. S., and S. B. Milligan. 1992. Estimating the potential of sugarcane families to produce elite genotypes using univariate cross prediction methods. Theor. Appl. Genet. 84:662-671.

4. Cox, M.C., D. M. Hogarth, and G. R. Smith. 2000. Cane breeding and improvement. In D. M. Hogarth,. and P. G. Allsopp (eds.). Manual of Cane Growing. Bureau of Sugar Experiment Stations, Brisbane, Queensland, Aust., pp. 91-108.

5. DeSousa-Vieira, O., and S. B. Milligan. 1999. Intra-row plant spacing and family x environment interaction effects on sugarcane family evaluation, Crop Sci. 39: 358-364.

6. Dodonov, G. P., D. A. Cherepanov, I. I. Raponovich, and O. S. Melik-Sarkisov. 1987. Variation and correlation of morphophysiological traits of sugarcane during ontogeny and their selection of seedlings. Soviet Agricultural Biology: Part 1 :Plant Biology 1987 (3):79-87. Allerton Press, New York.

7. Hogarth, D. M., 1971. Quantitative inheritance studies. II. Correlation and predicted response to selection. Aust. J. agric. Res. 22:103-109.

8. Hogarth, D. M. 1987. Genetics of sugarcane. In D. J. Heinz (editor), Sugarcane Improvement Through Breeding. Elsvier, New York. Pp. 255-272.

9. Miller, J. D., N. I. James, and P. M. Lyrene. 1978. Selection indices in sugarcane. Crop Sci. 18:368-372.

10. Miller, J. D., and N. I. James. 1975. Selection in six crops of sugarcane. I. Repeatability of three characters. Crop Sci.15:23-25.

11. Milligan, S. B., and B. L. Legendre. 1991. Development of a practical method for sugarcane cross appraisal. J. Am. Soc. Sugarcane Technol. 11:59-68.

12. SAS Institute. 1988. SAS/SAT User's Guide 6.03ed. SAS Inst. Inc., Cary, NC.

13. Skinner, J. C. 1967. Grading varieties for selection. Proc. ISSCT 12:938-949.

14. Tai, P. Y. P., J. D. Miller, B. S. Gill, and V. Chew. 1980. Correlations among characters of sugarcane in two intermediate selection stages. Proc. ISSCT 16:1119-1126.

15. Tai, P. Y. P., and J. D. Miller. 1989. Family performance at early stages of selection and frequency of superior clones from crosses among Canal Point cultivars of sugarcane. J. Am. Soc. Sugarcane Technol. 9:62-70.

16. Tai, P. Y. P., G. Powell, R. Perdomo, and B. R. Eiland 1996. Changes in sucrose and fiber contents during sugarcane maturation. Sugar Cane 1996(6):19-23.

17. Walker, D. I. T. 1963. Family performance at early selection stages as a guide to the breeding programme. Proc. ISSCT 11:469-483.

18. Walker, D. I. T. 1965. Some correlations in sugarcane selection in Barbados. Proc. ISSCT 12:650-655.

19. Wu, K. K., D. J. Heinz, H. K. Meyer, and S. L. Ladd. 1978. Minimum sample size for estimating progeny mean and variance. Crop Sci.18:57-61.

Table 1. Means and standard errors of some morphological and juice quality characters of small progeny tests and their selected Stage I clones from same crosses tested at Stage II.

Population†	Stalk			Visual rating	SR	Brix	Sucrose	Purity
	Diameter	Weight	Number					
	(mm)	(kg)			%			
1987 Crosses	22.17 ±0.29	0.62 ±0.05	-	3.48 ±0.18	23.92 ±2.45	14.07 ±0.14	9.60 ±1.49	67.63 ±0.91
CP 90 Stage II	-	1.39 ±0.08	-	-	1.24 ±0.17	16.19 ±0.13	12.33 ±0.23	75.90 ±0.77
1988 Crosses	20.81 ±0.24	1.10 ±0.07	3.12 ±0.08	3.97 ±0.17	20.36 ±1.67	15.85 ±0.13	13.77 ±0.20	85.92 ±0.60
CP 91 Stage II	-	1.88 ±0.05	-	-	1.84 ±0.44	17.70 ±0.08	16.57 ±0.16	92.69 ±0.61
1989 Crosses	24.35 ±0.34	0.88 ±0.06	3.86 ±0.08	4.00 ±0.15	23.72 ±0.21	17.35 ±0.17	16.22 ±0.36	93.38 ±1.71
CP 92 Stage II	-	1.63 ±0.09	-	-	2.93 ±0.21	17.76 ±0.17	15.97 ±0.29	89.87 ±1.21

†1987 Cross includes 33 seedling samples, 1988 Cross 44 samples, and 1989 Cross 29 samples. Stage I clones were selected from the original seedlings of same crosses and juice quality and stalk weight were measured on Stage II samples.

Table 2. Correlation between morphological characters and selection rating at various stages of selection.

		Progeny test					Seedling selection rate	Stage I selection rate
		Stalk Weight	Stalk number	Stool weight	Visual rating	Selection rate		
1987 Cross Series: df = 31								
Progeny:	Stalk weight (W1)	0.63**						
	Stalk number (N1)	-	-					
	Stool weight (K1)	-	-	-				
	Visual rating (R1)	0.43**	0.23	-	-			
	Selection rate (SR1)	0.51**	0.59**	-	-	0.32		
Seedling:	Selection rate (SR2)	0.55**	0.38*	-	-	0.31	0.38*	
Stage I:	Selection rate (SR3)	0.23	0.24	-	-	-0.09	0.29	0.72**
1988 Cross Series: df = 42								
Progeny:	Stalk weight (W1)	0.24						
	Stalk number (N1)	- 0.30*	- 0.12					
	Stool weight (K1)	0.01	0.78**	0.52**				
	Visual rating (R1)	0.37**	0.21	0.17	0.08			
	Selection rate (SR1)	0.44**	0.12	0.22	0.22	0.37		
Seedling:	Selection rate (SR2)	0.28	0.22	-0.12	0.13	0.13	0.15	
Stage I:	Selection rate (SR3)	0.10	- 0.05	0.17	0.06	0.14	0.06	0.29*
1989 Cross Series: df = 27								
Progeny:	Stalk weight (W1)	0.41*						
	Stalk number (N1)	0.06	0.09					
	Stool weight (K1)	0.74**	0.90**	0.52**				
	Visual rating (R1)	0.65**	0.48**	0.45**	0.56**			
	Selection rate (SR1)	0.78**	0.71**	0.36*	0.51**	0.24		
Seedling:	Selection rate (SR2	0.49**	0.42*	-0.19	0.26	0.44**	0.43*	
Stage I:	Selection rate (SR3)	0.37	0.36	-0.04	0.28	0.36	0.24	0.63*

*, **, Significant at P = 0.05 and 0.01, respectively.

Table 3. Correlation coefficients of juice quality characters between small progeny test and selected Stage I clones (CP 90 series from 1987 cross series, CP 91 series from 1988 cross series, and CP 92 series from 1989 cross series) tested in Stage II.

Correlation between†	Brix	Sucrose	Purity
1987 Crosses and selected CP 90 clones	0.40*	0.35*	0.36*
1988 Crosses and selected CP 91 clones	0.12	0.15	0.23
1989 Crosses and selected CP 92 clones	0.20	0.24	0.18

* Significant at P = 0.05.

† Data on Brix, sucrose, and purity were based on samples collected from Stage II test.

Table 4. Regression models for selection rate of small progeny test (SR1), regular Seedling Stage (SR2), and Stage I (SR3) for each of the three cross series.

Regression equation†	R^2
1987 Cross Series:	
$SR1 = -10.710 + 1.164(D1)(W1)$	0.46
$SR2 = -305.462 + 28.854(D1) - 0.622(D1)^2$	0.59
1988 Cross Series:	
$SR1 = -63.196 + 2.577(D1) + 0.233(D1)(N1) + 0.531(R1)(N1)$	0.58
$SR2 = -0.285 + 0.027(D1)^2$	0.47
$SR3 = 0.047 + 0.035(D1)(N1)$	0.35
1989 Cross Series:	
$SR1 = 526.900 - 25.126(D1) - 0.626(K1)^2 + 11.855(D1)(K1) - 28.239(W1)(N1)$	0.38
$SR2 = -435.283 + 39.631(D1) - 0.859(D1)^2$	0.59
$SR3 = 0.387 + 0.161(R1)(W1)$	0.53

†The models were picked using the stepwise regression procedure. Data on D1 = diameter (mm), K1 = stool weight (kg), N1 = stalk number per seedling, W1 = stalk weight (kg), and R1= visual rating used for constructing regression models were based on the progeny

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INCIDENCE AND SPREAD OF SUGARCANE YELLOW LEAF VIRUS IN SUGARCANE CLONES IN THE CP-CULTIVAR DEVELOPMENT PROGRAM AT CANAL POINT

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ABSTRACT

The incidence of sugarcane yellow leaf virus (SCYLV) in sugarcane clones increased the longer the clones were in the CP-cultivar development program and exposed to natural infection. During 1998 to 2002, the average incidence of SCYLV in Stage II clones was 30.1 %, while SCYLV incidence in Stage IV clones, in the program 3 years longer, was 55.6 %. A few clones had an incidence of SCYLV below 25 % by the time they were advanced to Stage IV. These clones may have partial resistance to the virus. The results have implications for breeding and selecting for resistance to the virus.

INTRODUCTION

Sugarcane yellow leaf syndrome was recognized in Hawaii in the 1980s and was subsequently observed in numerous countries (Comstock *et al.*, 2002b; Izaguirre-Mayoral *et al.*, 2002; Lockhart *et al.*, 1996; Lockhart and Cronje, 2000; Vega *et al.*, 1997; Viswanathan, 2002). Two different pathogens, sugarcane yellow leaf phytoplasma and sugarcane yellow leaf virus (SCYLV) have been associated with the sugarcane yellow leaf syndrome symptoms (Cronje et al., 1998; Lockhart *et al.*, 2000; Scagliusi and Lockhart, 2000). In Florida, only SCYLV has been reported (Comstock *et al.*, 1998). Disease losses of 25 % in Brazil in SP 71-6163 have been attributed to SCYLV (Vega *et al.*, 1997). Yield losses of 15 to 20 % also have been reported due to yellow leaf virus in Louisiana (Grisham *et al.*, 2002). Elevated Brix readings of juice extracted from the midribs of symptomatic leaves have been reported (Comstock *et al.*, 1994). Differences in leaf area, total reducing sugars, chlorophyll content, and sugar transport were observed between symptomatic and asymptomatic plants infected with SCYLV (Izaguirre-Mayoral *et al.*, 2002; Viswanathan, 2002). All reported changes negatively impact sugar yield.

Symptoms of SCYLV are more evident in mature and stressed plants (Lockhart and Cronje, 2000). Only isolated plants exhibit symptoms in Florida before the start of the harvest season that begins in mid-October. Symptoms start as the weather turns cooler in October-November, initially with the lower midrib of leaves 3 to 6 (counting from the top expanding leave downward) becoming yellow. The yellowing then expands into the leaf blade with necrosis starting from the leaf tip and progressing down the leaf blade becoming most evident in December until the end of the harvest season in March. During January through March, entire fields may appear yellowish.

This paper addresses SCYLV in the CP-cultivar development program in Florida. Symptoms of the syndrome were observed in 1994 in clones that were used in crossing at the USDA Sugarcane Field Station at Canal Point, Florida (Comstock *et* al., 1994). The presence of SCYLV was confirmed by a serological tissue blot assay using a SCYLV specific antibody (Comstock *et al.*, 2002a; Comstock *et al.*, 1999) and a reverse transcriptase polymerase chain

reaction assay using primers to detect the virus (Comstock *et al.*, 1998). There are no reports of the sugarcane yellow leaf phytoplasma in Florida.

The objectives of this paper are: 1) to determine the variability of incidence of SCYLV in clones in the CP-cultivar development program at Canal Point, Florida, 2) to determine if the incidence of SCYLV increases in the clones with time, 3) to determine if resistance exists in the current selection program and 4) to determine if natural infection can be used to select clones resistant to the virus.

MATERIALS AND METHODS

Surveys

Plants of sugarcane clones in Stages II through IV (four sequential years) of the CP-cultivar development program (USDA-ARS Sugarcane Field Station, Canal Point, Florida) were surveyed for the presence of SCYLV for 5 years, during 1998 through 2002. The number of clones, plants sampled, and locations of plots in the cultivar development program that were sampled during 1998 to 2002 are presented in Table 1. The incidence of SCYLV infection of the clones in each CP Series was an average of the incidence of all the clones based on the number of infected leaf samples divided by the total number of leaves sampled and assayed in that year and selection stage.

Tissue Blot Immunoassays

SCYLV infection was determined by assaying for the presence of the virus in the youngest fully emerged leaf by a tissue blot immunoassay using antibodies specific for the virus. Briefly, the leaf was removed from a plant and the leaf blade tissue was removed from the midrib. The basal portion of the midrib was cut with a sharp, razor-blade scalpel, and the freshly cut midrib was firmly pressed on a nitrocellulose membrane, leaving a clear impression of the leaf midrib on the membrane. One impression per leaf midrib was made. The membrane was serologically developed using SCYLV specific antibodies developed by B. E. Lockhart, University of Minnesota (Minneapolis) according to Schenck *et al.* (1997) except that Fast Blue was used as the enzyme substrate (Comstock *et al.*, 1998). A stereo-microscope was used to examine the leaf prints. Because SCYLV is located in the phloem, a sample was positive for the presence of the virus when the phloem bundles within the leaf print stained blue.

RESULTS AND DISCUSSION

The incidence of SCYLV infection among clones for each CP Series in Stage II through IV for years 1998 through 2002 is shown in Table 1. For each CP Series, the incidence of samples with SCYLV generally increased the longer the series was in the cultivar development program. The average yearly incidence of SCYLV infected clones in Stage II ranged from 25.6 to 32.0 % during the five years that they were sampled. The incidence of SCYLV infection among all clones that were advanced to Stage IV during the same period ranged from 41.2 to 66.8 % (Table 1). The average incidence of SCYLV in Stage II was 30.1 % for years 1998-2002 and increased to 55.6 % in Stage IV. These results plus the fact that the incidence of SCYLV among plants in grower's fields in Florida exceeds 85% clearly indicates a possible

threat of SCYLV in Florida. The virus is present in essentially all commercial CP-cultivars. The high incidence of infection in the selected population indicated that there is little resistance among CP sugarcane clones. Almost all parental clones used for crossing in the cultivar development program are infected with the virus or have symptoms indicating a lack of SCYLV resistance for the crossing program (Comstock *et al.*, 1998; Miller *et al.*, 1994).

In Venezuela, there were clear reductions in yield parameters between symptomatic and asymptomatic plants that are infected with the virus. However, without severe symptom development, the yield losses were not dramatic (Izaguirre-Mayoral *et al.*, 2002). In India, in similar comparisons of yield parameters between symptomatic versus asymptomatic plants, reduced stalk diameter, lower Brix readings, and lower photosynthetic rates were associated with symptomatic plants. SCYLV infection was based on visual symptoms and not on detecting the virus in test plants. However, serological tests confirmed the presence of the virus in most plants suspected of being infected in a separate diagnostic test (Viswanathan, 2002).

The incidence of SCYLV in the CP 95 through CP 98 Series clones is shown at each stage as they moved through the program from Stage II to Stage IV trials (Tables 2-5). Six individual clones (CP 96-1865, CP 97-1164, CP 97-1850, CP 97-1944, CP 97-1989 and CP 97-2068) had an incidence of SCYLV infection of 20 % or less in Stage IV. These clones presumably have some resistance to SCYLV infection, since there was equal opportunity for infection with other clones in field trials during the 7 years of testing after being derived from true seed. These clones with less than 20 % incidence of SCYLV infection apparently had a partial resistance. The clones had no common parentage.

The high increase in incidence of SCYLV in the cultivar development program indicates that little resistance has been incorporated using the present parental clones. An effort to introduce resistance from sources other than the CP clones presently used for breeding would assist in the development of SCYLV resistant clones. Clones of *Saccharum spontaneum* appear to be a good choice, since only seven of 100 clones surveyed in the World Collection at Miami were infected with SCYLV compared to 75 % of the *S. officinarum* clones (Comstock *et al.*, 2002a). Others have reported *S. spontaneum* clones as having a low incidence of infection (Schenck *et al.*, 1997). An alternative breeding option would be to use imported commercial clones that are reported resistant. Eight Hawaiian varieties (H varieties) with SCYLV resistance have been imported via the USDA quarantine for use in crossing. Additionally, several clones that appear to have partial resistance, since less than 25 % of the plants sampled were SCYLV infected in Stage IV, will be evaluated on their potential to produce resistant progeny. Their progeny also would be more commercially acceptable and therefore, more desirable than using wild *S. spontaneum* clones and imported commercial clones as parents.

A major restriction in incorporating resistance is a lack of an efficient method of inoculating plants to evaluate resistance. Although the spread of SCYLV is relatively fast, it is not fast enough to allow efficient screening of populations for the incorporation of resistance into a cultivar development program. Several years are required to insure adequate exposure of plants relying on natural infection by aphids. A period of 3-5 years to evaluate resistance restricts the cultivar development program. The low number of virus-free clones or clones with a low incidence of infection that remains after a 3-5 year exposure period is totally inadequate.

Methodology to inoculate massive numbers of plants using insectary aphids is needed but probably not feasible since the numbers of clones that can be evaluated will still be limited. Once the plants are inoculated, virus detection in plants is not a limitation since the tissue blot immunoassay allows the rapid determination of the presence of SCYLV in thousands of plants.

As an alternative to detecting resistant plants, a project to associate molecular markers with the resistance is in progress. If marker assisted selection can be developed for SCYLV resistance, the process for the development of resistant cultivars would be greatly enhanced.

REFERENCES

1. Comstock, J. C., J. E. Irvine, and J. D. Miller, 1994. Yellow leaf syndrome appears on the United States mainland. Sugar J. 56:33-35.

2. Comstock, J. C., J. D. Miller, and R. J. Schnell, 2002a. Incidence of sugarcane yellow leaf virus in clones maintained in the world collection of sugarcane and related grasses at the United States National Repository in Miami, Florida. Sugar Tech 3:128-133.

3. Comstock, J. C., J. D. Miller, P. Y. P. Tai, and J. E. Follis, 1999. Incidence of and resistance to sugarcane yellow leaf virus in Florida. Proceedings International Soc. Sugar Cane Technol. 23:366-372.

4. Comstock, J. C., M. Pena, J. Vega, A. Fors, and B. E. L. Lockhart, 2000b. Report of Sugarcane Yellow Leaf Virus (SCYLV) in Ecuador, Guatemala and Nicaragua. Plant Dis. 86:74.

5. Comstock, J. C., M. S. Irey, B. E. L. Lockhart, and Z. K. Wang, 1998. Incidence of yellow leaf syndrome in CP cultivars based on polymerase chain reaction and serological techniques. Sugar Cane 4:21-24.

6. Cronje, C. P. R., A. M. Timon, P. Jones, and R. A. Bailey, 1998. Association of a phytoplasma with yellow leaf syndrome of sugarcane in Africa. Ann. Appl. Biol. 133:177-186.

7. Grisham, M. P., Y-B. Pan, B. L. Legendre, M. A. Godshall, and G. Eggleston, 2002. Effect of sugarcane yellow leaf virus on sugarcane yield and juice quality. Proc. Int. Soc. Sugar Cane Technol. 24:434-438.

8. Izaguirre-Mayoral, M. L., O. Carballo, C. Aleste, M. Romano, and H. A. Nass, 2002. Physiological performance of asymptomatic and yellow leaf syndrome-affected sugarcane in Venezuela. J. Phytopathol. 150:13-19.

9. Lockhart, B. E. L., M. S. Irey, and J. C. Comstock, 1996. Sugarcane bacilliform virus, sugarcane mild mosaic virus, and sugarcane yellow leaf syndrome. Pages 108-112 in: Sugarcane germplasm conservation and exchange. B. J. Croft, C. T. Piggin, E. S. Wallis, and D. M. Hogarth, editors. Australian Centre for International Agricultural Research.

10. Lockhart, B. E. and C. P. R. Cronje, 2000. Yellow leaf syndrome. Pages 291-295 in: Rott, P., Bailey, R. A., Comstock, J. C., Croft, B. J. and Saumtally, A. S. (eds) A guide to sugarcane diseases. Centre de cooperation internationale en recherche agronomique pour le developpment (CIRAD) and International Society of Sugar Cane Technologists (ISSCT) Montpellier, France. 339 pp.

11. Miller, J. D., B. L Legendre, M. P. Grisham, J. C. Comstock, W. H. White, and D. M. Burner, 1994. Impact of leaf scald and yellow leaf syndrome on parental clones for use in 1994-1995 crossing season at Canal Point. Sugar Bulletin 72: 6, 19-22, 24-26, 28-29.

12. Scagliusi, S. M., and B. E. L. Lockhart, 2000. Transmission, characterization, and serology of a luteovirus associated with yellow leaf syndrome of sugarcane. Phytopathology 90:120-124.

13. Schenck, S., B. E. Lockhart, and J. S. Hu, 1997. Use of a tissue blot immunoassay to determine the distribution of sugarcane yellow leaf virus in Hawaii. Sugar Cane 4:5-8.

14. Vega, J., S. M. Scagliusi, and E. C. Ulian. 1997. Sugarcane yellow leaf disease in Brazil evidence of association with a luteovirus. Plant Dis. 81:21-26.

15. Viswanathan, R. 2002. Sugarcane yellow leaf syndrome in India: Incidence and effect on yield parameters. Sugar Cane Int. September/October pp. 17-23.

Table 1. Incidence of SCYLV in clones in the CP-cultivar development program.

	1998	1999	2000	2001	2002	Overall mean
Stage II						
Series	CP 97	CP 98	CP 99	CP 00	CP 01	
No. clones	1008	957	854	463	1423	
Leaves/clone	1 (2 dates)	1	1	3	1	
Location	CP Station	CP Station	CP Station	CP Station	CP Station	
% Positive[a]	25.6 %	38.3 %	27.8 %	32.0 %	27.0 %	30.1 %
Stage III						
Series	CP 96	CP 97	CP 98	CP99	CP 00	
No. clones	130	130	130	130	130	
Leaves/clone	20	10	10	10	10	
Location	Sugar Farms 46.7	Sugar Farms	Sugar Farms	-- --	-- --	
% Positive[a]	%	24.0 %	35.4 %	--	--	35.4 %
Location	--	Duda	Duda	Duda	Duda	
% Positive[a]	--	23.9 %	31.3 %	36.4 %	55.6 %	36.8 %
Stage III Inc.						
Series	CP 95	CP 96	CP 97	CP98	CP99	
No. clones	40	40	40	40	28	
Leaves/clone	20	10	10	10	10	
Location	Sugar Farms	Sugar Farms	Duda	Duda	Duda	
% Positive[a]	55.3 %	49.3 %	26.6 %	48.8 %	51.4%	46.3 %
Stage IV						
Series	CP 94	CP 95	CP 96	CP 97	CP 98	
No. clones	11	11	11	14	14	
Leaves/clone	80	40	40	40	40	
Location	Sugar Farms	Sugar Farms	Duda	Duda	Duda	
% Positive[a]	66.8 %	54.8 %	54.8%	41.2 %	60.2 %	55.6 %

[a] % positive is the number of leaves tested positive divided by the total number of leaves tested.

Table 2. Incidence of SCYLV in CP 95 Series clones during their advancement to Stage IV.

Clone	Stage II/1996*	Stage III/1997	Stage III Increase/1998	Stage IV/1999	Stage IV /2000
			%		
CP 94-2203	–	ND	0	2.5	42.7
CP 95-1039	+	100	92	100	82.0
CP 95-1076	ND	ND	ND	15	71.0
CP 95-1429	–	0	25	42.5	71.0
CP 95-1446	ND	100	ND	100	90.9
CP 95-1569	–	40	95	15	47.5
CP 95-1570	–	0	30	47.5	78.3
CP 95-1712	–	40	30	52.5	80.0
CP 95-1726	+	0	100	95	90.7
CP 95-1834	+	0	100	87.5	70.0
CP 95-1913	–	100	45	45	84.5

* A single leaf assayed per clone: + is positive and – is negative. ND = no data.

Table 3. Incidence of SCYLV in CP 96 Series clones during their advancement to Stage IV.

Clone	Stage II 1997*	Stage III 1998	Stage III Inc. 1999	Stage IV 2000	Stage IV ratoon/2001
			%		
CP 96-1161	++	80	70	52.5	90
CP 96-1171	–	75	100	ND	100
CP 96-1252	–	40	60	95	95
CP 96-1253	+++	100	100	100	100
CP 96-1288	+	55	90	47.5	100
CP 96-1290	–	20	10	27.5	32.5
CP 96-1300	+++	80	70	90	100
CP 96-1350	–	7	ND	55	75
CP 96-1602	–	45	50	35	100
CP 96-1686	–	50	30	100	42.5
CP 96-1865	+	10	0	0	17.5

* Each + or – indicates the number of leaves sampled per clone: + is positive and – is negative. ND = no data.

Table 4. Incidence of SCYLV in CP 97 Series clones during their advancement to Stage IV.

Clone	Stage II/ 1998 *	Stage III/1999	Stage III Inc./2000	Stage IV/ 2001	Stage IV ratoon/ 2002
		----------	%	----------	
CP 97-1068	– –	70	80	47.5	67.5
CP 97-1164	– –	10	0	0	2.5
CP 97-1362	– –	0	ND	47.5	80
CP 97-1387	+ +	90	ND	95	22.5
CP 97-1433	– –	10	50	72.5	ND
CP 97-1777	– –	30	0	20	47.5
CP 97-1804	– +	100	70	100	100
CP 97-1850	+ –	0	ND	2.5	12.5
CP 97-1928	– +	100	ND	50	97.5
CP 97-1944	– –	0	40	0	2.5
CP 97-1979	–	0	10	7.5	27.5
CP 97-1989	– –	0	ND	10	20
CP 97-1994	– –	0	0	97.5	42.5
CP 97-2068	– –	10	ND	26.7	7.5

* Each + or – indicates the number of leaves sampled per clone: + is positive and – is negative. ND = no data.

Table 5. Incidence of SCYLV in CP 98 Series clones during their advancement to Stage IV.

Clone	Stage II/ 1999 *	Stage III/ 2000	Stage III Inc. 2001	Stage IV/ 2002
		----------	%----------	
CP 98-1029	+	80	-	100
CP 98-1107	–	0	10	40
CP 98-1118	–	0	30	55
CP 98-1139	–	0	-	22.5
CP 98-1325	–	0	10	0
CP 98-1335	ND	0	-	100
CP 98-1417	–	70	-	15
CP 98-1457	+	-	100	95
CP 98-1481	–	-	-	12.5
CP 98-1497	–	10	-	65
CP 98-1513	ND	40	60	85
CP 98-1569	+	10	-	65
CP 98-1725	+	80	-	95
CP 98-2047	ND	-	80	92.5

* A single leaf assayed per clone: + is positive and – is negative. ND = no data.

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SECTION

EVALUATION OF A NEAR INFRARED SPECTROMETER FOR THE DIRECT ANALYSIS OF SUGAR CANE

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ABSTRACT

A FOSS InfraCana Near Infrared (NIR) spectrometer was installed at a Louisiana mill for the 2001/02 crushing season to assess its suitability for direct analysis of cane delivered to the mill. Analysis of cane by both wet disintegration and core press methods were used as the primary measurements. Calibration equations for pol, brix, fiber, moisture and ash in cane were produced. Values of standard error were excellent, and the prospects for the use of such an instrument for the accurate direct analysis of cane look promising.

INTRODUCTION

Currently, the core-press method (CPM) of analysis is used in Louisiana for determination of sugar cane quality. The results of these determinations are used to calculate the theoretical recoverable sugar (TRS), in lbs sugar per ton of cane. TRS is used to determine how much a given grower will be paid for a consignment of cane. Methods similar to core press are currently used in many other cane-growing regions such as Colombia, Trinidad, and the Philippines (Edye and Clark, 1996). Core press analysis requires a team of at least three analysts per shift, for two eight-hour shifts. The time required for sample turn-around is roughly four hours. Since this method is intensive both in terms of time and labor, sampling every load is impossible. Usually, moisture % residue figures are not finally generated until the end of the shift; this means that the nature of the cane is not known until well after it has entered the mill. The goal of this investigation is to improve the quality of cane analysis whilst decreasing overall seasonal cost.

The cost of cane analysis consists of personnel, supplies, and utilities. Supply costs include Octapol and/or ABC juice clarifier, glassware, and utilities. Loss of profit can result from inaccuracies in cane quality data and losses caused by mill stoppage. Increased rate of sampling and quicker analysis would not only result in a greater likelihood of achieving representative sampling, but may decrease down times caused by foreign material entering the mill. While examining new methodology, modern technology and high-speed computing has rendered near infrared reflectance spectroscopy (NIRS) worthy of inspection. The InfraCana uses large samples (5 to 15kg) so that sub-sampling for increased precision is unnecessary (Berding and Brotherton, 1996). It is necessary to point out that NIR spectroscopy and chemometrics can provide a result that is only as good as the data put into it. When calibrated using quality data, these new

instruments promise high-speed, increased analytical precision, and long-term net savings. These savings would directly improve profitability for both the farmers and the mills.

NIR technology has been validated for quality control use in a wide variety of industries, including forage, fiber, grain, and cereal. FOSS provided a prototype InfraCana NIRS system to the Audubon Sugar Institute, which was installed at Cinclare mill in Louisiana for the 2001-02 crushing season. The instrument was calibrated using data acquired via Direct Analysis of Cane (DAC), as specified in the International Commission for Uniform Methods of Sugar Analysis (ICUMSA 1994). The DAC results were compared to results achieved using the core press method. The NIRS was calibrated for pol, brix, fiber, moisture, ash % cane, and TRS using the WinISI (Infrasoft) Chemometrics software package. The results of this calibration equation were subject to cross validation between laboratory results and the NIRS predicted values. The results of this cross-validation were key in the evaluation of the instrument as an alternative to CPM for purposes of cane payment.

MATERIALS AND METHODS

The NIRS

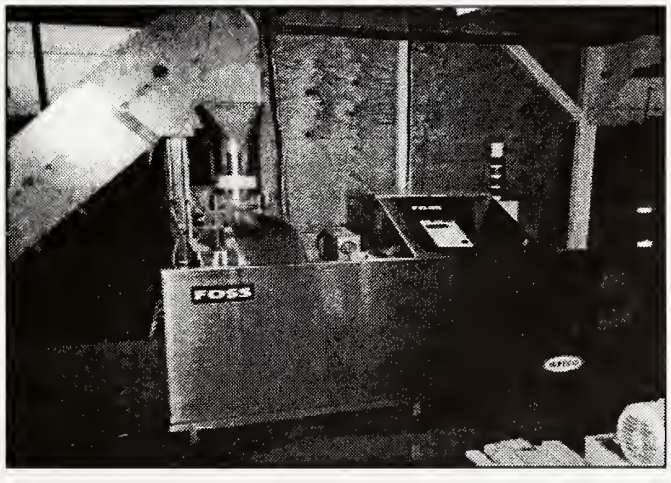

Figure 1. InfraCana Near Infrared Spectrometer.

The NIRS consists of four major components (Figure 1). The first, the sample conveyor, transfers a core sample evenly into the second component, the Jeffco Shredder. The fibrated sample is fed into component three, the read conveyor. Here, a cane-leveling device packs the cane into an even bed on a moving conveyor. When the cane bed is homogenous, infrared cane-height sensors tell the read head of the spectrometer to open, and to begin data acquisition. The average sample weighing 10kg will usually yield 60 total spectral replicates. Spectral scans are taken from 1100-2500nm until the cane height sensors indicate heterogeneity within the cane bed. The shutter on the read window snaps shut, a result "docket" is printed, and the fibrated cane is conveyed out of the instrument.

Acquisition of Laboratory Data

Samples of billeted cane were acquired using an inclined coring machine. A core sample consists of billets up to twelve centimeters in length, a sample weighing between five and twelve kilograms. Two core samples per truck were taken. One core sample was fibrated using the existing hydraulic shredder. The material prepared this way has approximately 65% open-cells, and is referred to as Core Shredded Material (CSM) (Figure 2). This sample was subject to analysis via CPM. The second sample was shredded using the Jeffco shredder built into the NIRS. Material thus prepared has approximately 95% open-cells; it is referred to as Jeffco Shredded Material (JSM) (Figure 3). This sample was automatically transferred to a second conveyor where the NIR spectra were observed, and the data were saved to hard drive. The sample was conveyed out of the instrument, where it was collected and subject to DAC.

Figure 2. Core Shredded Material.

Figure 3. Jeffco Shredded Material.

Sample Analysis

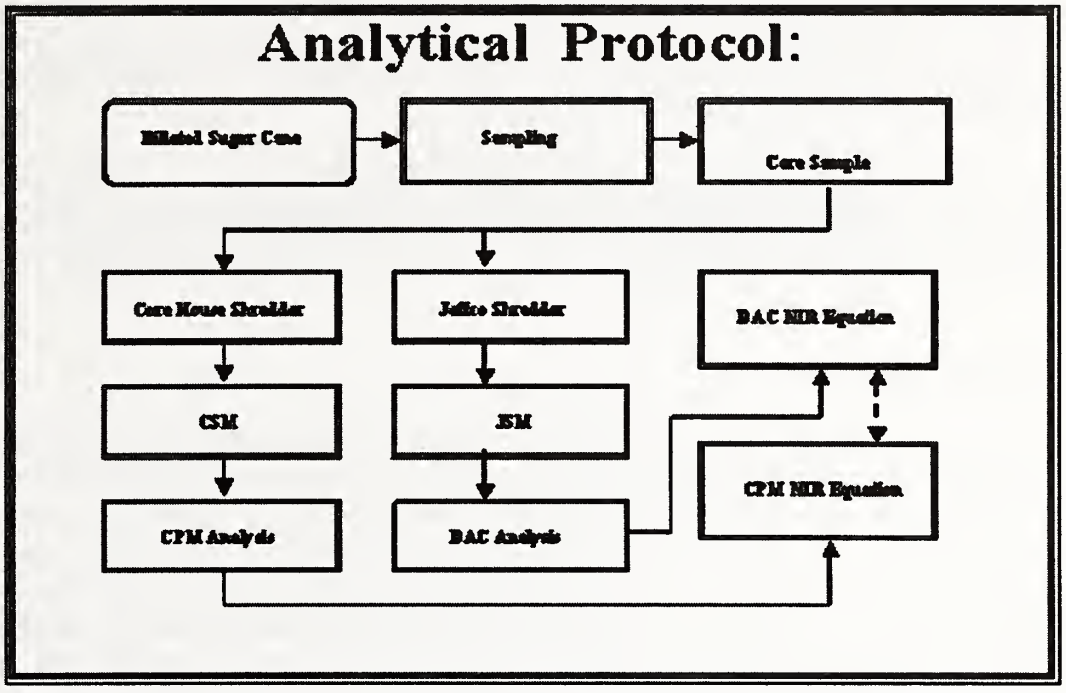

Figure 4. Flowchart of Analytical Protocol.

A flowchart describing analytical operations is included (Figure 4). A one-kilogram sample of JSM was weighed into a water-jacketed wet disintegrator pot. To this was added two kilograms of water. This deviation from ICUMSA DAC was necessary as Jeffco shredded material tends to absorb extraction water forming a sticky ball that does not macerate well; our wet disintegrator pot would not hold 6L. The sample was disintegrated for eight minutes at 7200 rpm. A 10g sample of the resulting extract was transferred into a 15mL conical centrifuge tube. This sample was centrifuged at 4000 rpm for ten minutes and analyzed for brix by refractometer. 100ppm Sodium azide was added as a preservative and sample was frozen. A 150mL sample of the extract was transferred into a glass jar. To the 150mL sample was added 19 grams of Octapol flocculent. The sample was shaken then filtered, whilst discarding the first 25mL of filtrate. The clarified filtrate was analyzed for polarimetric sucrose using an automatic saccharimeter. The frozen sample was taken back to the lab for sugar analysis (sucrose, glucose, and fructose) by HPLC. 500 grams of JSM were dried to constant weight, not to exceed -2g in 30 minutes (ICUMSA), at 105°C using a Deitert Moisture Teller forced draught air drier. The sample, once dried to constant weight, was placed into a plastic bag for storage and transport.

The results were used to calculate pol, brix, fiber, and moisture % cane. These figures were used to calculate TRS.

After the season, the stored dry matter was subjected to analysis for carbonated ash. All samples were analyzed in duplicate. The sample was placed into a tared dish, and a screen was placed over the top. The sample was incinerated at 650°C for 45 minutes. The sample was removed from the furnace, and allowed to cool to ~150°C. The screen was removed, and the dish containing the ash was weighed. The sample was carefully stirred and further incinerated at

650°C for ten minutes. The sample was removed from the furnace and allowed to cool. The sample was weighed, and transferred into a plastic bag for storage.

These data were used to calculate ash % cane. This number was subtracted from the fiber % cane to produce a figure for corrected fiber % cane.

The results from the core press analysis were provided by the mill administration. The given data provide pol and brix % juice, residue weight (from 1.0kg), and volumetric sediment. From these data were calculated pol, brix, fiber, and moisture % cane. These figures were used to calculate the TRS.

Calibrating the NIRS

Both of the data sets were entered into the WinISI software package. Here, the spectral results were matched to the laboratory data. Constituents for pol, brix, fiber, moisture % cane, and TRS were entered. The first derivatives of the spectral data were taken, and it was to these that the laboratory data is assigned. The data sets were regressed using a modified Partial Least Squares (PLS) algorithm. "Outliers" with a Global H value (distance from the global average) of more than three were re-evaluated. If the outlier was determined to result from anomalous spectral data, it was removed from the data set. For each constituent an equation was generated, and standard error of calibration (SEC) was calculated.

Ash % cane exhibits a logarithmic trend. To generate an equation that is not heavily biased by the average, this constituent was calibrated using the $\log_{10}$ of the laboratory data. The instrument then predicts ash % cane as a logarithm. The anti-log is taken, and the result subsequently produced. SEC and r^2 are produced for the $\log_{10}$ result.

The equations were used to evaluate a sample of the spectra. Here, lab results were compared with the NIR predicted values. This cross-validation is the final verification needed to determine if the equation produces representative predictions. The standard error of cross-validation (SECV) was used to determine the equation accuracy.

RESULTS

Laboratory results for DAC and CPM compared well. However, the pol % cane for CPM was always higher than that for DAC, as seen in Figure 5. This was attributed to extraction efficiency. DAC analysis used added water and provided more complete extraction. Fiber % cane for CPM values were, on average, between 10 and 17%. The DAC results displayed unusual spikes, ranging from 20 to 45%, as seen in Figure 6. Fiber % cane is a figure derived by difference from moisture and brix. As a result, any component other than water or brix will be seen as fiber % cane. Other components can include mud and/or trash. The spikes seen in the DAC-derived fiber % cane reflected the presence of mud, trash, or both.

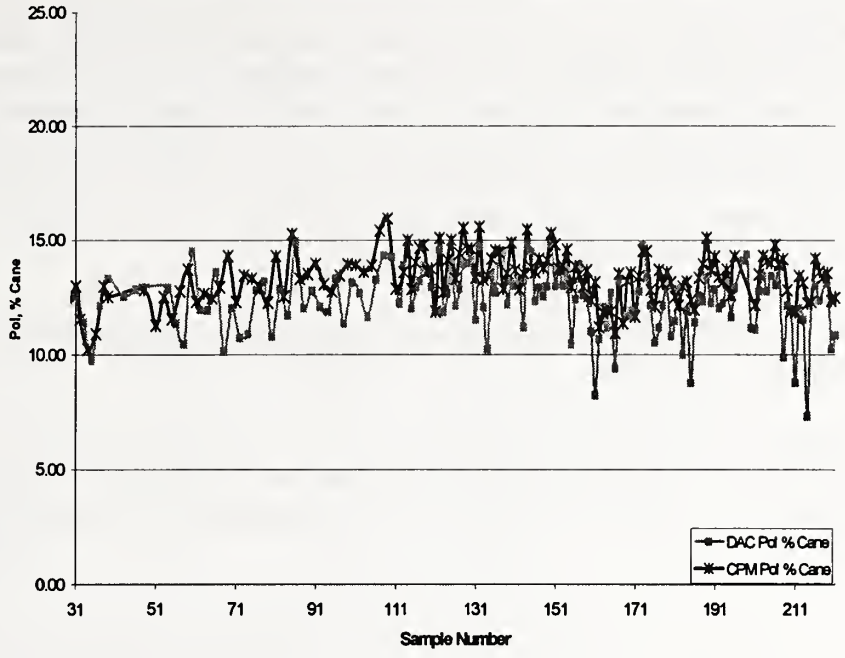

Figure 5. Pol % Cane, by core press method and by DAC. Arranged by parallel sample number.

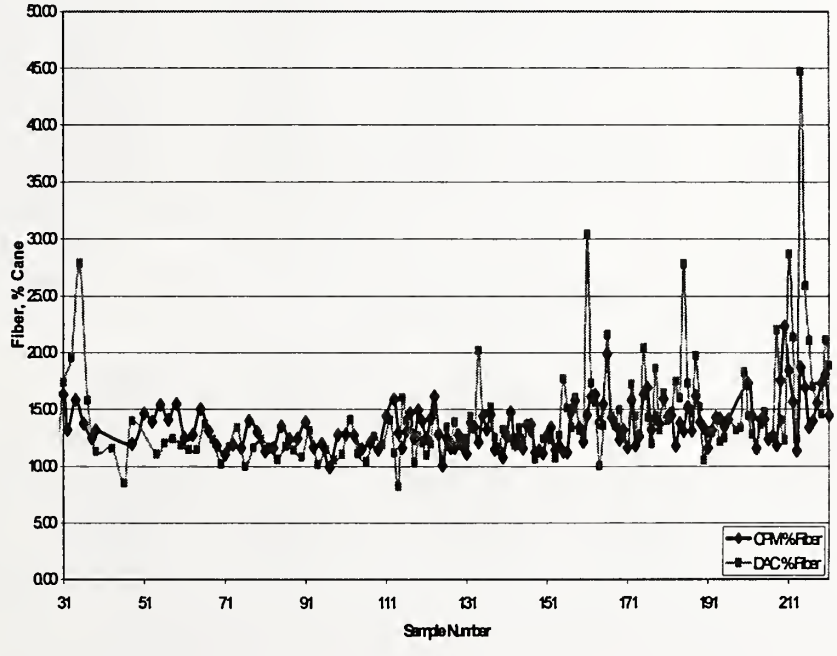

Figure 6. Fiber % Cane, by core press method and by DAC. Arranged by parallel sample number.

After calibration, the software calculated the standard error of calibration (SEC), and the square of the linear correlation coefficient r^2 (RSQ). The standard error of cross validation (SECV) refers to the compound error relating the differences between actual and predicted results. The constituent results for the calibration derived from DAC (Table 1) and CPM (Table 2) data sets demonstrated the effects of non-representative sampling. Both sets were based on the same spectra. Although laboratory data correlates reasonably well, SEC and RSQ demonstrate that the CPM results do not correlate well to the spectra.

The statistics for the DAC based NIR equation closely paralleled those found in literature (Table 3). A comparison of DAC results for SECV is given in Table 4.

The samples that were frozen were analyzed by HPLC for sucrose, glucose, and fructose. The results did not correlate with the pol sucrose. This effect was attributed to a lack of biocidal (NaN_3, 100ppm) efficacy; the samples biologically degraded during processing, storage and transport.

Table 1. NIR equation based upon DAC analytical data. N is the number of samples used, SEC is the standard error of calibration, RSQ is the linear correlation coefficient, SECV is the standard error on cross validation; 1-VR relates to the correlation on population variance.

Constituent	N	Mean	SEC	RSQ	SECV	1-VR
Pol%Cane	180	12.90	0.237	0.961	0.325	0.927
Brix%Cane	183	15.44	0.246	0.966	0.427	0.898
Moisture%Cane	170	71.49	0.489	0.912	0.592	0.870
Fiber%Cane	171	12.91	0.518	0.901	0.699	0.818
CRFiber%Cane	170	11.17	0.411	0.907	0.488	0.869
Logash%Cane	185	0.228	0.082	0.870	0.099	0.811
TRS	173	216.7	5.31	0.948	7.14	0.905

Table 2. NIR equation based upon CPM analytical data.

Constituent	**N**	**Mean**	**SEC**	**RSQ**	**SECV**	**1-VR**
Pol % Cane	194	13.16	0.507	0.648	0.579	0.545
Brix % Cane	182	15.66	0.379	0.793	0.431	0.733
Fiber % Cane	171	16.74	0.844	0.777	0.908	0.743
% Moisture	186	71.19	0.872	0.604	0.933	0.546
TRS	192	215.7	11.51	0.526	12.50	0.442

Table 3. Results for DAC derived NIR equation and the average literature values (Bentley, Staunton, Atherton, and Henderson, 2001; Berding and Brotherton, 1999; Edye and Clarke, 1996; Larrahondo, Palau, Navarrete, and Ramirez; Johnson, 2000; Schaffler, Staunton, Lethbridge, Grimley, Streamer, Rogers, and Mackintosh, 1999)

Constituent	N		SEC		RSQ	
	Our work	From Literature	Our work	From Literature	Our work	From Literature
Pol % Cane	**180**	970	**0.24**	0.14-0.44	**0.96**	0.94-0.99
Brix % Cane	**183**	985	**0.25**	0.25-0.44	**0.97**	0.95-0.99
Fiber % Cane	**171**	745	**0.52**	0.52-0.56	**0.90**	0.87
% Moisture	**170**	622	**0.49**	0.57	**0.91**	0.92-0.95
Ash%Cane	**185**	1340	**n/a**	0.44	**0.87**	0.78
TRS	**173**	n/a	**5.31**	13.13	**0.95**	0.84

Table 4. Results for DAC derived NIR equation and the average literature value of SECV.

Constituent	N		SECV	
	Our work	From Literature	Our work	From Literature
Pol % Cane	**180**	970	**0.33**	0.18-2.10
Brix % Cane	**183**	985	**0.43**	0.25-0.70
Fiber % Cane	**171**	745	**0.70**	n/a
% Moisture	**170**	622	**n/a**	n/a
Ash%Cane	**185**	1340	**n/a**	0.50
TRS	**173**	n/a	**7.14**	13.62

DISCUSSION

As seen in Tables 1 and 2, NIR equations calibrated on DAC and CPM analytical data sets agreed poorly. We believe that this results from the sample-to-sample variation that occurs between two different core samples taken from the same load. The inclined core sampler was designed for use with whole cane, whereby a 23kg sample may be achieved. When this method is used for billets, the cutting head scatters some of the cane, while achieving a sample of only 5-15kg. The small sample size resulted in increased sample heterogeneity; in effect, the DAC and CPM analyses were performed on two different samples, albeit from the same truckload. NIRS is fast enough to compensate for small sample sizes by analyzing a larger number of samples.

For each constituent, a range of cited values was given; see Tables 3 and 4. When compared, the DAC derived SEC, RSQ, and SECV for each constituent were within the ranges seen in the literature. The DAC % of LIT refers to the result of our calibration relative to the

average of the cited range for a particular constituent. Based upon analysis of these figures, the DAC based NIR equation performed at least as well as the literature cited. The SECV achieved for DAC calibrations were within the ranges found in the literature. These equations provided accurate as well as precise predictions relative to the laboratory results, as seen in Figures 7- 9.

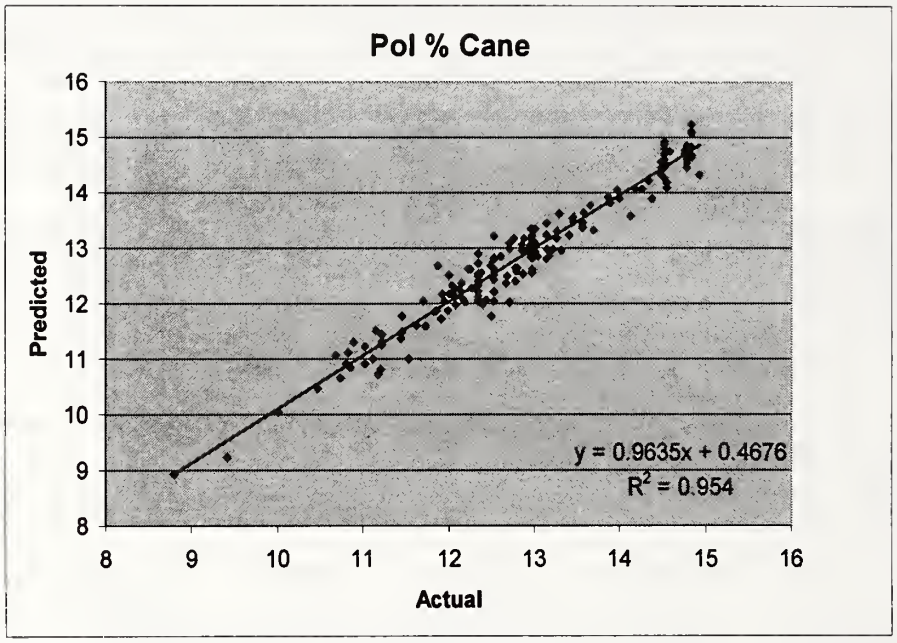

Figure 7. Pol % cane, DAC lab result vs. NIR prediction.

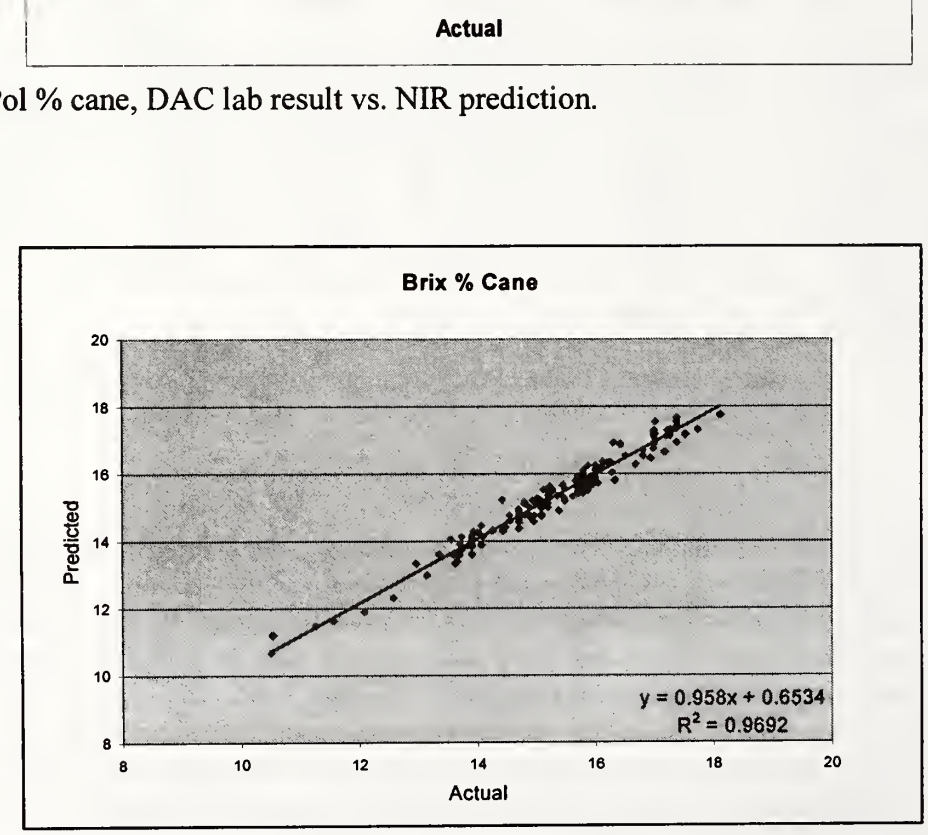

Figure 8. Brix % cane, DAC lab result vs. NIR prediction.

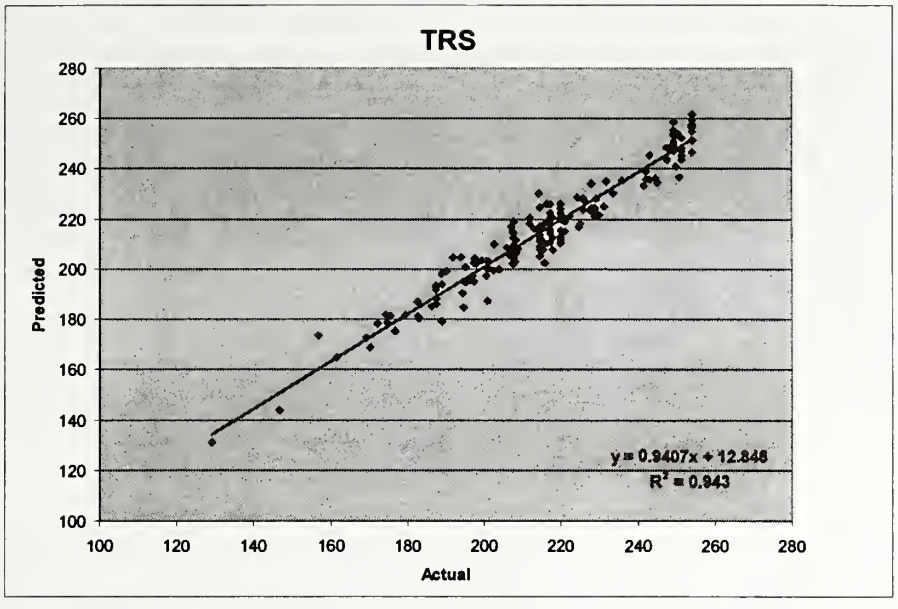

Figure 9. TRS, DAC lab result vs. NIR prediction.

Calibration of the NIRS for ash % cane required some special considerations. The NIRS reads samples containing soil. A viable method for quantitating soil in cane is combustion ash analysis. Samples containing soil reflected this as ash. WinISI software can only fit experimental data to a linear model, causing high ash % cane results to be discarded as outliers. This resulted in an equation that will not produce a predicted result in excess of the average global maximum (Figure 10), which in this case is ~5.0 %. To force the software to retain these points, the equation was linearized using the $\log_{10}$ values of the laboratory data. The high results were no longer regarded as outliers, and the equation can, pending secondary calculation of the antilog, produce a predicted result that was between 87 and 117% of the actual value. The fit of the log equation to lower values was not jeopardized by these manipulations.

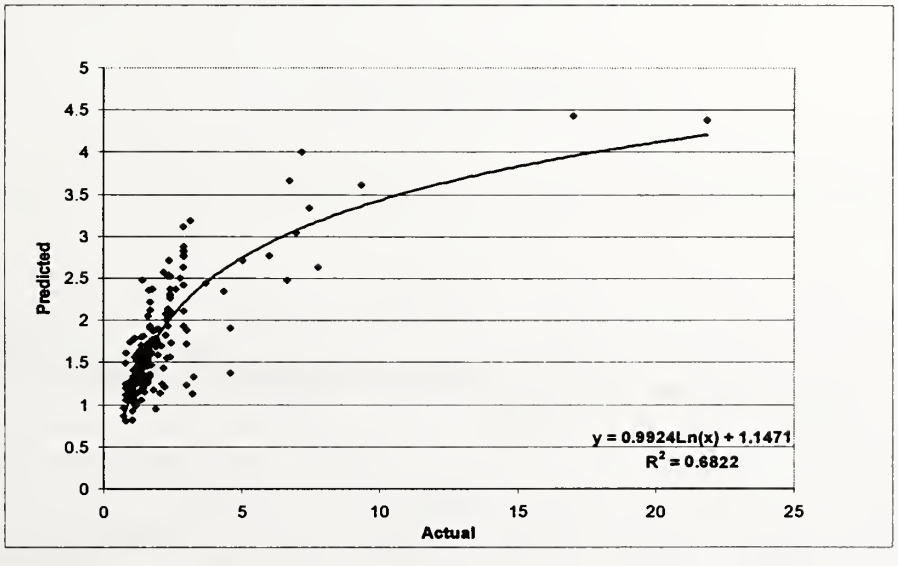

Figure 10. Prediction of ash % cane: the log curve fit has been added to demonstrate the distribution shape of the actual vs. predicted values.

Analysis of the lab data has clarified several questions. The fiber % cane includes the ash and soil present in the sample. It became obvious that CPM does not reflect this since mud fouls the press; juice cannot be expressed from mud without added extraction water. In addition to this, the mud must then be cleaned out of the press while accumulating a sample backlog. An NIRS instrument calibrated by DAC will be able to measure samples containing large amounts of soil. A more accurate fiber result is achieved by difference (Figure 11). This figure has been called "corrected fiber" (CRFiber, Figure 12) and has been added as a constituent to the DAC derived NIR equation set.

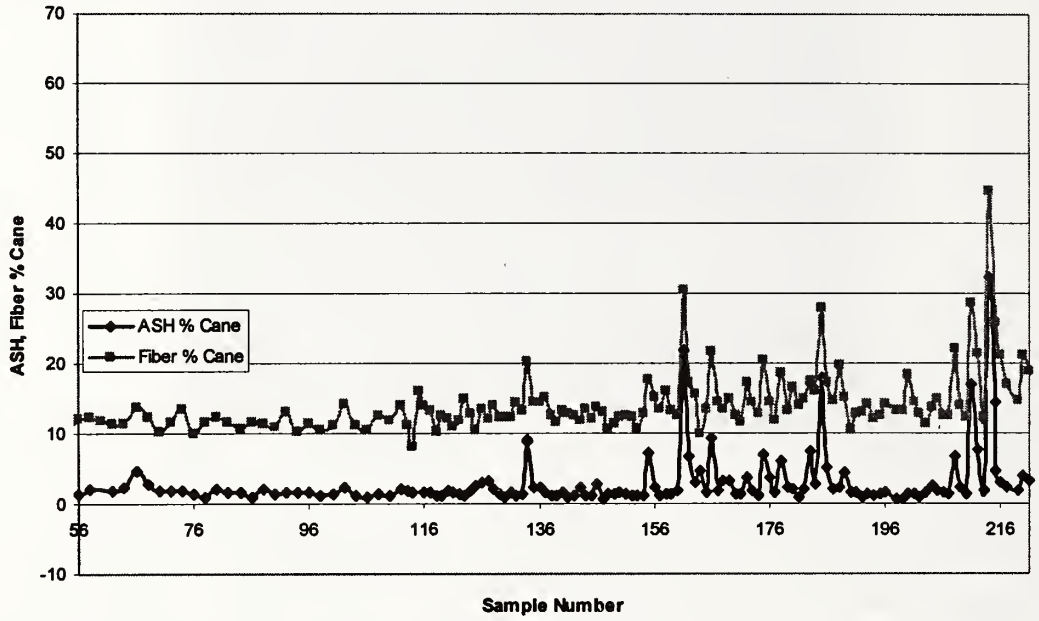

Figure 11. Ash % and Fiber % Cane Lab Data from DAC.

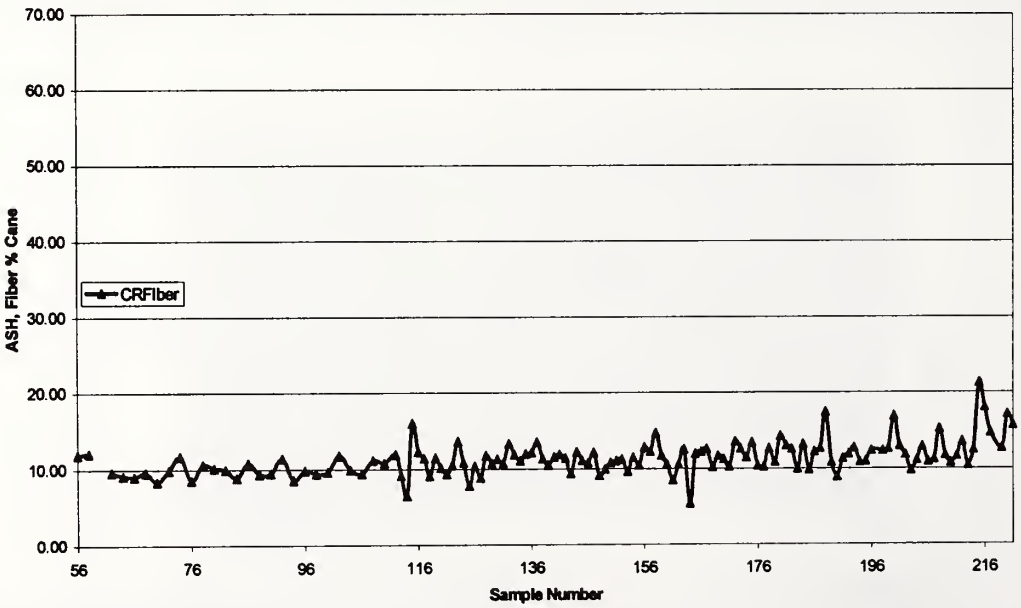

Figure 12. Corrected Fiber % Cane, taken by difference from the DAC results for fiber and ash % cane.

Actual data from a Louisiana core lab showed costs of ~$85,000 per season on employees and supplies. The same lab, using the NIRS might have spent ~$14,000 per season. A net saving of ~$70,000 per season may be achieved. At an initial cost of $160,000 dollars, a NIRS system of this type could be paid for in less than 3 years. Savings resulting from accurate data have not been assessed, but are likely to be even more significant.

If NIRS is installed, a qualified technician may manage continuing calibration verification (CCV), once per week. This technician should serve to monitor the instrument, update calibration, and to serve as liaison for support in the event of technical difficulty. For Louisiana, serving 15 mills, only one liaison technician should be required, and could be subcontracted as an independent body.

CONCLUSIONS

The instrument was able to meet or exceed calibration values found in the literature for fibrated cane. Analysis of core-sampled cane can be completed within 120 seconds, while providing accurate results for pol, brix, fiber, moisture, ash % cane, and TRS. The possibility of discriminating and quantitating "trash" from mud has been realized, and may be exploited in the future. Increased throughput will allow for more comprehensive sampling. Improvement in sample representation will result in accurate payments. Immediate knowledge of excessive mud or "trash" at the weighbridge might be used to decrease the amount of foreign material entering the mill, reducing mill stoppage.

The instrument needed no mechanical maintenance (other than routine cleaning) during the course of this trial, even under the most hostile ambient conditions. Use of the InfraCana will require only one operator per shift, rather than 3-5 per shift as at present, and is not subject to experimental error. In light of these developments, it can be concluded that the InfraCana NIRS may be proven a viable alternative to current core press method of cane analysis.

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The authors would like to thank the following, for without their mutual investment of time, patience, and knowledge, this project may not have reached fruition:

The **American Sugar Cane League** contributed the funds required for this research. **Julio Petersen** of Foss NIRSystems was constantly available; his help allowed us to successfully negotiate the WinISI software to generate a useful set of NIRS equations. **Torsten Hansen** of Foss/Tecator provided expeditious solutions to complex software issues. **Colin Jeffress** of Jeffco Engineering engineered the InfraCana and provided technical support and firmware upgrades. **Barry Forse** accommodated us warmly at Cinclare Sugar Mill, and provided an excellent prepared site for the instrument. From fabrication and maintenance to negotiation of site resources, **Joe Bell**, **Lamar Aillet**, and **Scott Barrow** from the Audubon Sugar factory were always at the ready.

REFERENCES

1. Bentley, S. Staunton, P. G. Atherton, and C. Henderson. 2001. Application of NIR cane analysis technology to small consignments of cane in Fiji. Sugar Cane Technol. 24: 59-65.

2. Berding, Nils, and G. A. Brotherton. 1999. Analysis of fibrated sugarcane by NIS: The laboratory solution. 2nd Annual NIR Users Meeting for the Sugar and Alcohol Industries, Sao Paulo, Brazil. pp. 6-7.

3. Berding, Nils, and G. A. Brotherton. 1996. Grabbing the BIG picture: a novel approach to beating within-sample material heterogeneity. NIR News 7(6): 14.

4. Edye, L .A., and M. A. Clarke. 1996. Sugarcane quality analysis by near infrared spectroscopy. Proc. S. Afr. Sug. Technol. Assoc. 7: 127.

5. ICUMSA Method GS5/7-1. 1994. The determination of pol (polarisation), Brix and fiber in cane and bagasse by the wet disintegrator method – Official.

6. Larrahondo, J. E., F. Palau, A. Navarrete, and C. Ramirez. 2000. Applications of near infrared spectroscopy in the sugarcane industry of Colombia. Centro de Investigacion de la Cana de Azucar de Colombia, Cenicana, Cali, Colombia 163-164

7. Johnson, T. P. 2000. Cane juice analysis by near infrared (NIR) to determine grower payment. SPRI Annual Meeting. 9-12.

8. Peterson, J. C. 1999. Near Infrared (NIR) Technology in the Sugar and Alcohol Industries. FOSS-NIRSystems, 12101 Tech Rd., Silver Spring, Md. 10904, USA. 3 pp.

9. Schaffler, K. J., and J. H. Meyer. 1996. Near infrared analysis of shredded cane: a potential replacement for direct analysis of cane. Proc. S. Afr. Sug. Technol. Assoc. 70: 134.

10. Staunton, S. P., P. J. Lethbridge, S. C. Grimley, R. W. Streamer, J. Rogers, and D. L. Mackintosh. 1999. Analysis of fibrated sugarcane by NIS: The on-line solution. Proc Aust. Soc. Sugar Cane Technol. 21:20-27

AGRICULTURAL ABSTRACTS

Green Cane Trash Blankets: Influence on Ratoon Crops in Louisiana

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Approximately 75% of Louisiana's 2000 sugarcane crop was harvested with a chopper harvester. A significant portion of the chopper-harvested sugarcane was harvested green, especially early in the season. Information on the impact of the post-harvest, green-cane residue blankets on subsequent ratoon crops is inconclusive, but yield reductions have been reported. To insure maximum yields, the residue is generally removed by burning during the winter months when weather conditions are more favorable in reducing the likelihood the smoke will offend the public. The effects of residue blanket management methods on ratoon crops were studied following the 2000 harvest. In one study, burning the residue in January resulted in higher (14%) sugar yields of first-ratoon LCP 85-384 compared to the no removal treatment. Delaying the burning of the residue until February or March did not significantly improve sugar yields over the no removal treatment. In a second study designed to evaluate varietal responses to dates of residue removal, first-ratoon crops of CP 70-321, LCP 85-384, HoCP 85-845, and HoCP 91-555 were found to respond similarly to the removal of the residue. The average sugar yield (6.6 Mg/ha) for the four varieties was 11% higher than the no removal treatment (5.9 Mg/ha) when the residue was removed in early January, regardless of whether the residue was mechanically removed to the row sides or completely burned off. When burning was delayed until March, the average sugar yield (5.3 Mg/ha) was 10% lower than the no removal treatment suggesting that some damage to the emerged shoots was occurring with the later burn. Soil temperature and soil moisture readings taken early in the growing season (January to April, 2002) indicate that the soil is colder and wetter under the blanket of residue. The cold and wet soil condition created by the thick blanket of residue may be affecting crop emergence in the spring and ultimately sugar yields.

The Effect of Combine Speed on Cane Quality at Alma Plantation in 2001

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The parallel acceptance of a new sugarcane variety LCP 85-384 and the use of combine harvesters have significantly redefined the Louisiana sugarcane industry in recent years. The importance of high quality cane deliveries has been emphasized due to the new harvest method and the challenges faced by raw sugar processors. This study was conducted to help determine the influence of forward speed on cane quality. Alma Plantation in Lakeland, LA agreed to participate

in the experiment throughout the 2001 harvest season. Weekly sampling was conducted using the same operator and a 2000 model 7700 Case Combine Harvester. The extractor fan speed was 900 to 950 rpm in burned cane and 1100 rpm in green cane. The treatments (speeds) were 1.5, 2.5, 3.5 and 4.5 mph and were monitored with a handheld radar unit to ensure accurate ground speed. For 12 consecutive weeks, one truckload was cut at each speed and delivered to the mill to be weighed and sampled using the mill's core sampler. While the delivered tons of cane per acre was significantly less when the combine was slowed down to 2.5 and 1.5 mph, the pounds of sugar per ton of cane was only higher in the 1.5 mph treatment as compared to 3.5 and 4.5 mph ($P = 0.05$). There was no significant difference in the resulting yield of pounds of sugar per acre between the treatments. The 4.5 mph treatment had the highest fiber % cane, but sediment readings were not significantly different among treatments. When the mill's incentive formula was applied to the yield results, the 1.5 mph treatment received a bonus of 3.36 pounds of sugar per ton of cane which was only significantly greater than the -1.57 pounds of sugar per ton of cane for the 4.5 mph treatment. The data demonstrates that forward speed of the combine harvester has a significant influence on delivered cane yield and quality. Practical application of this information could be used to determine other optimal combine settings to improve cane quality from combine-harvested sugarcane in Louisiana.

Use of Cover Crops in Rotation with Sugarcane in a South Florida Mineral Soil

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The establishment of cover crops (grasses or legumes) prior to planting sugarcane (interspecific hybrids of *Saccharum* spp.) offers many potential agricultural and ecological benefits to the grower. These benefits include organic matter production to enrich the soil, ground cover to reduce windblown soil erosion, weed control (including less herbicide use), reduced runoff, improved infiltration, soil moisture retention, and soil tilth, nutrient enhancement, and food for wildlife. By improving soil organic matter, cover crops directly influence the soil water holding capacity by increasing water retention and lateral water movement within the soil. Rotation of susceptible agronomic crops with crops that are not nematode pest hosts or are resistant to certain nematodes has been a successful nematode management strategy. The objective of this study was to evaluate the impact of eight cover crops on sugarcane grown on sandy soils. Cowpeas, *Aeschynomene*, Hairy indigo, Sorghum sudangrass, Sterile sorghum, Sorghum sudan/cowpeas mixture, Japanese millet, and Tifleaf millet were planted in April 1992-1994 in 0.25 to 1.2 acre (0.10 to 0.50 ha) plots. Cover crop biomass was measured in August of each year, followed by sugarcane planting in September, which was subsequently harvested in November of the following year (1993-1995). Cover crop yield was significantly higher for the grasses than for the legumes in 1993 and 1994. Cool temperatures and flooded fields during the establishment period resulted in thin stands and low yields of the cover crops. *Aeschynomene* had the best ground cover (46%) of all cover crops. Cowpeas did not tolerate periods of standing water, indicating that this crop should be planted on

drier sites. Japanese millet, which tolerates wet field conditions, should not be planted until late April or early may to prevent early (within 21 days of planting) seedhead emergence. The optimum time to plant warm-season cover crops may be early May, so that at least 4 months of growth are obtained before sugarcane is planted. In the 1993-1995 crop, sugarcane yield (tonnage and sucrose content) obtained for *Aeschynomene* was numerically higher than for all other cover crops treatments and the control treatment (fallow field with no cover crop planted with sugarcane). However, significant differences (Fisher's protected L.S.D. test , P=0.05) for sugarcane yields were only obtained between the *Aeschynomene* treatment and the Sorghum sudangrass and the Sorghum sudangrass/cowpeas mixture.

Evaluation of Sorghum-Sudangrass Hybrids for Biomass Potential in Southern Louisiana

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As close relatives of sugarcane, sorghum-sudangrass hybrids are easy to establish (seed propagated), could be used as an interim crop (April - July) during the fallow season, and may have potential as an complimentary bioenergy crop. Ten sorghum-sudangrass (*Sorghum bicolor x S. bicolor* var. sudanese) hybrids were evaluated for biomass potential at the site of the USDA-ARS Sugarcane Research Unit in Houma, Louisiana. The experiment was designed to be largely observational with single-row unreplicated plantings. Beginning 14 May and continuing weekly through 10 July (nine weeks), 10-stalk samples of each hybrid were collected and analyzed to obtain fresh weight, dry weight, and Brix estimates. One of the hybrids known to be photoperiod sensitive, was non-flowering, and therefore expressed an indeterminate growth habit, continuing to increase in weekly cumulative dry matter content through the end of this experiment. At 97 days following planting (4 Apr 2001 – 10 Jul 2001) the nine hybrids with determinate growth habit, averaged 3 tons green matter/acre, 0.80 tons dry matter/acre, 8.5 Brix, and just over 7 ft height. By contrast the non-flowering hybrid achieved 8 tons GM/acre, 1.75 tons DM/acre, 6.7 Brix, and reached 12 ft height. During 2002, the bioenergy potential of this non-flowering hybrid will be entered into a sorghum test at Houma and directly compared with sorghum varieties considered for commercial bioenergy production in sugarcane-growing areas of Southwestern Louisiana.

ENVOKE: A New Herbicide for Weed Control in U.S. Sugarcane

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Envoke® [N-(4,6-Dimethoxy-2-pyrimidinyl)carbamoyl)-3-(2,2,2-trifluoroethoxy)-pyridin-2-sulfonamide sodium salt] is a new broad-spectrum, post-emergence herbicide that Syngenta Crop Protection is developing for use in sugarcane, cotton, citrus and almonds. It has been field tested as a 75% water dispersible granule for several years in North America, South America, Africa, and Asia under the code name CGA-362622. The proposed common name is trifloxysulfuron-sodium. Envoke® will offer control of certain broadleaf, sedge, and grass weeds in cotton, sugarcane, citrus, and almonds including yellow nutsedge, purple nutsedge, flatsedge, redroot pigweed, spiny pigweed, pitted morningglory, ivyleaf morningglory, scarlet morningglory, hemp sesbania, cocklebur, sicklepod, broadleaf panicum, spurge, spanish needles, and horseweed.

In sugarcane, 0.3 - 0.6 ounces product/A (15.8 - 31.6 g ai/ha) of Envoke® can be applied post-emergence, depending on cultivar, with excellent crop tolerance. For optimum post-emergence activity, the addition of NIS is recommended at 0.25% v/v. The very low use rate of 0.3 to 0.6 ozs/A together with its favorable toxicological, ecotoxicological and environmental properties make Envoke® an excellent tool for sugarcane farmers. Envoke® is readily absorbed by shoots and roots and is readily translocated in weeds. Susceptible weeds are inhibited following an application of Envoke® with complete death occurring within 1 to 2 weeks after application.

Envoke® is compatible with other herbicides including AAtrex® and Evik® which can be used to increase the weed spectrum and duration of control. Envoke® can be applied in combination with Evik®, post-directed only, to increase speed of activity and weed spectrum, especially the grasses.

Experimental Products for Weed Control in Florida Sugarcane

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Several new herbicides are being evaluated for weed control in Florida sugarcane. Both pre-emergence (PRE) and post-emergence (POST) herbicides are being evaluated. Control of a wide range of common weeds, including fall panicum, broadleaf panicum, alligator weed, purple nutsedge,

yellow nutsedge, and several other species is being evaluated. The PRE products in testing include flumioxazin and azafenidin, applied alone or in conjunction with labeled PRE herbicides. These treatments are being evaluated in comparison to standard PRE treatments. POST products under evaluation include carfentrazone, trifloxysulfuron, and flumioxazin. These products are being evaluated both alone and in conjunction with standard POST treatments, such as asulam, atrazine, halosulfuron, and ametryn.

Early results indicate potential for good control of a range of weeds utilizing these new products alone or in tank-mixture with currently labeled products. Detailed results will be presented during the conference.

Effect of Calcitic Lime and Calcium Silicate Slag Rates and Placement on LCP 85-384 Plant Cane on a Light-Textured Soil

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Substantial sugarcane yield responses to silica application have been documented in Florida and Hawaii, but not in Louisiana. Our research determined the effect of calcitic lime and calcium silicate slag rates and placement on plant cane yields grown on a light-textured soil in Louisiana. Results showed that mixing 2.24 Mg ha^{-1} and 4.48 Mg ha^{-1} of calcium silicate slag into soil before planting, or placing 2.24 Mg ha^{-1} of slag under cane at planting resulted in higher ($P \leq 0.10$) sugar yields compared to the check. Mixing 2.24 Mg ha^{-1} and 4.48 Mg ha^{-1} of calcitic lime, however, into the soil before planting did not increase ($P \leq 0.10$) sugar yields. Higher sugar yields obtained with calcium silicate slag vs. calcitic lime indicates that the yield response obtained with calcium silicate slag was due to its silica content.

Sugarcane Leaf P Diagnosis in Organic Soils

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Most of the sugarcane production in south Florida is on organic soils. Phosphorus is an essential plant nutrient that contributes to optimum sugarcane yields, but producers are required to reduce P levels in waterways. One way to monitor P nutrition is through leaf diagnosis. The objective of this study was to determine the best time to leaf sample during the summer months and

to relate optimum leaf P tissue content and yield. A 3-year field study was conducted on four organic soil locations in south Florida. An 8 by 3 factorial experimental design with four replications was used at each location with eight sugarcane (interspecific hybrids of *Saccharum* sp.) genotypes in combination with three fertilizer P rates (0, 24, and 48 kg P ha^{-1}). Fertilizer rates were based on soil test analysis with 24 kg ha^{-1} being the recommended rate. Upper-most fully expanded leaves were sampled in early, mid, and late summer prior to three harvests (plant cane, first ratoon, and second ratoon). Two locations had optimum cane and sugar yields at 24 kg P ha^{-1} for all harvests. There was no response to P fertilizer at one location for any harvest year, while the other location had the highest cane yields at 48 kg P ha^{-1} for all harvests. Analysis of variance for leaf P content showed significant interactions for location by P rate by harvest and for location by P rate by leaf-sample time. Leaf P content did not always correspond to yield data. Within each location, sometimes the leaf P content increased with increasing P rate as did yield, and sometimes yields did not show a response to P fertilizer even though leaf P increased. Consistent patterns in time of leaf sampling within locations could also not be obtained. Correlation analysis of yield vs. leaf P content across all treatment in early and mid summer were statistically significant ($P<0.05$), but coefficients were very low (r=0.14 and 0.26, respectively). Correlations of harvests within location at each leaf sample time were occasionally significant ($P<0.01$) with the highest correlation of r=0.79. But, there was no consistent pattern relating leaf P tissue content with yields. Optimum leaf P tissue content should be calibrated for each field, harvest, and sampling date for precision agriculture applications.

Wireworm Effects on Sugarcane Emergence After Short-Duration Flood Applied at Planting

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Sugarcane (interspecific hybrids of *Saccharum* spp.) growers in Florida normally apply a soil insecticide at planting to limit wireworm *(Melanotus communis* Gyll.*)* damage to planted stalk sections. Long-duration floods prior to planting sugarcane are also used to control wireworms. A recent study found that sugarcane emergence was improved by floods of 2-12 days applied at planting. The purpose of this study was to analyze sugarcane emergence after floods of 7, 14, and 21 days applied at planting, as well as following a conventional application of an organophosphate insecticide at planting without flooding. In three outdoor experiments, wireworms were applied at the severe rate of 13 larvae per meter of row in plastic containers filled with Pahokee muck soil. In the first experiment, emergence under the flood treatments was lower than under the insecticide treatment, probably due to lower than normal air and soil temperatures. Emergence in the 14- and 21-day flood treatments and the insecticide treatment were similar in the final two experiments. However, reductions in plant weight were associated with some flood treatments. Previous work reported that wireworms damaged growing plants in containers, but damage was primarily limited to reduced emergence in field studies. The successful wireworm control of the 14- and 21-day floods

and the negative effects on plant weights reported in this study need to be verified in field studies.

Laboratory Screening of Insecticides for Preventing Injury by the Wireworm *Melanotus communis* (Coleoptera: Elateridae) to Germinating Sugarcane

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A laboratory bioassay was investigated for screening candidate materials for preventing stand losses by wireworms in germinating plant cane. For liquid materials, single-eye billets were dipped into different concentrations of a material and then planted in plastic containers of organic soil; wireworms were then introduced, airtight lids were placed onto the containers, and wireworm survival and damage were assessed 4 wk later. Tests with granular materials were similar except the containers were partially filled with untreated soil; 30 ml of soil treated with the granular material were then added to the container; an untreated single-eye billet was placed onto this treated soil; an additional 30 ml of treated soil was then placed on and around the billet; and finally untreated soil was added to fill the container. Conditions inside the bioassay containers appeared suitable for germination and growth of most varieties. Airtight lids were advantageous from the standpoint of maintaining soil moisture. Data indicated it may be disadvantageous to hold wireworms for a long period of time before using them to screen a material.

Bifenthrin, thiamethoxam 25WG, thiamethoxam 2G, and tefluthrin 3G appeared to have value as materials for reducing damage by wireworms to germinating eyes of seed cane planted in organic soils. However, germinated shoots of billets treated with these materials were sometimes injured by wireworms. Another material, ethiprole, was found to inhibit germination of CL77-797 when applied in solutions greater than ~ 1,000 ppm. Little wireworm mortality occurred in containers of billets treated with ethiprole at any rates tested, but surviving wireworms frequently caused injury to the billets. Another material, zeta-cypermethrin, appeared to have no value as a wireworm control material at the rates studied (75 to 125 ppm). Overall based on limited data, the most promising of these materials with respect to reducing wireworm damage to both germinating eyes and young shoots appeared to be thiamethoxam 25WG at 12,000 ppm.

Management Thresholds for the Sugarcane Borer on Louisiana Varieties

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The sugarcane borer (SCB) is responsible for greater than 90% of the total insect damage to sugarcane in Louisiana, and the process to decide when to spray is determined by many variables (i.e.

infestation levels, weather conditions, economics of the grower, environmental concerns, etc.). Therefore the overall goal of this study is to provide key facts that would allow the industry to have a greater flexibility in controlling the SCB on different varieties while maintaining a high level of confidence that a reduction in sugar per acre and buildup of SCB pest populations can be avoided. SCB larval infestations were monitored weekly with leaf sheath sampling. The SCB resistant varieties CP70-321 and HoCP85-845, and the susceptible varieties LCP85-384 and HoCP91-555 with four regimes of SCB control were treated with insecticide when the designated threshold levels were reached.

Results indicated that the variety HoCP91-555 (highly susceptible) required three applications of insecticide during the growing season for both the 5% SCB infestation threshold (5%) and 5% early and 10% late season threshold (5%/10%). In comparison, LCP85-384 (susceptible) required three insecticide applications for the 5% management threshold, but only two insecticide applications for the 5%/10% management threshold. The resistant variety HoCP85-845 required two applications for the 5% threshold and only one application for the 5%/10% threshold. CP70-321 required only one application under the 5% and the 5%/10% management regimes. This study further demonstrates some positive results for the industry's leading variety LCP85-384 (it currently represents about 80% of the sugarcane grown in Louisiana) in terms of growers being able to manage this variety against the SCB with the use of timely application of insecticides. The 5%/10% threshold shows promise and supports the industry's desire to reduce unneeded insecticide applications during the season due to increasing economic and environmental concerns.

Yellow Sugarcane Aphid (*Sipha flava*) Colonization Strategy and its Effect on Development and Reproductive Rates on Sugarcane

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Yellow sugarcane aphid (YSA) is an occasional serious pest of sugarcane throughout the subtropics and tropics. Leaf feeding on susceptible cultivars results in red spots of various sizes and density usually followed by chlorosis and then necrosis. Prolonged feeding results in fewer new shoots, reduced stalk diameter and yield. Field samples indicate that winged aphids (alates) normally stay in one place on favored cultivars once they start reproduction and that alates are frequently found together in groups on leaves. This aphid also prefers leaves that are about half way between the top visible dewlap (TVD) and the youngest senescing leaves. Research was begun to examine whether group feeding affected development rates, nymph production and development rates of the subsequent F2 generation. Leaf position relative to the TVD was also evaluated for its possible effect on these population parameters. Tests were conducted in a greenhouse using the susceptible cultivar CP80-1827 inoculated with YSA from a laboratory colony maintained on a Sorghum-Sudan hybrid. Individual aphids and those in small groups took longer to develop to adults and produced fewer nymphs per day than those that developed within larger groups. The F2 generation reached

adulthood and started reproducing in 25% less time than did the F1. Leaf position had a minor effect on these population parameters.

Field Trials of a Multiple-Pathogen Bioherbicide System with Potential to Manage Guineagrass in Florida Sugarcane

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Guineagrass (*Panicum maximum*) is a problematic weed in sugarcane in Florida due to its capacity for prolific spread and tolerance to chemical herbicides. Development of host-specific fungal plant pathogens as bioherbicides may provide a nonchemical option to manage these weedy grasses. Three fungi indigenous to Florida, *Drechslera gigantea*, *Exserohilum longirostratum*, and *E. rostratum* were evaluated in July and September 2001 in Pahokee, FL for the control of guineagrass (*Panicum maximum*). Mini-plots, each 10' x 5', with a 5' buffer zone between plots, were set up. A mixture of the three pathogens (1:1:1 v/v; total 10^6 spores per ml; 250 ml spore suspension per plot @54GPA) was applied to guineagrass in each plot (3 to 4 inches tall (July) and 1 to 2 inches tall (Sep.)) as follows: (1) Sunspray 6E 40% - Paraffin Oil 10% (Inoc-40E-10P); (2) Sunspray 6E 30% - Paraffin Oil 10% (Inoc-30E-10P); (3) Sunspray 6E 20% - Paraffin Oil 10% (Inoc-20E-10P); (4) Sunspray 6E 40% (Inoc-40E); and (5) Paraffin Oil 10% (Inoc-10P). Guineagrass in uninoculated control plots were treated with the respective carriers alone. The treatments were applied on July 03 and 18 and Sep. 02 and 22. A completely randomized block experimental design with four replicates for each treatment was used. At 3 weeks after initial inoculation (WAI), disease severity ranged from 15 to 27 % in July, and 52-90 % in Sep. on guineagrass applied with Inoc-40E, Inoc-20E-10P, Inoc-30E-10P, and Inoc-40E-10P fungal mixture treatments. Uninoculated guineagrass plants treated with the carriers alone, were healthy. At 4 WAI, plant growth was stunted, and reduction in panicle number per sq. m. area was 82%, 90% and 93% in July, and 99%, 99%, and 99% in Sep in Inoc-30E-10P, Inoc-40E, and Inoc-40E-10P treatments, respectively. The reduction in panicle number was higher (P=0.05) than the control treatments. Thus, the mixture of *D. gigantea*, *E. longirostratum*, and *E. rostratum* has potential to be developed as a bioherbicide system for guineagrass in sugarcane.

Molecular Identification of Virus Isolates Causing Mosaic in Louisiana Sugarcane

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Ten strains of sugarcane mosaic virus (SCMV) and three strains sorghum mosaic virus (SrMV) have been reported to cause mosaic in Louisiana; however, only strains H, I, and M of SrMV were recovered from commercial fields during surveys conducted between 1973 and 1995. Annual surveys were discontinued because of the large amount of labor required to identify strains using host differentials. At the time of these surveys, this was the only technique available to identify strains of these viruses, and results had changed little during the last 10 years. Recent advances in technology have led to the development of a laboratory procedure capable of distinguishing the mosaic virus strains. A survey was conducted in 2001 using reverse transcriptase-polymerase chain reaction-based restriction fragment length polymorphism (RT-PCR-RFLP) analysis to determine if changes have occurred among the strains of virus causing mosaic of sugarcane in Louisiana. Strain I and strain H of SrMV were associated with approximately 65% and 21% of the sugarcane plants with mosaic symptoms, respectively. In the earlier surveys, more than 80% of the plants were infected with strain H each year. The remainder of the plants (14%) surveyed in 2002 appeared to be infected by a new strain with a distinctive RFLP banding pattern. Nucleotide sequencing is being conducted to identify the virus strain. Sugarcane plants with mosaic symptoms will be collected in 2002 from a wider geographical area of the state and virus strains infecting the plants will be determined by RT-PCR-RFLP analysis.

Incidence of Sugarcane Yellow Leaf Virus in Clones of *Saccharum* spp. in the World Collection at Miami and in the Collection at the Sugarcane Field Station, Canal Point

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Sugarcane yellow leaf virus (SCYLV) was detected in clones of *Saccharum* spp. in the World Collection and in the collection at Canal Point using a leaf mid-rib tissue blot immunoassay. The incidence of infection varied by the species of *Saccharum*. At Miami, approximately half the clones in the collection for each *Saccharum* spp. were sampled and the incidence of SCYLV in the clones was 7.0% for *S. spontaneum*, 74.5% for *S. officinarum*, 62.5% for *S. robustum*, 46.2% for *S. sinense*, and 14.0% for *S. barberi*. At Canal Point, there were only sufficient numbers of *S officinarum*, *S. robustum* and *S. spontaneum* clones to sample and the incidence of SCYLV was 59.7% for the 134 clones of *S. officinarum* sampled, 60.7% for the 28 clones of *S. robustum* and 15.4% for the 52 clones of *S. spontaneum*. The results clearly indicate that SCYLV is present in clones present in the

World Collection in Miami and that *S. spontaneum* and *S. barberi* are the two most resistant of the five species of *Saccharum.*

Selection of Interspecific Sugarcane Hybrids using Microsatellite DNA Markers

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Three types of species-specific DNA markers, namely, PCR, RAPD, and microsatellites, have been recently developed at the USDA-ARS, SRRC, Sugarcane Research Unit, Houma, Louisiana. Among these, the microsatellite markers are the most polymorphic and can produce distinctive fingerprints (or molecular alleles) among sugarcane varieties as well as their wild relatives. In 2001, 11 wild x elite biparental crosses were made that involved 10 clones of *Saccharum spontaneum* and six commercial-type sugarcane varieties. The *S. spontaneum* clones were used as maternal parents to explore the possible impact of their cytoplasm on our varietal development program. A problem associated with sugarcane breeding is the potential for self-pollination of the maternal wild parents. We have demonstrated in earlier work that self-pollination can occur even after a hot-water treatment to emasculate the maternal tassels. Therefore, some of the seeds were selfed progeny. Since *S. spontaneum* is on the Federal noxious weed list, direct planting of *S. spontaneum* (including selfed progeny) to the field is prohibited. To circumvent the planting of selfed *S. spontaneum*, we used microsatellite markers to screen the seedlings from these crosses while they were still in the greenhouse. In this presentation, we will show the percentage self-pollination in these crosses where the *S. spontaneum* flowers were hot-water treated. We also will demonstrate how microsatellite markers can be used to eliminate at the seedling stage unwanted selfs from the basic breeding and selection program.

Development of Microsatellite Markers from Sugarcane Resistance Related Genes

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Microsatellites are arrays of short DNA sequence motifs, with 1 to 6 base pairs in length and are characterized by their hyper variability, abundance, reproducibility, Mendelian inheritance and co-dominant nature. The Microsatellite marker technique is simple, robust, reliable and suitable for a large throughput system. It is also applicable when the plant material available for analysis is limited in quantity and sufficiently quick to allow early decisions to be made prior to further screening. These advantages make the microsatellite technique a suitable tool for molecular selection in large breeding programs.

Expressed Sequence Tags (EST) in the sugarcane database were electronically searched for microsatellites and 402 were identified. Out of 267 (245 disease and 22 pest) resistance-EST investigated, 37 (34 disease and 3 pest) were positive for the presence of microsatellites. PCR primers flanking these microsatellites were designed and tested as markers on ten sugarcane genotypes – four commercial hybrids and 6 wild genotypes. Polymorphisms were evident both at the commercial clones, as well as among the *Saccharum* species. The presence of microsatellites within disease resistance genes could be the flexible mechanism that sugarcane possesses to ensure response to a new pathogen. DNA rearrangements, resulting from slippage during replication, which is characteristic of microsatellite sequences, would be allowing the cane plant to generate novel resistance to match the changing pattern of pathogen virulence.
In humans, a few disease genes carry tri-nucleotide microsatellites. A novel mechanism for the amplification of these microsatellites sequences seems to be the root cause of these genetic abnormalities. Should the same mechanism work in plants, mapping microsatellites markers from disease resistance EST may increase the probability of tagging resistance genes in sugarcane commercial as well as in wild germplasm.

Microsatellites were also found in other 75 EST coding for proteins not related to disease resistance, such as sugar metabolism, and can be used as molecular markers for linkage mapping and tagging of other genes.

The Effect of Temperature on Flowering and Seed Set in Sugarcane at Canal Point.

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South Florida experiences wide variation in the frequency and intensity of flowering in sugarcane in different years. The crossing program at Canal Point has maintained about 2000 pot cultures of at least 150 cultivars per year for each of the past 10 years. The individual cultivars have varied throughout the period but they are representative of the same genetic background. The number and time of emergence of tassels based on the number of tassels cut for use in crosses will be correlated to the minimum temperatures from September through January. The effect of low temperature on pollen fertility is well documented, but little information is available about the effect of low temperatures on tassels to be used as females. The plants used to produce the male tassels used in these crosses were protected from low temperatures by being moved into the crossing and photoperiod houses at night. The effect of temperature on flowering and seed set in sugarcane at Canal Point will be discussed.

Characterization of *S. Spontaneum* Collection for Juice Quality

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In order to utilize a wider germplasm sample and more efficiently explore wild Saccharum species for breeding purposes, we initiated the characterization of 94 *S. spontaneum* and 2 *S. sinense* clones from the Copersucar germplasm collection at Piracicaba, SP, Brazil. Laboratory analysis was carried out for juice quality of these genotypes. Data were collected for Brix, Purity, Reducing Sugar, Pol and Fiber. Within the *spontaneum* genotypes, values ranged from 7.2 to 16.5 for Brix, from 0.4 to 7.8 for Pol and from 21% to 45% for Fiber.
Molecular marker analysis (southern) with an EST from Sucrose synthase as DNA probe on the DNA of 11 *S. spontaneum* genotypes is presented, showing polymorphism at this locus. Electronic search on sugarcane DNA sequence database shows Simple Sequence Repeats within genes controlling sugar metabolism.

The analysis on juice quality showed a wide variation for sugar content among spontaneum genotypes, which suggests genetic variation for these traits within this species. The molecular data shows high polymorphism at the chromosome locus where the gene controlling the Sucrose synthase enzyme is located, suggesting that cane breeders could use molecular markers for marker-assisted selection to introduce positive alleles into commercial genotypes. Such a strategy would speed up the Back Cross method to introduce wild alleles in commercial varieties aiming to widen the narrow sugarcane genetic basis.

Family Selection in Sugarcane: Notes from Australia

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Sugarcane breeding programs typically commence by evaluating a large number of seedlings derived from true seed. Mass selection applied at this stage of the program has been shown to be inefficient due to lack of replication, and the associated confounding effects of the environment. In Australia, the introduction of mobile weighing machines made it possible to implement family selection. Several research projects demonstrated that family selection when followed by mass selection was superior in terms of genetic gain and more cost effective than either family or mass selection alone. This combination of family and mass selection is now used routinely in all the Australian programs. Families are evaluated using replicated plots for cane (mechanically harvested and weighed) and sucrose yield in the plant crop. Individual clones are selected (mass selection), based mainly on visual appraisal for cane yield, from selected families in the first ratoon crop. Family selection is usually liberal with about 30 – 40 % of families selected. More clones are

selected from the best families with progressively fewer clones being selected from the moderate to average families. The availability of objective family data makes it possible to estimate the breeding value of parents using the Best Linear Unbiased Predictor (BLUP). This information is used to retain or drop parents from the crossing program and to plan better cross combinations.

Assessment of Trends and Early Sampling Effects on Selection Efficiency in Sugarcane

S.J. Edme, P.Y.P. Tai, and J.D. Miller
USDA-ARS
Canal Point, FL

Quantitative data on agronomic traits are normally affected by field trends or spatial heterogeneity, which often mask the genetic potential of the tested varieties. To identify promising selections from Stage II clones with some degree of confidence, a moving means analysis was performed on 754 experimental sugarcane clones (CP 2000 Series) tested along with five check varieties distributed across three fields with unequal frequencies. The data were subjected to three different methods (linear, quadratic, and row x column) to remove any potential field trend, as revealed by the variance of the checks, and to approximate the true genotypic values of the clones under selection. The best method was chosen as the one that accounts for the greatest variance of trends and the least variance of checks. In field A (16 blocks of 43 plots each), cane (TCA) and sugar tonnage (TSA) were more efficiently assessed by the quadratic method (2 neighbors). For the clones in fields B (16 blocks of 23 plots each) and C (14 blocks of 10 plots each), a row x column method was more appropriate in analyzing TCA and TSA. The ranking of varieties changed significantly when comparing the adjusted values with the field data. Though positive and significant (r_{tsa}=0.44 and r_{brix}=0.28, p=0.001), the correlation between early and late sampling revealed that the former is not indicative and predictive of the latter. Consequently, a late March sampling yielded 32 additional clones for advancement to Stage III, with Brix values ranging from 18.6 to 22.3. Further analyses are warranted to ascertain the benefit of these approaches as prediction methods for identifying the most promising clones.

Selection and Advancement of Sugarcane Clones in the Louisiana "L" Sugarcane Variety Development Program

K. P. Bischoff and K. A. Gravois
LSU AgCenter Sugar Research Station
St. Gabriel, LA

The primary objective of the Louisiana "L" Sugarcane Variety Development Program is to efficiently develop improved sugarcane cultivars for the Louisiana sugarcane industry. Each year, 300 to 600 crosses are made at the sugarcane breeding facilities of Louisiana State University Ag Center's Sugar Research Station located in St. Gabriel, La. This begins a process of selection,

advancement and testing which spans a period of 12 years culminating with the release of new sugarcane varieties to growers of the Louisiana sugar industry. Although the main goal of the program has never changed, procedures and techniques have evolved and improved over the years to the extent that this program is operating more economically efficient than ever.

This paper will outline the procedures and techniques used by LSU personnel in the seedling production through infield testing phases of the Variety Development Program. For purposes of discussion, the numbers of clones moving through the program during the year 2001 will be used.

MANUFACTURING ABSTRACTS

The Florida Sugar Industry: Trends and Technologies

J. F. Alvarez and T. P. Johnson
Sugar Cane Growers Cooperative of Florida
Belle Glade, FL

The Florida Sugar Industry has been consistently improving the operation and efficiency of several sugar mills. The trends in operation and efficiency are first discussed followed by a survey of technologies and applications that cumulatively have contributed to these improvements in operation. The Florida Sugar Industry has consistently increased the processing rate while at the same time improving the overall recovery of sugar. No attempt is made to formulate cause and effect of the technologies, but general comments are made on the experience of some of the technologies and the possible trends that these technologies may take the industry in the future. The technologies covered are in the areas of milling, processing, and the power plant as well as quality control and information technology. The industry has benefited by borrowing and implementing technologies from other industries as well as from other sugarcane growing areas such as Australia and South Africa. The technologies involved range from computational fluid dynamics, new materials, digital and electronic devices and equipment, larger and more efficient sugar processing equipment, computer automation and information technologies. Technologies that are being developed that may change the sugar process are still years away from commercial implementation. The economic pressure of globalization will continue to force the Florida sugar industry to continue the technological trend.

Versatility of the Antibody Dextran Test Method

D. F. Day[1], J. Cuddihy[2] and J. Rauh[2]
[1]Audubon Sugar Institute, LAES, Baton Rouge, LA
[2]Midland Research labs, Inc., Lenexa, KS

The monoclonal antibody test (Sucrotest™, Midland Research Labs, Inc.) has proven be a versatile means of determining dextran. It can handle any dextran containing liquid sample and give a value in about one minute. It correlates very well with the Haze test. Samples ranging from the raw factory, to the refinery, to white sugar can be rapidly analyzed. The source of the sample is not important, whether it is from Mauritius or Louisiana this test produces reliable information. The test is being used in both raw factories and refineries world wide. Results showing the scope of uses, and correlations with existing methods will be presented.

Evaluation of a Near Infrared Spectrometer for the Direct Analysis of Sugar Cane

L. R. Madsen II, B.E. White and P.W. Rein
Audubon Sugar Institute, LSU AgCenter
Baton Rouge, LA

A Foss InfraCana Near Infrared (NIR) spectrometer was installed at Cinclare mill in Louisiana for the 2001/02 crushing season, to assess its suitability for direct analysis of cane delivered to the mill. The system prepared core-sampled cane in a Jeffco shredder and measured reflectance over a range of wavelengths. Analyses of cane by wet disintegration and by the existing core press method were used as the primary measurements. Calibration equations for pol, brix, fiber, moisture and ash in cane were produced. Values of standard errors were excellent, and prospects for the use of such an instrument for accurate direct analysis of cane look promising.

Effect of pH and Time Between Wash-outs on the Performance of Evaporators

G. Eggleston[1], A. Monge[2] and B. Ogier[1]
[1]USDA-ARS-Southern Regional Research Center, New Orleans, LA
[2] Cora Texas Manufacturing Co., White Castle, LA

Factory staff must consider all costs to make good economic decisions on how to improve the performance of evaporators. These include knowing optimum pH levels to minimize sucrose losses, and knowing when to wash-out evaporators to reduce the impact of scaling on sucrose losses. A comprehensive study was conducted at a factory during the 2001 grinding season, to determine the effects of time between evaporator wash-outs and pH on sucrose losses and overall evaporator performance. The factory operated Robert's Type calandria evaporators, with two (30,000 and 25,000 ft^2, respectively) pre-evaporators in parallel and three sets of triple-effect evaporators in series. In this investigation the second set of triple-effect evaporators was studied and each body was 12,500ft^2. Retention times were 11.4 and 9.5 mins in the two pre-evaporators, respectively, and increased from 10.0 to 21.8 mins across the triple-effect evaporators. Gas chromatography was used to determine glucose, fructose, and sucrose concentrations in and out of the evaporators. Changes in Brix adjusted pH, Brix, color and turbidity, as well as chemical analyses of condensates were monitored. Most sucrose losses to inversion occurred in the pre-evaporators and were more a function of temperature, heating surface, and pH than retention time. Sucrose inversion occurred in the first and second evaporator bodies only when scale had built up ~3-4 days after a wash-out and, generally became worse until the next wash-out. Although color formed in the pre-evaporators, it was relatively less than what occurred in the first and second evaporators. Increasing the factory target pH of the clarified juice (CJ) or final evaporator syrup (FES) systematically reduced losses of sucrose and a target FES pH of ~6.3-6.4 is recommended. A target CJ pH of 6.7, giving an equivalent FES target pH of 5.9, caused approximately 1.97-3.05 lbs sucrose lost/ton of cane in the pre-evaporators from mid to late season, whereas a target CJ pH of ~7.1 and FES pH of 6.3 reduces

this loss to 1.46-2.28 lbs sucrose lost/ton of cane. More sucrose losses occur at the beginning of the season. Further recommendations are discussed.

Maximize Throughput in a Sugar Milling Operation using a Computerized Maintenance Management System (CMMS)

K. A. Elliott
Maintenance Systems Technology (MST) (Pty) Ltd
Pretoria, South Africa

The sugar industry relies on expensive mechanical plant for sugar production. Loss of production during the crushing season due to downtime means huge revenue losses. Excessive downtime and high maintenance costs can be avoided if a throughput focused CMMS Software system is implemented. The CMMS provides valuable information to base decisions on, but also enables valuable operational tools to ensure an optimized availability and sustained throughput.

This paper presents a success story about a CMMS implementation at 14 sugar mills in Southern Africa, for a leading, global, low cost sugar producer and a significant manufacturer of high-value downstream products. The group has extensive agricultural and manufacturing operations in Southern Africa. Group sugar production of almost 2.0 million tons of sugar derives from South Africa at 1.25 million tons, Malawi 240 000 tons, Swaziland 220 000 tons, Zambia 205 000 tons and Tanzania 75 000 tons.

By implementing a focused and effective Maintenance Management System, the Group was able to ensure operational reliability during the crushing season, and improved uptime, without sacrificing maintenance expenditure. The paper highlights the challenges that the business faced, provides a roadmap to the implementation, as well as the realized benefits as a result of the implementation.

The steps to adopting a philosophy of Scientific Maintenance Management and Total Quality Management (TQM) for the two distinct phases of Plant Maintenance namely, Production Season and Off-crop, demand the following key elements that will direct Maintenance in the business:

Taking a life cycle long term view.
Defining key performance indicators that are measurable.
Ensuring Quality at the source of work execution.
Basing decisions first on factual information and cross checking it with historical information.
Challenge past maintenance practices.
Focusing on prevention rather than cure.

All maintenance work done in both the crushing season and the off-crop, have as its primary objective the reduction of Lost Time Available during season and effective planning and

management of off-crop maintenance, to reduce maintenance spend. This paper is based on the experience gained by the author and his associates from CMMS implementations over a period of 15 years.

Experiences with the First Full Scale Plate Evaporator in the North American Cane Sugar Industry

N. Swift[1], T. D. Endres[2] and F. Mendez[2]
[1]Alfa Laval, Richmond, VA
[2]Raceland Raw Sugar, Raceland, LA

An Alfa Laval EC 700 plate evaporator was installed at Raceland Raw Sugar Corp during the 2001 crop. The evaporator was installed as a second effect booster. The unit ran for the last 34 days of the 2001 crop with excellent results. On average 1500 TCD more was ground after the evaporator had been installed compared with the previous period. Steam economy improved by up to 130 pounds steam per ton cane. A heat transfer coefficient of around 390 BTU/ft^2/F °(2.2 W/m^2/C °) was achieved on average for the operating period.

Organic Acids in the Sugar Factory Environment

D. F. Day and W. H. Kampen
Audubon Sugar Institute, Louisiana Agricultural Experiment Station,
Baton Rouge, LA.

Volatile and non-volatile organic acids (ranging from acetic, through lactic to higher acids) can be found in raw sugar process streams. They are products both of microbial degradation and decomposition of cane waxes. The concentrations increase from the primary juice to significant levels by the end of the separation process. The specific sources of some of these acids are traced and implications of their presence on corrosion and sugar recovery are highlighted.

Experiences with Unwashed Cane at Raceland

T. D. Endres
Raceland Raw Sugar
Raceland, LA

Cane washing was stopped on the fifth day of grinding and remained off for around 70% of grinding. The performance of the plant in the extraction, steam generation and clarification various areas was monitored in order to assess the impact of this modus operandi. Overall sugar recovery was enhanced by 13 pounds of sugar per ton cane whilst operational difficulties in the extraction and

steam generation areas were minimal. Clarification of juice improved during periods of no washing whilst increased mud quantities experienced during this period could be handled if anticipated in good time. Attempts have been made to estimate the effect on recovery by comparing results during periods of washing and no washing. Work done by Birkett and Stein during 2000 suggests that the value of additional sugar to the industry by not washing cane is USD 18 million or USD 1.2 per ton. This provides sufficient incentive to both growers and millers to work together to ensure that this practice remains sustainable.

POSTER SESSION

Soil Erosion Research on Alluvial Soils Planted to Sugarcane: Experimental Approach and Preliminary Results

T. S. Kornecki, B. C. Grigg, J. L. Fouss and L. M. Southwick
USDA-ARS, Soil and Water Research Unit
Baton Rouge, LA

Each spring, quarter-drains are installed to carry runoff from sugarcane fields. Each meter length of quarter-drain requires removal of about 0.065 m^3 of soil, which is discharged on the ground surface. High intensity storms can cause soil erosion from these drains. The loose soil discharged during their construction is often washed into quarter-drains causing their drainage capacity to diminish by sedimentation. To address the quarter-drain soil erosion problem, a field experiment is being conducted on our research site in St. Gabriel, LA to study the effectiveness of applying polyacrylamide (PAM) to the soil-walls of the drain channel in reducing erosion. PAM has been shown to be effective in controlling soil erosion induced by irrigation water flows in surface channels. In March of 2002, PAM was applied as a spray directly to the soil-walls of the quarter-drains at a rate of 18 kg/ha in a split application with a concentration of 500 ppm. Soil erosion and sedimentation were measured after each storm event to develop a 3-D view of changes in cross-sectional shape of the quarter-drains. Preliminary data show that PAM preserved the original shape of semicircular quarter-drains through four consecutive storms in March and April 2002, totaling 19 cm of rain. Where PAM was not applied, a gradual deterioration of the side-walls of the quarter-drain was visible including at transition points where erosion up to 3.0 cm was recorded. Comparison of quarter-drains with and without PAM showed that the average soil loss was 10 kg/m less for plots treated with PAM, and soil erosion from quarter-drains without PAM was 11% higher. These preliminary results in using PAM to minimize soil erosion are encouraging, however, only results from the early spring storms have been recorded. The experiment is ongoing and more data will be collected during the current sugarcane season.

Laboratory Rearing of the Parasitoid *Cotesia flavipes* on Sugarcane Borer *Diatraea saccharalis*

G. Hannig and D. G. Hall
United States Sugar Corporation
Clewiston, FL

The parasitic wasp *Cotesia flavipes* is being used as a biological control agent of an extremely important pest of sugarcane, the sugarcane borer *Diatraea saccharalis*. *Cotesia* are reared and then released into the field. The sugarcane borer is reared as well as a host in which *Cotesia* are oviposited and develop. This biological control program has been very successful in controlling sugarcane borers in the field. The percent acreage where sugarcane borer problems were solved exclusively with the parasitoid *Cotesia flavipes* increased by 32.7 % and 24.9 % in 1999 and 2000,

respectively. Acreage scouted where insecticide sprays were recommended went from 12,310 acres in 1998 to 4,041 acres in 1999 to 460 acres in 2000, which is a significant decrease in insecticide use.

Disease Incidence and Yield Comparisons of KLEENTEK® Seedcane to Traditional Sources in Four Commercial Varieties in South Florida.

J. L. Flynn[1], K. Quebedeaux[1], L. Baucum[2], and R. Waguespack[3]
[1]Certis USA, Baton Rouge, LA
[2]U.S. Sugar Corp., Clewiston, FL
[3]Certis USA, Moore Haven, FL

Replicated field plots were planted using seedcane from either Kleentek (KT), a commercially available healthy seedcane based on meristem culture, or progeny of hot water treated material (HT) for varieties CP89-2143, CP 85-1382, CP 80-1827, and CP 70-1133. For the latter two varieties, an on-farm field run (FR) source of seed cane was obtained (no recent heat treatment history). Disease incidence and yield evaluations were performed over a 3-year crop cycle. The FR CP80-1827 had a 100% incidence of RSD. All other sources tested negatively for RSD in plant cane. HT and FR material for all varieties except CP 70-1133 were virtually 100% infected with Sugarcane yellow leaf virus (ScYLV). KT plots tested clean in plant cane. By second ratoon, ScYLV incidence in KT ranged from 10% in CP 70-1133 to 27% in CP80-1827.

Stalk counts were significantly higher for KT compared to HT for CP 89-2143 and CP85-1382 with overall advantages of 18.4% and 35%, respectively. Cane tonnage and sugar per acre yields averaged highest in the KT plots for all varieties. Significant increases in cane tonnage in KT over HT were noted for all varieties except CP 70-1133. Percent sugar yields were lower for the KT vs. HT for CP 85-1382. KT and HT % sugar yields were lower than FR in the CP 80-1827. Significant advantages in sugar per acre were found for KT vs. HT for CP 89-2143 and CP 85-1382 and for KT vs. FR for CP 80-1827. Over the crop cycle, sugar per acre yields of KT were 25.3% and 39.4% higher than HT for CP 89-2143 and CP 85-1382, respectively. For the older varieties (CP 80-1827 and CP 70-1133) KT yielded 18.1% and 20.4% more sugar per acre than HT and FR, respectively.

AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS
EDITORIAL POLICY

Nature of papers to be published:

Papers submitted must represent a significant technological or scientific contribution. Papers will be limited to the production and processing of sugarcane, or to subjects logically related. Authors may submit papers that represent a review, a new approach to field or factory problems, or new knowledge gained through experimentation. Papers promoting machinery or commercial products will not be acceptable.

Frequency of publication:

The Journal will appear at least once a year. At the direction of the Joint Executive Committee, the Journal may appear more frequently. Contributed papers not presented at a meeting may be reviewed, edited, and published if the editorial criteria are met.

Editorial Committee:

The Editorial Committee shall be composed of the Managing Editor, Technical Editor for the Agricultural Section, and Technical Editor for the Manufacturing Section. The Editorial Committee shall regulate the Journal content and assure its quality. It is charged with the authority necessary to achieve these goals. The Editorial Committee shall determine broad policy. Each editor will serve for three years; and may at the Joint Executive Committee's discretion, serve beyond the expiration of his or her term.

Handling of manuscripts:

Four copies of each manuscript are initially submitted to the Managing Editor. Manuscripts received by the Managing Editor will be assigned a registration number determined serially by the date of receipt. The Managing Editor writes to the one who submitted the paper to inform the author of the receipt of the paper and the registration number which must be used in all correspondence regarding it.

The Technical Editors obtain at least two reviews for each paper from qualified persons. The identities of reviewers must not be revealed to each other nor to the author during the review process. Instructions sent with the papers emphasize the necessity for promptness as well as thoroughness in making the review. Page charges will be assessed for the entire manuscript for non-members. Members will be assessed for those pages in excess of ten (10) double spaced Times New Roman (TT) 12 pt typed pages of 8 1/2" x 11" dimension with one (1) inch margins.

When a paper is returned by reviewers, the Technical Editor evaluates the paper and the recommendations of the reviewers. If major revisions are recommended, the Technical Editor sends the paper to the author for this purpose, along with anonymous copies of reviewers' recommendations. When the paper is returned to the Technical Editor, he/she will judge the adequacy of the revision and may send the paper back to any reviewer for further review. When the

paper has been revised satisfactorily, it is sent to the Managing Editor for publishing. A paper sent to its author for revision and held more than 6 months will be given a new date of receipt when returned. This date will determine the priority of publication of the paper.

A paper rejected by one reviewer may be sent to additional reviewers until two reviewers either accept or reject the paper. If a paper is judged by two or more reviewers as not acceptable for the Journal, the Technical Editor returns it to the author along with a summary of the reasons given by the reviewers for the rejection. The registration form for the paper is filled out and returned to the Managing Editor along with copies of the reviewers' statements and a copy of the Technical Editor's transmittal letter to the author. The names of all reviewers must be shown on the registration form transmitted to the Managing Editor.

If the paper as received is recommended by two reviewers for publication in the Journal, it is read by the Technical Editor to correct typographical, grammatical, and style errors and to improve the writing where this seems possible and appropriate, with special care not to change the meaning. The paper is then sent by the Technical Editor to the Managing Editor who notifies the authors of the acceptance of the paper and of the probable dates of publication. At this time, the Managing Editor will request a final version in hardcopy and on diskette in WordPerfect format from the corresponding author.

Preparation of papers for publication:

Papers sent by the Technical Editor to the Managing Editor are prepared for printing according to their dates of original submittal and final approval and according to the space available in the next issue of the Journal.

The paper is printed in the proper form for reproduction, and proofs are sent to the authors for final review. When the proofs are returned, all necessary corrections are made prior to reproduction. The author will be notified at the appropriate time to order reprints at cost.

Any drawings and photographs for the figures in the paper are "scaled" according to their dimensions, the size of lettering, and other factors. They are then sent to the printer for camera work. Proofs of the illustrations are sent to the authors. Any changes requested at this stage would be expensive and authors will be expected to pay the cost of such changes.

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RULES FOR PREPARING PAPERS TO BE PRINTED IN THE JOURNAL OF THE AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS

Format

Unless the nature of the manuscript prevents, it should include the following sections in the order listed: ABSTRACT, INTRODUCTION, MATERIALS and METHODS, RESULTS, DISCUSSION (OR RESULTS AND DISCUSSION), CONCLUSIONS, ACKNOWLEDGMENTS, and REFERENCES. Not all the sections listed above will be included in each paper, but each section should have an appropriate heading that is centered on the page with all letters capitalized. Scientific names shall be italicized.

All material (including tables and figures) shall be submitted on 8½ X 11 inch paper with one inch margins on all sides. If using WordPerfect, set the bottom margin at 0.5 inches. This will set the page number at 0.5 inches and the final line of text at 1 inch from the bottom margin. Exactness in reproduction can be insured if electronic copies of the final versions of manuscripts are submitted. Authors are encouraged to contact the managing editor for specifics regarding software and formatting software to achieve ease of electronic transfer.

Authorship

Name of the authors, institution or organization with which they are associated, and their locations should follow the title of the paper.

Abstract

The abstract should be placed at the beginning of the manuscript, immediately following the author's name, organization and location. The abstract should be limited to a single self-contained paragraph of about 250 words. State your rationale, objectives, methods, results, and their meaning or scope of application. Be specific. Identify the crops or organisms involved, as well as soil type, chemicals, or other details that figure in interpretation of the results. Do not cite tables, figures, or references. Avoid equations unless they are the focus of the paper.

Tables

Number the tables consecutively and refer to them in the text as Table 1, Table 2, etc. Each table must have a heading or caption. Capitalize only the initial word and proper names in table headings. Headings and text of tables should be single spaced. Use TAB function rather than SPACE BAR to separate columns of a table.

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Number the figures consecutively and refer to them in the text as Figure 1, Figure 2, etc. Each figure must have a legend. Figures must be of sufficient quality to reproduce legibly.

Drawings & Photographs

Drawings and photographs must be provided separately from the text of the manuscript and identified on the back of each. Type figure numbers and legends on separate pieces of paper with proper identification. Drawings and photographs should be of sufficient quality that they will reproduce legibly.

Reference Citations

The heading for the literature cited should be REFERENCES. References should be arranged such that the literature cited will be numbered consecutively and placed in alphabetical order according to the surname of the senior author. In the text, references to literature cited should be made by name of author(s) and year of publication from list of references. Do not use capital letters in the titles of such articles except in initial words and proper names, but capitalize words in the titles of the periodicals or books.

Format Example

ITCHGRASS *(ROTTBOELLIA COCHINCHINENSIS) CONTROL* IN SUGARCANE WITH POSTEMERGENCE HERBICIDES

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and

Edward P. Richard, Jr.
Sugarcane Research Unit, USDA-ARS, Houma, LA 70361

ABSTRACT

INTRODUCTION

MATERIALS AND METHODS

RESULTS AND DISCUSSION

Table 1. Visual itchgrass control and sugarcane injury as influenced by over-the-top herbicide application at Maringouin and Thibodaux, LA, 1989.

CONCLUSIONS

ACKNOWLEDGMENTS

REFERENCES

GUIDELINES FOR PREPARING PAPERS FOR JOURNAL OF ASSCT

The following guidelines for WordPerfect software are intended to facilitate the production of this journal. Authors are strongly encouraged to prepare their final manuscripts with WordPerfect 6.0 or a later version for Windows. Please contact the Managing Editor if you will not use one of those software packages.

Paper & Margins: All material (including tables and figures) shall be submitted on 8½ X 11 inch paper with one inch margins on all sides. To achieve this with WordPerfect, set the top, left, and right margins at one inch. However, set the bottom margin at 0.5 inches. This will place the page number at 0.5 inches and the final line of text at one inch.

Fonts: Submit your document in the Times New Roman (TT) 12pt font. If you do not have this font, contact the Managing Editor.

Alignment: Choose the full alignment option to prepare your manuscript. The use of SPACE BAR for alignment is not acceptable. As a general rule SPACE BAR should only be used for space between words and limited other uses. Do not use space bar to indent paragraphs, align and indent columns, or create tables.

Do not use hard returns at the end of sentences within a paragraph. Hard returns are to be used when ending paragraphs or producing a short line.

Place tables and figures within the text where you wish them to appear. Otherwise, all tables and figures will appear after your References section.

Styles: ***Italicize*** scientific names. Do not use underline.

Tables: Use Tab stops and the **Graphics** line draw option when constructing tables. Avoid the space bar to separate columns (see alignment). All lines should begin with the left most symbol in their left most column and should end with the right most symbol in their right most column.

Citations: When producing Literature Citations, use the indent feature to produce text as below.

1. Smith, I. M., H. P. Jones, C. W. Doe, 1991. The use of multidiscipline approaches to control rodent populations in plants. Journal of American Society of Plant Management. 10:383-394.

CONSTITUTION OF THE AMERICAN SOCIETY OF SUGAR CANE TECHNOLOGISTS

As Revised and Approved on June 21, 1991
As Amended on June 23, 1994
As Amended on June 15, 1995

ARTICLE I

Name, Object and Domicile

Section 1. The name of this Society shall be the American Society of Sugar Cane Technolo-gists.

Section 2. The object of this society shall be the general study of the sugar industry in all its various branches and the dissemination of information to the members of the organization through meetings and publications.

Section 3. The domicile of the Society shall be at the office of the General Secretary-Treasurer (as described in Article IV, Section 1).

ARTICLE II

Divisions

The Society shall be composed of two divisions, the Louisiana Division and the Florida Division. Each division shall have its separate membership roster and separate officers and committees. Voting rights of active and honorary members shall be restricted to their respective divisions, except at the general annual and special meetings of the entire Society, hereinafter provided for, at which general meetings active and honorary members of both divisions shall have the right to vote. Officers and committee members shall be members of and serve the respective divisions from which elected or selected, except the General Secretary-Treasurer who shall serve the entire Society.

ARTICLE III

Membership and Dues

Section 1. There shall be five classes of members: Active, Associate, Honorary, Off-shore or Foreign, and Supporting.

Section 2. Active members shall be individuals residing in the continental United States actually engaged in the production of sugar cane or the manufacture of cane sugar, or research or education pertaining to the industry, including employees of any corporation, firm or other organization which is so engaged.

Section 3. Associate members shall be individuals not actively engaged in the production of sugar cane or the manufacture of cane sugar or research pertaining to the industry, but who may be interested in the objects of the Society.

Section 4. Honorary membership shall be conferred on any individual who has distinguished himself or herself in the sugar industry, and has been elected by a majority vote of the Joint Executive Committee. Honorary membership shall be exempt from dues and entitled to all the privileges of active membership. Each Division may have up to 15 living Honorary Members. In addition, there may be up to 5 living Honorary members assigned to the two Divisions jointly.

Section 5. Off-shore or foreign members shall be individuals not residing in the continental United States who may be interested in the objects of the Society.

Section 6. Supporting members shall be persons engaged in the manufacturing, production or distribution of equipment or supplies used in conjunction with production of sugar cane or cane sugar, or any corporation, firm or other organization engaged in the production of sugar cane or the manufacture of cane sugar, who may be interested in the objects of the Society.

Section 7. Applicants for new membership shall make written application to the Secretary-Treasurer of the respective divisions, endorsed by two members of the division, and such applications shall be acted upon by the division membership committee.

Section 8. Minimum charge for annual dues shall be as follows:

Active Membership	$10.00
Associate Membership	$25.00
Honorary Membership	NONE
Off-shore or Foreign Membership	$20.00
Supporting Membership	$50.00

Each Division can assess charges for dues more than the above schedule as determined by the Division officers or by the membership at the discretion of the officers of each Division.

Dues for each calendar year shall be paid not later than 3 months prior to the annual meeting of the member's division. New members shall pay the full amount of dues, irrespective of when they join. Any changes in dues will become effective in the subsequent calendar year.

Section 9. Dues shall be collected by each of the Division's Secretary-Treasurer from the members in their respective divisions. Unless and until changed by action of the Joint Executive Committee, 50 percent of the minimum charge for annual dues, as described in Section 8 for each membership class, shall be transmitted to the office of the General Secretary-Treasurer.

Section 10. Members in arrears for dues for more than a year will be dropped from membership after thirty days notice to this effect from the Secretary-Treasurer. Members thus dropped may be reinstated only after payment of back dues and assessments.

Section 11. Only active members of the Society whose dues are not in arrears and honorary members shall have the privilege of voting and holding office. Only members (all classes) shall have the privilege of speaking at meetings of the Society.

ARTICLE IV

General Secretary-Treasurer and Joint Executive Committee

Section 1. The General Secretary-Treasurer shall serve as Chief Administrative Officer of the Society and shall coordinate the activities of the divisions and the sections. He or she will serve as ex-officio Chairperson of the Joint Executive Committee and as General Chairperson of the General Society Meetings, and shall have such other duties as may be delegated to him or her by the Joint Executive Committee. The office of the General Secretary-Treasurer shall be the domicile of the Society.

Section 2. The Joint Executive Committee shall be composed of the elected members of the two division Executive Committees, and is vested with full authority to conduct the business and affairs of the Society.

ARTICLE V

Division Officers and Executive Committee

Section 1. The officers of each division of the Society shall be: a President, a First Vice-President, a Second Vice-President, a Secretary-Treasurer or a Secretary and a Treasurer, and an Executive Committee composed of these officers and four other members, one from each section of the Division (as described in Section 3 of Article VII), one elected at large, and the President of the previous Executive Committee who shall serve as an Ex-Officio member of the Division Executive Committee. The office of the Secretary-Treasurer in this constitution indicates either the Secretary-Treasurer, or the Secretary and the Treasurer.

Section 2. These officers, except Secretary-Treasurer, shall be nominated by a nominating committee and voted upon before the annual division meeting. Notices of such nominations shall be mailed to each member at least one month before such meeting. Ballots not received before the annually specified date will not be counted.

Section 3. The Secretary-Treasurer shall be appointed by and serve as a non-voting member at the pleasure of the Division Executive Committee. The Secretary-Treasurer may not hold an elected office on the Executive Committee.

Section 4. The duties of these officers shall be such as usually pertain to such officers in similar societies.

Section 5. Each section as described in Article VII shall be represented in the offices of the President and Vice-President.

Section 6. The President, First Vice-President, and Second Vice-President of each Division shall not hold the same office for two consecutive years. Either Section Chairperson (as described in Section 3 of Article VII) may hold the same office for up to two consecutive years. The terms of the other officers shall be unlimited.

Section 7. The President shall be elected each year alternately from the two sections hereinafter provided for. In any given year, the Presidents of the two Divisions shall be nominated and elected from different sections. The President from the Louisiana Division for the year beginning February, 1970, shall be nominated and elected from the Agricultural Section. The president from the Florida Division for the year beginning February,

1970, shall be nominated and elected from the Manufacturing Section.

Section 8. Vacancies occurring between meetings shall be filled by the Division Executive Committee.

Section 9. The terms "year" and "consecutive year" as used in Articles V and VI shall be considered to be comprised of the elapsed time between one annual division meeting of the Society and the following annual division meeting of the Society.

ARTICLE VI

Division Committees

Section 1. The President of each division shall appoint a committee of three to serve as a Membership Committee. It will be the duty of this committee to pass upon applications for membership in the division and report to the Secretary-Treasurer.

Section 2. The President of each division shall appoint each year a committee of three to serve as a Nominating Committee. It will be the duty of the Secretary-Treasurer of the Division to notify all active and honorary members of the Division as to the personnel of this committee. It will be the duty of this committee to receive nominations and to prepare a list of nominees and mail this to each member of the Division at least a month before the annual meeting.

ARTICLE VII

Sections

Section 1. There shall be two sections of each Division, to be designated as:

1. Agricultural
2. Manufacturing

Section 2. Each active member shall designate whether he or she desires to be enrolled in the Agricultural Section or the Manufacturing Section.

Section 3. There shall be a Chairperson for each section of each Division who will be the member from that Section elected to the Executive Committee. It will be the duty of the Chairperson of a section to arrange the program for the annual Division meeting.

Section 4. The Executive Committee of each Division is empowered to elect one of their own number or to appoint another person to handle the details of printing, proof reading, etc., in connection with these programs and to authorize the Secretary-Treasurer to make whatever payments may be necessary for same.

ARTICLE VIII

Meetings

Section 1. The annual General Meeting of the members of the Society shall be held in June each year on a date and at a place to be determined, from time to time, by the Joint Executive Committee. At all meetings of the two Divisions of the Society, five percent of the active members shall constitute a quorum. The program for the annual meeting

of the Society shall be arranged by the General Secretary-Treasurer in collaboration with the Joint Executive Committee.

Section 2. The annual meeting of the Louisiana Division shall be held in February of each year, at such time as the Executive Committee of the Division shall decide. The annual meeting of the Florida Division shall be held in September or October of each year, at such time as the Executive Committee of that Division shall decide. Special meetings of a Division may be called by the Executive Committee of such Division.

Section 3. Special meetings of a Section for the discussion of matters of particular interest to that Section may be called by the President upon request from the respective Chairperson of a Section.

Section 4. At Division meetings, 10 percent of the active division members and the President or a Vice-President shall constitute a quorum.

ARTICLE IX

Management

Section 1. The conduct and management of the affairs of the Society and of the Divisions including the direction of work of its special committees, shall be in the hands of the Joint Executive Committee and Division Executive Committees, respectively.

Section 2. The Joint Executive Committee shall represent this Society in conferences with the American Sugar Cane League, the Florida Sugar Cane League, or any other association, and may make any rules or conduct any business not in conflict with this Constitution.

Section 3. Four members of the Division Executive Committee shall constitute a quorum. The President, or in his or her absence one of the Vice-Presidents, shall chair this committee.

Section 4. Two members of each Division Executive Committee shall constitute a quorum of all members of the Joint Executive Committee. Each member of the Joint Executive Committee, except the General Secretary-Treasurer, shall be entitled to one vote on all matters voted upon by the Joint Executive Committee. In case of a tie vote, the General Secretary-Treasurer shall cast the deciding vote.

ARTICLE X

Publications

Section 1. The name of the official journal of the Society shall be the "Journal of the American Society of Sugar Cane Technologists." This Journal shall be published at least once per calendar year. All articles, whether volunteered or invited, shall be subject to review as described in Section 4 of Article X.

Section 2. The Managing Editor of the Journal of the American Society of Sugar Cane Technologists shall be a member of either the Florida or Louisiana Divisions; however, he or she shall not be a member of both Divisions. The Division affiliation of Managing Editors shall alternate between the Divisions from term to term with the normal term being three years, unless the Division responsible for nominating the new Managing Editor reports that it has no suitable candidate. The Managing Editor shall

be appointed by the Joint Executive Committee no later than 6 months prior to the beginning of his or her term. A term will coincide with the date of the annual Joint Meeting of the Society. No one shall serve two consecutive terms unless there is no suitable candidate from either Division willing to replace the current Managing Editor. If the Managing Editor serves less than one year of his or her three-year term, another candidate is nominated by the same Division, approved by the other Division, and appointed by the General Secretary-Treasurer to a full three-year term. If the appointed Managing Editor serves more than one year but less than the full three-year term, the Technical Editor from the same Division will fill the unexpired term of the departed Managing Editor. In the event that the Technical Editor declines the nomination, the General Secretary-Treasurer will appoint a Managing Editor from the same Division to serve the unexpired term.

Section 3. The "Journal of the American Society of Sugar Cane Technologists" shall have two Technical Editors, which are an Agricultural Editor and a Manufacturing Editor. The Managing Editor shall appoint the Technical Editors for terms not to exceed his or her term of office. Any Technical Editor shall be a member of either the Louisiana or Florida Division. Each Division will be represented by one technical editor at all times unless the Executive Committee of one Division and the Managing Editor agree that there is no suitable candidate willing to serve from that Division.

Section 4. Any member or nonmember wishing to contribute to the Journal of the American Society of Sugar Cane Technologists shall submit his or her manuscript to the Managing Editor. The Managing Editor shall then assign the manuscript to the appropriate Technical Editor. The Technical Editor shall solicit peer reviews until, in the opinion of the Technical Editor, two responsible reviews have been obtained that either accept (with or without major or minor revision) or reject the manuscript. For articles accepted with major revision, it shall be the responsibility of the Technical Editor to decide if the authors have satisfactorily completed the major revision(s). The Technical Editor may solicit the opinion of the reviewers when making this decision. The Technical Editors shall not divulge the identity of any reviewer. The Managing Editor shall serve as Technical Editor of any manuscript which includes a Technical Editor as an author.

ARTICLE XI

Amendments

Section 1. Amendments to this Constitution may be made only at the annual meeting of the Society or at a special meeting of the Society. Written notices of such proposed amendments, accompanied by the signature of at least twenty (20) active or honorary members must be given to the General Secretary-Treasurer at least thirty (30) days before the date of the meeting, and he or she must notify each member of the proposed amendment before the date of the meeting.

ARTICLE XII

Dissolution

Section 1. All members must receive notification from the General Secretary-Treasurer of any meeting called for the purpose of terminating the Society at least thirty (30) days prior to the date of the meeting. After all members have been properly notified, this organization may be terminated at any time, at any regular or special meeting called for

that purpose, by an affirmative vote of two-thirds of the total honorary and active members in good standing present at the meeting. Thereupon, the organization shall be dissolved by such legal proceedings as are provided by law. Upon dissolution of the Joint Society, its assets will be divided equally between the two Divisions of the Society. Dissolution of the Joint Society will not be cause for automatic dissolution of either Division. Upon dissolution of either Division, its assets will be divided in accordance with the wishes of its members and in conformity with existing IRS regulations and other laws applicable at the time of dissolution.

ARTICLE XIII

Assets

Section 1. No member shall have any vested right, interest or privilege of, in, or to the assets, functions, affairs or franchises of the organization; nor any right, interest or privilege which may be transferable or inheritable.

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