2007

The effects of nitrogen on sugarcane sucker production and sugar yield

John Eriton Richard
Louisiana State University and Agricultural and Mechanical College, jrich29@lsu.edu

THE EFFECTS OF NITROGEN ON SUGARCANE SUCKER PRODUCTION AND SUGAR YIELD

A Thesis

Submitted to the Graduate Faculty
of Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science

in

The Department of Agronomy and Environmental Management

by
John Eriton Richard
B.S. Southern University, 2000
May, 2007

ACKNOWLEDGEMENTS

First and foremost I would like to express thanks to my mother, Belva J. Richard for all of her love and support throughout my college career. I would like to thank my two sisters, Katrina and Sabrina, and my brother, Kevin Richard for all of their love and support in every aspect of my life.

I would like to express my sincere appreciation to Dr. Collins Kimbeng and Dr. Kenneth Gravois, for their precious time, massive amounts of patience and never-ending support. I am very grateful to both for allowing me to study under their supervision. I would also like to thank Dr. Howard "Sonny" Viator for allowing me to work as a research associate at the Iberia Research Station while pursuing my master's degree.

Thanks to the members of my graduate committee, Dr. Kenneth Gravois, Dr. Chuck Kennedy, and Dr. Jeff Hoy for their constructive criticism and time on this research project.

I would like to thank the crew at the St Gabriel Research Station, Dr. Keith Bishoff, Mr. Chris Laborde, Mr. Al Orgeron, Mr. Terry Bacon, Mr. Todd Robert, Mrs. Gert Hawkins, Mr. Joel Hebert, Mrs. Alice Moman and Mr. Allen Arceneaux for the endless amount of time and help you provided throughout this research project.

To my amazing wife Tiffany and beautiful daughter Darian, without your love and support I would not have been able to achieve this goal. Thank you!

TABLE OF CONTENTS

ABSTRACT

Sugarcane suckers, otherwise known as bullshoots or water sprouts have been reported in south Louisiana. Suckers are physiologically immature shoots and tend to accumulate less sucrose compared to mature stalks. Suckers may affect productivity by increasing biomass while contributing little to sucrose content. An understanding of the environmental and cultural factors responsible for sugarcane sucker production in Louisiana may provide answers that could be useful in minimizing its negative effect on production. The study objective was to investigate the effects of nitrogen (N) treatments on sugarcane and sugarcane sucker production in variety HoCP 85-845 under Louisiana growing conditions. This variety had previously been identified as having a high propensity to produce suckers. A secondary objective was to investigate the effects of a split N application on sugarcane sucker production and sugar yield.

Two experiments were conducted; the first was planted in the fall of 2000 (plant cane data) on a Sharky clay soil and a second was planted in the fall of 2001 (ratoon and plant cane data) on a Commerce silt loam soil.

Significant differences ($P \leq 0.05$) in sucker population were found among treatments in the 2001 ratoon crop in mid-September before Tropical Storm Isidore and Hurricane Lili affected southern Louisiana. Severe lodging due to the two tropical systems prevented stalk counts from being made in the 2001 plantcane experiment. At time of harvest (mid-December) significant differences were found for cane yield, sucrose content, and stalk weight in both experiments however no significant differences were found among treatments for sucker population. These results were not conclusive because of the high amounts of rainfall and severe lodging experienced. On

average, suckers contributed 1.6% and 0.93% to total cane yield in the 2001 ratoon and plantcane crops, respectively. For sugar yield in the same year and crops, 9.4% and 2.2% of total sugar yield was attributed to suckers, respectively. Given the added costs of transportation and milling, suckers are likely to have an overall negative effect on sugar production and processing.

INTRODUCTION

Sugarcane (interspecific hybrids of *Saccharum L*) is a vegetatively propagated, perennial crop grown for its ability to accumulate sucrose in its stem or stalk vacuoles. It belongs to the grass family (*Gramineae*) and tribe *Andropogoneae*. Like several other members of the grass family, sugarcane can produce multiple stalks in a single plant or stool. This process is called tillering and grasses rely on it as one way to multiply vegetatively. The average number of tillers per plant varies between sugarcane varieties and is probably dependent upon a combination of the genetic make up of the plant and the environment in which the sugarcane plant is grown. For example, high N levels stimulate many grasses to tiller.

Tillering is the sprouting of lateral-buds, which can later develop into mature stalks. In sugarcane, tiller development takes place in a compact rhizomatous growth from the original bud sprout, developing into a tuft or stool, borne on nodes of tapered stalk portions in sequence from primary to secondary, secondary to tertiary and so on (Yadava, 1991). Tillering is an indeterminate process in sugarcane as new tillers continue to appear whiles the older ones elongate and mature. The result is that a single plant can have tillers at different morphological and physiological stages (Yadava, 1991).

In sugarcane production systems, tillers can conveniently be classified based on the time of their emergence and maturity stage in the cropping cycle (Yadava, 1991). The early tillering phase starts soon after germination and emergence of a leaf on the main shoot. Late tillers appear well after the main flush of early tillers and in some cases when early tillers have more or less matured. Sometimes, late tillers fail to reach physiological maturity before the time of harvesting. These are commonly referred to as suckers, bull shoots, or water sprouts and can be recognized by their distinct juvenile appearance and large barrel. Suckers tend to accumulate less sucrose compared to physiologically mature tillers at time of harvest. Suckers, therefore, may adversely affect sugar production by increasing biomass and contributing very little to sucrose yield. Furthermore, they may add to the cost of transportation and milling by increasing extraneous matter and diluting sucrose concentration during the sugar extraction process (Clarke et al., 1988). In Australia, greater occurrence of suckers coincided with a general decline in sucrose levels (Salter and Bonnett, 2000).

Sugarcane is primarily a tropical plant that usually requires between 8 to 24 months to reach maturity and temperatures high enough to permit rapid growth for 8 or more months depending on location. In areas where sugarcane is grown as a two-year crop, for example in Hawaii, suckers form an important beginning towards the next crop cycle. In Louisiana, however, sugarcane is grown under temperate conditions with one of the shortest growing seasons in the world. Mature stalks or billets are usually planted in August and September to begin a crop cycle but the emerging shoots soon experience a winter freeze in November or December and do not recommence growth until spring (late March to early April) of the following year. The crop usually matures around October and is harvested between October 1 and January 10, and again after harvest the buds remain dormant until spring. According to Inman-Bamber (1994), maximum tillering in sugarcane occurs approximately 500°C d after regrowth, which in Louisiana would fall between late April and June. The short growing season in

Louisiana may prohibit later emerging tillers, say in July, from reaching physiological maturity prior to harvest.

Suckers have been reported in Louisiana since the introduction of sugarcane to the state in 1751 (Stubbs, 1897). However, little is known about the factors responsible for sugarcane suckering in Louisiana. Information about the environmental factors responsible for sucker production is important in designing strategies to minimize the negative impact of suckers. It has been postulated that suckers develop from dormant underground buds that are produced several months before they actually appear (Salter and Bonnet, 2000). However, what actually triggers suckers to emerge and develop is not well understood. According to Griffee (2000), sugarcane shows a strong apical dominance which can be broken in various ways including lodging and light reaching the base of the plant allowing the underground buds to develop into new shoots. When formed late in the development of the crop, these new shoots remain immature to form suckers.

Nutrient availability has also been implicated in suckering. As mentioned earlier, a general decline in sucrose levels in the wet tropics of Australia was responsible for suckering gaining prominence as a potential problem in sugarcane production. Around the same period, growers and researchers became increasingly aware of the build up of organic matter under the green cane trash blanketing cultural practice (Salter and Bonnett, 2000). They hypothesized that plants in the subsequent crop may be obtaining additional N from this residue blanket left on top of the crop. In Louisiana, approximately 60 to 80 percent of the crop is harvested green. That is, no burning prior to harvesting which leaves a residue blanket on top of the subsequent crop. The crop residue left after harvest decreases subsequent crop yields due to wetter and cooler conditions caused by the residue during winter dormancy. Most of these residues are burned after harvest because of the deleterious effects of the trash blanket (Richard, 1999).

Thus, at least two main factors, namely available N and sunlight (heating of soil surface) seem to influence suckering in sugarcane. Salter and Bonnett (2000) reported that increased plant available N increased the number of sugarcane suckers in the wet tropics of Australia. Hes (1954) suggested that direct heating of the soil surface by sunlight might play a role in sugarcane sucker production, which may be responsible for profuse suckering that frequently occurs after a crop lodges.

The primary objective of this study was to investigate the effect of N on sugarcane sucker production in Louisiana and how this may influence total sugar production. A secondary objective was to investigate the effect of split application of N in sugarcane suckers and sugar yield.

LITERATURE REVIEW

A Brief History of Sugarcane Production in Louisiana

Sugarcane has been a vital part of the south Louisiana economy and culture for over 200 years. In 1751, Jesuit missionaries brought sugarcane into South Louisiana, laying the foundation for south Louisiana's sugar industry (Stubbs, 1897). The first sugarcane varieties grown in south Louisiana replacing the cultivation of indigo were "Creole" and "Otaheite." Creole was sweet and excellent for chewing. In 1797, Etienne De Bore produced the first granulated sugar from Otaheite at his plantation in Audubon near New Orleans. However, both of these varieties were very susceptible to frost (cool temperatures) that occurred in south Louisiana's less than tropical climate. In 1825, two new varieties, which became branded as Louisiana Purple and Louisiana Striped, were introduced to Louisiana. Both of these sugarcane varieties were more frost resistant than Creole or Otaheite, which allowed the industry to further expand. These varieties were called the "Noble" canes (*Saccharum officinarum*) and were characterized by large stalk diameter, low fiber content, and sucrose content satisfactory for sugar production under Louisiana conditions (Yadava, 1991).

The production of sugarcane seedlings in Barbados and evaluated at the LSU Sugar Station in New Orleans, Louisiana improved later sugarcane varieties (LSU AgCenter, 2001). In 1919, sugarcane crossing began at the USDA-ARS Sugarcane Field Station at Canal Point, Florida. In 1922, the LSU Sugar Station received seed from Canal Point for evaluation as new sugarcane varieties. In 1923, the USDA-ARS established an experiment station in Houma, Louisiana for variety development and disease evaluations. The evaluation of varieties through the cooperative efforts of the

LSU Agricultural Center, the United States Department of Agriculture, and the American Sugar Cane League was initiated in 1924 under the terms of a "Three-Way Agreement", which was first signed in 1926. Variety development in Louisiana has been achieved by this cooperative agreement for 80 years.

Sugarcane Production in Louisiana

Sugarcane is an important crop to Louisiana. During the early years of cultivation, the average yield of sugarcane in Louisiana ranged from 35.8 and 44.8 T/ha (LSU AgCenter, 2001). The state sugar crop averaged around 672,000 Mt of sugar per year and was a source of livelihood for approximately 500,000 people. Today, Louisiana sugarcane yields range from 67.2 to 112 T/ha, with recoveries ranging from 87.5 to 112.5 g/kg of sugar produced from each metric ton of cane (LSU AgCenter, 2001). These sugar levels are similar to yields obtained in the tropical sugarcane-growing regions. These advances are primarily the result of sugarcane breeding efforts.

New sugarcane varieties are the livelihood of Louisiana's sugar industry. Louisiana sugarcane varieties have been improved through the production of sugarcane seed through crossing and subsequent selection and variety testing efforts by the cooperative efforts of the LSU Agricultural Center, United States Department of Agriculture and the American Sugar Cane League. Progressive improvements in cane yield, sugar yield, and sucrose content through plant breeding has contributed in sustaining the industry over the years. Louisiana's sugarcane-breeding program has had, and will continue to have a positive impact on keeping Louisiana in the sugar business. That is why sugar continues to be a major part of the south Louisiana economy.

In 1999, sugarcane was produced on more than 182,186 hectares in 25 of 64 Louisiana parishes (LSU AgCenter, 1999). In 2000, sugarcane was produced on 186,234 hectares and in 2001, the industry sugarcane was cultivated on 199,908 hectares of land by 773 producers in 24 Louisiana parishes. An estimated 183,915 hectares was harvested for sugar, with a total production of 1.36 million metric tons of sugar. The gross farm value of $377,865,930 for sugar and molasses, as reported in the crop production statistics, is 61% of the total value of the sugar and molasses produced, with the remaining 39% going to processing and marketing. The production of sugarcane and its processing is estimated to be more than $2 billion per year in Louisiana.

Economic Impact of Suckers in Sugarcane Production

High sucrose content is required to maintain financial viability. Knowledge about factors affecting sucrose content is important in decision-making, especially with regard to harvest time (Hughes et al., 2000). A factor that may contribute to the decline of commercially recoverable sugar in the sugarcane crop is the presence of suckers at harvest.

In Australia, Wilson and Leslie (1997) noted a decline in sucrose concentration in previously productive varieties and identified suckers as a major factor responsible for this decline. Suckers are generally less physiologically mature and accumulate very little sucrose compared to mature stalks. Ivin and Doyle (1989) reported that the sucrose content for suckers measured as commercial cane sugar (CCS), of four varieties averaged 1.3 compared to 14.7% for mature stalks.

In Louisiana, sucrose content (g of sucrose per kg of cane) of suckers ranged from 3.6 to 26.8 among five varieties compared to a range of 117.3 to 127.8 for mature stalks (Gravois et al., 2002). Gravois et al., (2002) suggested that the presence of suckers in sugarcane at harvest is a likely factor for reduced sucrose content in some Louisiana varieties such as HoCP85-845, which derived 16.1% of its total cane yield from suckers.

Suckers can also adversely affect sugar production by diluting the total sugar that is extracted during milling and by adding to the cost of transportation. In Australia, for example, sugarcane is harvested as billets using mechanical combine harvesters and sucker culms are not separated from normal cane. Therefore, suckers dilute sugar extraction by adding to the extraneous matter and fiber content of the cane that is being milled (Clarke et al., 1988). Crook et al. (1999) found that the difference between sucrose content measured using mature stalks and that measured during the milling process was mostly due to the presence of suckers.

Berding (2000) reported that the potential sucrose content in field (sound and unsound stalks) and post-harvest (sound and unsound stalks) sucrose content of 154.6 and 147.7 g / kg were well above the mill-realized value. In the same experiment, in-field sucker culms and extraneous matter made up 29.7% of the total crop biomass. Berding used these results to question the efficacy of current harvesting philosophy and technology in Australia.

In Louisiana Gravois et al. (2002) found that suckers constituted 21.5% of the total cane yield of variety HoCP85-845 in the plantcane crop harvested in 1998.

Harvesting a sugarcane crop with a large amount of suckers will add to the cost of harvesting and processing, which will reduce the profitability of any sugar industry.

Jackson et al. (2000) modeled the cost of harvesting, crushing, and processing a high suckering variety (30% of the harvest mass) compared to a low suckering variety (5% of the harvested mass) and found that it would be worth about $4.9 million (Australian) to the sugar industry in one region alone. However, the full impact of suckering on profitability of sugarcane production in Louisiana remains unidentified.

Cultural Practices of Sugarcane Production in Louisiana

In Louisiana, sugarcane is grown under temperate conditions and has one of the shortest growing seasons in the world. In Louisiana, Mature stalks or billets are usually planted in August and September to begin a crop cycle, but the emerging shoots soon experience a winter freeze in November or December and do not recommence growth until spring of the following year. The crop is then harvested after only 7-9 months of growth. Sugarcane is a tropical plant that requires anywhere from 8 to 24 months to reach maturity and high temperatures to permit rapid growth during this time frame. Therefore, because of Louisiana's climate, some sugarcane tillers will not reach maturity during the season and may be considered as suckers.

In addition to the unique growing season, Louisiana also has a unique cultural practice known as off-barring that is believed to aid in the growth of sugarcane.   Off-barring is the removal of soil from each side of the sugarcane bed in early spring (late March or early April). Louisiana is the only sugarcane growing state in the USA that uses this cultural practice.   It is postulated that the practice is used to more quickly help warm the soil around the plants. Off-barring is meant to expose the root zone and promote heating of the root zone by solar energy which is believed to help initiate early spring re-growth in the crop. Judice (2005) found that the off-baring process did not help to warm the soils any more quickly than the absence of cultivation.

Off-barring is also believed to be important for managing N availability in sugarcane seedbeds. Its importance for fertilizer application may lie in augmenting N placement, as the fertilizer is banded on each side of the row. Off- barring is most likely benefit is to aid in keeping the integrity of sugarcane rows by filling in undesirable ruts left in fields after harvest during wet conditions, which is a common Louisiana practice.

Hypothesized Factors Responsible for Sucker Production

For a long time, suckers were accepted as a natural phenomenon of the crop that could not be suppressed or selected against since sugarcane is a member of the grass family and multiples through tillering (Stubbs, 1897). Research has since shown that some varieties tend to produce more suckers than others and sucker production varies with year (Stevenson, 1965; Gravois et al., 2002), indicating that both genotype and environmental conditions may influence sucker production.

The possible roles of N, the short growing season, and cultural practices in Louisiana have not been investigated, but it has been speculated that these practices lead to increased sucker production in sugarcane at harvest. The environmental factors responsible for suckers in a sugarcane crop at harvest have not been evaluated in sugarcane grown in south Louisiana.

Hurney and Berding (2000), conducted research to better understand the impact of N and varieties on CCS (sucrose content) and cane yield of plantcane crops grown on three different soil types as influenced by lodging and suckering. The experiment included three varieties, Q117, Q120, and Q138, which differed in cane yield and sucrose content potential. The performance of each variety was tested at four different rates of N. N was applied at rates of 0, 70, 140, and 210 kg N/ha. They found that N had no effect on cane yield, CCS, suckering, or lodging. The data indicated that lodging was not influenced by site but by the effects of strong winds and rainfall. However, negative effects on cane yield of up to 8% were obtained by lodging. Comparisons of erect and lodged stalks across all varieties and sample times showed that lodging reduced CCS by 1.2 units on average. In addition to lodging, CCS was negatively impacted by suckers. Suckers had a mean CCS of 1.98. Suckers reduced CCS by one unit for each 10% by weight of suckers included in the sample. There were 10, 7, and 20% suckers by cane yield weight at final harvest for the three varieties used in this study.

In another study conducted by Salter and Bonnet (2000), they evaluated the application of addition N fertilizer at the end of the wet season to test the hypothesis that increased plant available N in the autumn/winter prior to harvesting would lead to an increase in sucker number and size. All treatments received a recommended application of 150 kg N/ha after ratooning. Three treatments had an additional 70 kg N/ha applied in May, June, and July. Every month the numbers of suckers per hectare were counted and soil samples were taken to determine whether N increased soil nitrate levels. Their results showed that N applications increased soil nitrate concentrations in the soil, thus plant available N in all treatments. Sucker number did increase following N applications. However, at their final sampling date, the number of suckers/ha was similar in all treatments when compared to the control. This was primarily the result of a flush of small suckers in the final two weeks of the experiment. Their study concluded that the effect of increased N availability at autumn and winter prior to harvest will have a great effect on CCS, as a result of a large number of suckers.

According to these two studies, N has several different roles and effects on a sugarcane crop. Hurney and Berding (2000) did not get a response to N because rarely does a plantcane crop respond to N under Australian conditions, whereas Salter and Bonnet (2000) conducted their study on a ratoon crop. Furthermore, a plantcane crop has a higher plant population compared to a first or second ratoon crop, hence less available space for sucker formation. N may be a factor that influences sucker production, but other environmental cues may interact with N to bring about suckering.

Another factor that has been suggested to play a role in sucker production is direct heating of the soil surface by sunlight (Hes, 1954). Direct heating of the soil surface may be responsible for the profuse suckering that occurs after a crop lodges. It is very common to observe a flush of suckers soon after lodging in a crop. However, varieties, such as CP 72-370, can produce suckers even when the crop remains erect (Gravois et al., 2002). They suggested that the propensity to sucker in the variety CP 72-370 could be attributed to its leaf angle, which is extremely erect and may allow enough sunlight to penetrate the canopy, thus allowing suckers to form late in the growing season. Little is known about this suppostion because no research has been done to test the hypothesis. When a crop is lodged, the sunlight is able to reach the soil surface causing the soil temperature to increase, which may influence sucker formation. Van Dillewijn (1952) asserts from visual observations that suckers are most numerous in part of the fields where sunlight is allowed to enter freely. Hes (1954) again postulated that suckers develop in fields where sunlight is able to penetrate the crop canopy and reach the soil causing underground buds to germinate. The same authors postulated that germination actually takes place several months before the appearance of suckers in the field. As a result, the suckers emerge late in the season because of the sunlight directly heating the soil after a crop lodges.

MATERIALS AND METHODS

A field study was initiated at the Sugar Research Station in St. Gabriel, Louisiana, using a variety with a high propensity to sucker, HoCP 85-845, to determine the effects of N on sugarcane sucker production. The first experiment was planted in the fall of 2000 on a Sharky clay (v*ery fine, montmorillontic, nonacid, thermic, Vertic Halauept*) soil with the plantcane harvested in 2001 and the first ratoon harvested in 2002 and a second experiment was planted in the fall of 2001 on a Commerce silt loam (*fine-silty, mixed, nonacid, thermic Aeric, Fluvaquent*) soil with the plantcane harvested in 2002.

Each plot (experimental unit) consisted of three rows 12.2 m long, 1.8 m wide, and a 1.5 m alley between plots. Treatments consisted of different rates and timings of ammonium nitrate 34% N fertilizer. Fertilizer rates were 56, 112, 168, and 224 kg N/ha all applied in early April and an additional 56 kg N/ha applied in July to the 112 kg N /ha and 168 kg N/ha plots. The six treatments were arranged in a randomized complete block design with four replicates giving 24 plots. The fertilizer treatments were applied by banding in the shoulder of the row of each plot.

In each experiment, stalk population (stalks/ha) counts were taken in the early fall before harvest. Sucker population (suckers/ha) was also monitored monthly starting in early fall in each plot until harvest. A final stalk population and sucker population count was taken at harvest. Hand-cut samples (including 10 mature stalks and all suckers) were counted and weighed from the middle row of each plot to estimate mean stalk weight (kg). Sucker cane yield (t/ha) was calculated as the product of sucker population (stalks/ha) and mean sucker stalk weight (kg) divided by 1000. Cane yield (t/ha) was calculated as the product of stalk population (stalks/ha) and mean stalk weight (kg) divided by 1000. Sucrose analysis was determined for each sample of suckers and mature stalks at the St. Gabriel Research Station sucrose laboratory. Sucrose content (g/kg) was determined by using Brix (estimated by a refractometer) and pol (measured by a saccharimeter) estimates (Gravois and Milligan, 1992). Sugar yield (t/ha) was calculated as the product of estimated cane yield and sucrose content divided by 1000. Stalk density (g/cm^3) was estimated as stalk weight (kg) divided by 1000 divided by stalk volume (cm^3). Stalk volume was determined by water displacement in a calibrated 30-cm-diameter water-filled cylinder using methods described by Gravois (1988). Stalk density was not measured in 2002 for mature stalks due to curvature of stalks caused by the two tropical systems. Fiber content (g kg^{-1}) was also determined at the St. Gabriel Research Station sucrose laboratory as reported by Gravois and Milligan (1992). Samples were ground up in a Jeffco cutter grinder (Jefferies, Brothers Ltd., Brisbane Queensland, Australia), mixed, and a 600-g sub sample was taken for fiber analysis. Each sample was pressed with a hydraulic press at 16,560 kPa for 1 min to separate the juice from the residue (bagasse). The residue was weighed and oven-dried for 72 hours at 40.5 C. The weight of the dry plug was recorded. A portion of the crusher juice was analyzed for Brix (percent soluble solids w/w) using a refractometer (Chen and Chou, 1993). Pol of the clarified juice was obtained with an automated saccharimeter.

Soil samples were taken by compositing three cores taken from random locations within each plot to a depth of 25 cm to test soil nitrate levels and determine availability of N to the plant. Soils sampled for nitrate levels were pulverized and placed in a paper bag. The samples were dried down at 60 C but no higher within one hour of sampling. Dried samples were stored at 4 C and later air-dried for nitrate analysis. Nitrate was extracted using 2.0 N KCl. Each extraction consisted of 5.0 g of soil in 25 ml KCl. Soil nitrate concentrations were determined using a modified method of Keeney and Nelson (1982).

Meteorological data (rainfall and atmospheric temperature) covering the period of the experiments was obtained from the website of the National Climatic Data Center (NCDC 2006).

Data were available for the 2000 plantcane crop and 2001 ratoon and plantcane crops for analysis. The data were subjected to Proc Mixed in SAS (SAS version 9.0, SAS Inc., 2002) with blocks considered random effects and treatments considered fixed effects in the model. Regression analysis was performed to investigate any association between sucker production and the other traits (Hurney and Berding, 2000).

RESULTS AND DISCUSSION

2000 Plantcane Experiment

The analysis of variance for the 2000 plantcane experiment showed that increasing soil N or split applications of N had no effect on sugar yield, cane yield, sucrose content, mean stalk weight, stalk population (Tables 1 and Table 2). In this experiment, suckers were not observed as the crop remained erect with a closed canopy for the entire growing season. Unlike the experience of Gravois et al. (2002), suckers did not develop under these conditions of a closed canopy. Apparently, there are other interactive triggering factors initiating or deterring sucker development within the sugarcane crop.

In a similar study conducted by Hurney and Berding (2000), increasing N fertilizer had no effect on CCS (sucrose content), cane yield, lodging, or suckering at any of the sampling times in a plant crop. Salter et al. (2000) data showed that elevated rates of N resulted in no significant differences between the number of suckers, total fresh mass of suckers and average fresh mass of suckers for any of the treatments at final harvest.

Research has shown that responses to N fertilizer have been limited in the plantcane crop and increased incrementally in succeeding ratoon crops to its highest level in the second and subsequent ratoons (Wiedenfeld, 1997). This could further account for the lack of treatment differences observed in this experiment because this experiment was a plantcane crop. Kennedy and Legendre (2005) reported that LCP 85-384, the major variety grown in Louisiana on more than 91% of the planted areas in 2004, responded best at lower than recommended rates of nitrogen (N), not more.

Extensive fertilizer response experiments had not been conducted in Louisiana for this new variety prior to its release. Data collected by Kennedy and Legendre beginning in 2000 to 2005 from 18 environments indicated LCP85-384 produced optimal yields (usually greater than 90% of the maximum yield and not statistically different) at fertilizer N rates that were generally 20-40 lb/a lower than the older established fertilizer N rate recommendations. Anecdotal evidence from farmers who have reduced the fertilizer N rate applied by 20-40 lb/a, indicate the new recommendations are effective for LCP85-384. Fertilizer N rates used in this study were based on older established fertilizer N rates and not current recommendations suggested by the work of Kennedy and Legendre (2005).

Fertilizer N is vulnerable to losses by denitrification and leaching, which would suggest a benefit for split N fertilizer applications. However, in this experiment split applications of N fertilizer showed no benefit in increasing sugar yield, cane yield, sucrose content, mean stalk weight and stalk population (Tables 1 and 2). Berding et al. (2005) showed that split application of N reduced Brix and polariscope reading leading to a 6% reduction in CCS in the plant crop and 3% reduction in the ratoon crop compared to the zero N treatments. The single application of N gave a small reduction in Brix and polariscope reading in the plantcane crop, but had little effect on CCS in the plant crop and none in the ratoon crop. Other studies have indicated that split applications of N have rarely been found to provide any significant benefit (Bieske, 1972; Keating et al., 1993).

Yield and yield component for the 2000 plantcane experiment were influenced by adverse weather conditions caused by Tropical Storm Allison in June, which

Table 1. Analysis of variance of fixed effects for a plantcane experiment to determine the effects of nitrogen treatment rates and timing of N on sugarcane production in a 2000 experiment conducted at the St. Gabriel Research Station, St. Gabriel, Louisiana.

Plantcane crop	Sugar yield (Estimated)	Cane yield (Estimated)	Sucrose Content	Mean stalk weight	Stalk population
	--------P-value--------				
Mature stalks	0.465	0.435	0.071	0.058	0.740

Table 2. Mature stalks and sucker trait means for a plant crop of HoCP85-845 for an experiment conducted in 2000 at the St. Gabriel Research Station, St. Gabriel, Louisiana.†

Plantcane crops	April treatments (kg N/ha)	July treatments (kg N/ha)	Sugar yield (Estimated) (t/ha)	Cane yield (Estimated) (t/ha)	Sucrose content (g/kg)	Mean stalk weight (kg)	Stalk population (stalks/ha)
Mature stalks	56		10.18	86.75	117	1.16 AB	74917
	112		10.00	85.57	117	1.08 AB	79201
	168		9.20	83.70	110	1.16 AB	71928
	224		9.63	91.83	104	1.14 AB	79998
	112	56	9.23	87.18	106	1.20 A	72626
	168	56	8.05	72.20	112	0.97 B	74917
Significance			NS	NS	NS		NS

† Values in each column followed by the same letter are not significantly different at the P=0.05.

produced in excess of 230 mm of rainfall (Figure 1). The high amount of rainfall received may have affected the experiment by N losses due to leaching, microbial immobilization, denitrification and/or volatilization.

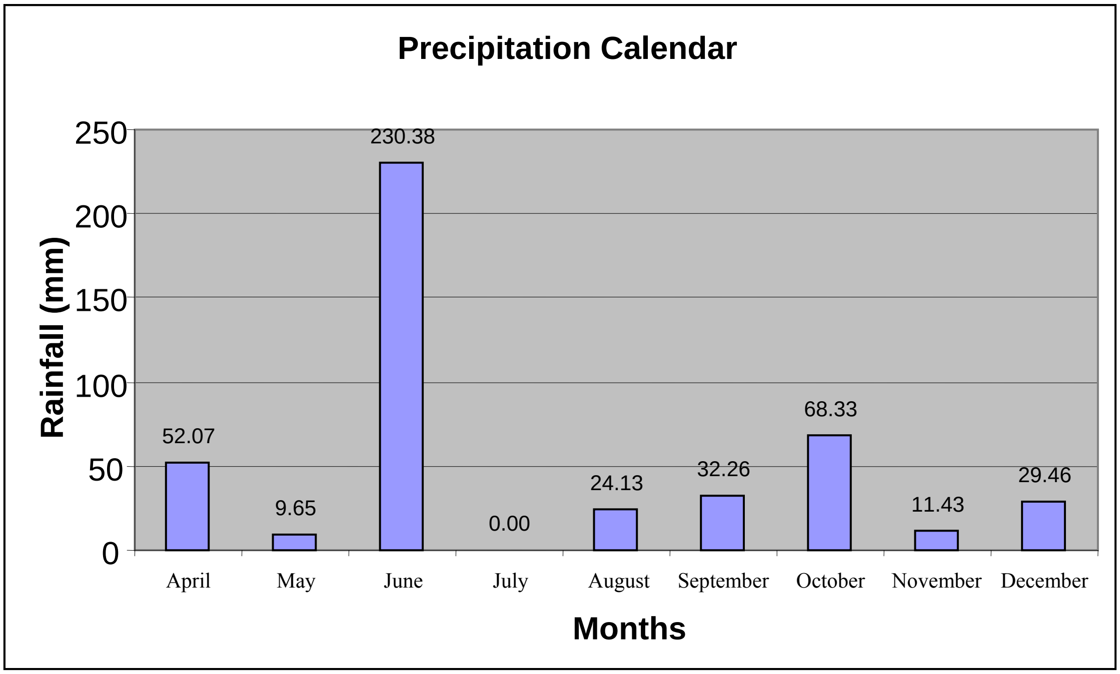

Figure 1. The total monthly rainfall data (mm) collected by the Southern Regional Climate Center Louisiana Office of State Climatology for the St. Gabriel Research Station in 2001 located in St. Gabriel, Louisiana.

2001 First Ratoon Experiment

The analysis of variance results for the 2001 first ratoon crop of HoCP 85-845 at harvest showed increased soil N resulted in a significant ($P \leq 0.05$) treatment effects for mature stalk sucrose content (Table 3). Increased soil N did not result in significant differences for mature stalk sugar yield, cane yield, sucker sugar yield, sucker cane yield, mature stalk weight, sucker stalk weight, mature stalk population, sucker population, mature stalk fiber content, sucker fiber content or sucker stalk density.

Mature stalk sugar yield ranged from 7.55 to 10.28 t/ha (Table 4). Sucker cane yield ranged from 0.74 to 1.41 t/ha (Table 4). Numerically, the split application of 112

+ 56 kg N/ha treatment resulted in the lowest sucker cane yield, whereas the sucker cane yield was highest in the single application of 112 kg N/ha. At time of harvest, suckers contributed 1.6% of total cane yield in the 2001 first ratoon experiment. Sucker contribution on average was calculated as 9.4% of total sugar yield in the 2001 first ratoon experiment. Although suckers can contribute greatly at times toward total cane yield, sucker effects on total sugar yield were minimal in this study.

In the 2001 first ratoon crop, the application of N late in the growing season resulted in an increase in suckers in mid-September (Table 5). Significant differences ($P \leq 0.05$) in suckers were noted among treatments in the 2001 ratoon crop in mid-September under a closed canopy where sugarcane was erect. The single application of 56 kg N/ha produced significantly less suckers/ha compared to the single application of 224 kg N/ha when suckers were counted in mid-September (Table 6). The single application of 168 kg N/ha yielded significantly less suckers compared to the single application of 224 kg N/ha and the split application of 168 + 56 kg N/ha in mid-September. There were no differences between the spilt application of 112 + 56 kg N/ha versus the single application of 168 kg N/ha or between the split application of 168 + 56 kg N/ha versus the single application of 224 kg N/ha in mid-September. However, no treatment mean differences were found for suckers/ha at time of harvest (December) after the crop lodged (Table 6). Hurney and Berding (2000) found that suckering may occur under full canopy and concluded that lodging is not a pre-requisite for sucker initiation, although it may encourage sucker growth. Slater et al. (2000) indicated that while there was a general increase in suckers throughout the growing season following N application, the number of suckers at the end of the season showed no significant differences among N treatments.

In the 2001 first ratoon experiment, significant differences in sucker numbers were found in mid-September as the crop remained erect allowing sunlight to penetrate the crop canopy reaching the soil surface resulting in a large flush of small suckers (Table 6). Hes (1954) suggested that direct heating of the soil surface by sunlight might play a role in sucker production. In this study, sunlight was able to penetrate the crop canopy after being affected by Hurricane Lili in September, which partially lodged the crop resulting in available space for suckers to form. By December, the crop was severely lodged due to Tropical Storm Isidore that struck Louisiana in October, which made it difficult to walk through the plots to count and sample suckers. Additional suckers counted at harvest were certainly the result of a second flush of suckers that emerged after the cane had lodged and light was able to reach the base of the plants (Griffee, 2000). Some suckers counted in mid-September lodged with the crop which made it difficult to accurately report all suckers present at harvest.

Orthogonal contrasts were performed on sucker population present in the 2001 first ratoon crop in mid-September (Table 5). Significant differences in sucker population were observed between the spilt application of 112 + 56 kg N/ha versus the single application of 168 kg N/ha. The split application of 112 + 56 kg N/ha yielded significantly more suckers compared to the single application of 168 kg N/ha thus the split application was not beneficial in hindering sucker production. There was no difference between the highest split application of 168 + 56 kg N/ha and the highest single application of 224 kg N/ha. A significant difference was observed between the

Table 3. Analysis of variance of fixed effects for a ratoon experiment conducted in 2001 to determine the effects of nitrogen treatments on sugarcane and sugarcane sucker production in an experiment conducted at the St. Gabriel Research Station, St. Gabriel, Louisiana.

	Sugar yield (Estimated)	Cane yield (Estimated)	Sucrose Content	Stalk weight	Stalk population	Fiber content	Stalk density
Ratoon crop	----------	----------	----------	P-value	----------	----------	----------
Mature stalks	0.133	0.121	0.039	0.400	0.076	0.062	
Suckers	0.259	0.507	0.841	0.472	0.426	0.873	0.436

Table 4. Mature stalks and sucker trait means for a ratoon crop of HoCP85-845 for an experiment conducted in 2001 at the St. Gabriel Research Station, St. Gabriel, Louisiana. †

First ratoon crop	April treatments (kg N/ha)	July treatments (kg N/ha)	Sugar yield (Estimated) (t/ha)	Cane yield (Estimated) (t/ha)	Sucrose content (g/kg)	Mean stalk weight (kg)	Stalk population at harvest (stalks/ha)	Fiber content (g kg^{-1})	Stalk density (g/cm^3)
Mature stalks	56	-	8.95	75.98	118 A	1.09	69537	11.58	-
	112	-	7.63	67.13	114 A	0.96	69737	10.83	-
	168	-	9.43	82.40	114 A	1.08	75813	10.86	-
	224	-	10.28	95.53	108 AB	1.09	88067	10.78	-
	112	56	9.60	84.55	114 A	1.18	71330	10.03	-
	168	56	7.55	75.30	100 B	0.98	78503	11.06	-
Significance			NS	NS		NS	NS	NS	
Suckers	56	-	0.01	0.92	11	0.32	3088	9.26	1.00
	112	-	0.03	1.41	19	0.44	3088	9.28	1.01
	168	-	0.01	0.98	14	0.38	2491	8.97	0.85
	224	-	0.01	0.84	8	0.30	4183	8.90	1.03
	112	56	0.01	0.73	12	0.24	2590	8.31	0.97
	168	56	0.01	1.19	12	0.33	3885	9.15	0.99
Significance			NS	NS	NS	NS	NS	NS	NS

† Values in each column followed by the same letter are not significantly different at the P=0.05.

split applications of 168 + 56 kg N/ha compared to all other treatments. The single application of 168 kg N/ha produced significantly fewer suckers compared to all other treatments.

Bonnett et al. (2005) conducted orthogonal contrasts for analysis of an experiment in Australia, which revealed a significant increase in sucker populations due to N application, but no significant difference (P≤0.05) was detected between N fertilizer application rates for two varieties.

Berding et al. (2005) concluded there were no significant differences between the split and single N applications on cane yield in plantcane and ratoon crops in Australia. In this experiment, split N applications were not significantly different from treatments that received all N in April, but numerically, sucker populations were higher for treatments that received N in April and July (as a split application) (Table 6).

Table 5. Orthogonal contrast of sucker population (suckers/ha) before lodging in ratoon experiment of HoCP 85-845 at the St. Gabriel Research Station, St. Gabriel, Louisiana in 2001.

Ratoon Crop	112 + 56 kg N/ha vs. 168 kg N/ha	168 + 56 kg N/ha vs. 224 kg N/ha	168 + 56 kg N/ha vs. 112 + 56 kg N/ha vs. all other treatments	112 + 56 kg N/ha vs. all other treatments	168 + 56 kg N/ha vs. all other treatments
			P-value		
Suckers/ ha	0.02	0.49	0.80	0.80	0.03

In this study there was no indication of N accumulation in the soil from high amounts of N or late season N fertilization (Table 7). The data indicates that the July

Table 6. Sucker means averaged across treatments for suckers/ha before and after lodging occurred in the 2001 ratoon crop of HoCP85-845 at St. Gabriel, Louisiana.

April treatments (kg N/ha)	July treatments (kg N/ha)	Suckers population (suckers/ha) before lodging (mid-September)	Suckers population (suckers/ha) after lodging (December)
56	-	3586 BC	3088 A
112	-	4283 ABC	3088 A
168	-	2689 C	2490 A
224	-	6077 A	4184 A
112	56	4582 ABC	2590 A
168	56	5578 AB	3885 A

† Values in each column followed by the same letter are not significantly different at the P=0.05.

(split) N application did not increase the soil nitrate level in the soil, which could explain why there was no yield benefit from the July (split) application of N. In this study, the lack of increased soil available N due to the July treatments could be explained by the high amounts of rainfall received throughout the growing season particularly with the occurrence of Hurricane Lili and Tropical Storm Isidore in September and October of 2002, respectively. Tropical Storm Isidore and Hurricane Lili produced 302.01 and 232.41 mm of rainfall, respectively (Figure 3). The high amounts of rainfall produced by these rainfall events may have reduced the amount of oxygen present in the soil pores. Under anaerobic conditions, some bacteria meet their energy needs by reducing nitrate to dinitrogen gas or to nitrogen oxide (N_2O) (Prasad and Power, 1997). This biological process is called denitrification, which results in a loss of nitrogen from the soil and the return of nitrogen to the atmosphere. Estimates of N losses by denitrification have been known to vary from 3 to 62% of applied N in arable soils.

Table 7. T-test of soil samples taken for nitrate analysis in the ratoon crop of HoCP 85-845 before and after N application at an experiment conducted in 2001 at the St. Gabriel Research Station, St. Gabriel, Louisiana.

Treatment numbers	April treatments (kg N/ha)	July treatments (kg N/ha)	Initial Soil Samples	Final Soil Samples
			--------ppm of nitrate	----------------------
1	56	-	<42	<50.0
2	112	-	<44	<39
3	168	-	<41	<39
4	224	-	<42	<40
5	112	56	<41	<40
6	168	56	<42	<39
Means			42.0 ± .4	41.1 ± 1.8
Pr>[t]			0.64	

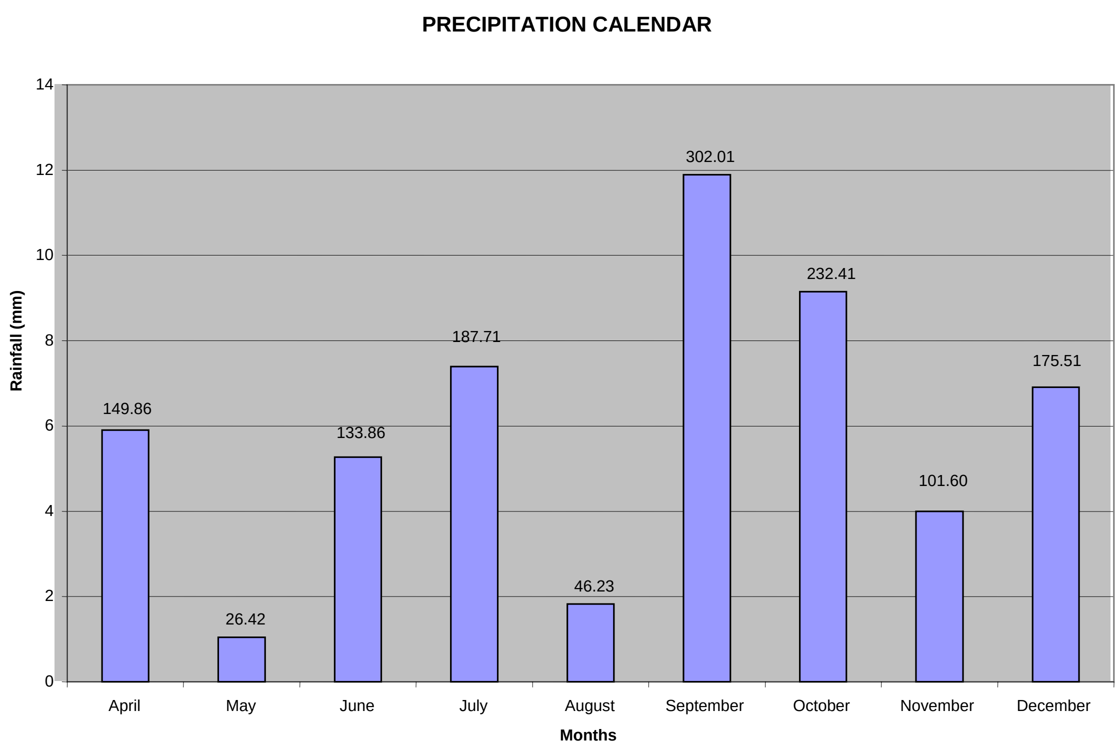

Figure 3. The total monthly rainfall data (mm) collected by the Southern Regional Climate Center Louisiana Office of State Climatology for the St. Gabriel Research Station in 2002 located in St. Gabriel, Louisiana.

2001 Plantcane Experiment

The analysis of variance for the 2001 plantcane crop showed that increasing N significantly ($P \leq 0.05$) affected mature stalk weight and sucker cane yield (Table 8). Mean stalk weight ranged from 1.07 to 1.29 kg for mature stalks (Table 9). Increased soil N did not result in significant differences for mature stalk sugar yield, mature stalk cane yield, sucker sugar yield, sucker stalk weight, mature stalk population, sucker population, mature stalk fiber content, sucker fiber content or sucker stalk density.

Sucker cane yield ranged from 0.58 to 1.08 t/ha (Table 9). Gravois et al. (2002) estimated that sucker content ranged from 2.1 to 21.5% of total cane yield in an experiment that included five Louisiana varieties. Sucker content varied from 0.5 to 33.4% in 95 sugarcane clones in a final assessment trial in north Queensland (Berding and Hurney, 2000). Hurney and Berding (2000) reported that suckers increased cane yields by up to 26.3% in Australia.

Of particular interest, sucker cane yield was highest in the two split N application treatments of 112 + 56 kg N/ha and 168 + 56 kg N/ha (Table 9). Sucker cane yield was 1.08 t/ha for both split treatments. The single application rate of 168 kg N/ha yielded the lowest sucker yield. This would suggest that increased rates of N due to split application or available N late in the growing season did lead to increased suckering. Split application of N did not show any benefit in increasing mature stalk sugar yield or cane yield (Table 9). Mature stalk cane yield ranged from 82.13 to 96.73 t/ha.

Golden (1969) reported on results in English units from split applications of N as anhydrous ammonia where fertilizer was applied in early spring and at lay-by (May or early June). He found that more than half of the experimental split applications of N resulted in increases of 2 to 3 tons of cane per acre when the rate of total N applied was 80 or more pounds per acre.

In this experiment reported in metric units mature stalk sugar yield ranged from 10.0 to 11.7 t/ha. On average, suckers contributed 2.2% to total sugar yield in the 2001 plantcane experiment. At time of harvest, sucker contribution was 0.9% of total cane yield in the 2001 plantcane experiment.

Soil tests taken after final harvest showed no evidence of N accumulation in the soil from excessive N or late season N fertilization (Table 10). The data indicated that the July (split) N application did not increase the soil nitrate level in the soil, which could explain why there was no cane yield advantage from the July (split) application of N. Berding et al. (2005) conducted an experiment that demonstrated increases in suckering due to N applications late in the growing season. They found that after the second application of an N split treatment, soil nitrate levels were significantly higher in the split than the other N treatments. Thus, the split treatment was successful in providing more available N to the plants. At final harvest, analysis of their soil did not show elevated levels of N, which was the result of a large rainfall event after N application. They also concluded that different rates of N applied at the beginning of the season did not result in increased sucker populations.

Table 8. Analysis of variance of fixed effects for a plant experiment conducted in 2001 to determine the effects of nitrogen treatments on sugarcane and sugarcane sucker production in an experiment conducted at the St.Gabriel Research Station, St. Gabriel, Louisiana.

	Sugar yield (Estimated)	Cane yield (Estimated)	Sucrose Content	Stalk weight	Stalk population	Fiber content	Stalk density
Plantcane crop	--------------------	--------------------	--------------------	P-value	--------------------	--------------------	--------------------
Mature stalks	0.300	0.349	0.080	0.035	0.215	0.055	
Suckers	0.437	0.038	0.555	0.198	0.572	0.929	0.060

Table 9. Mature stalks and sucker trait means for a plant crop of HoCP85-845 for an experiment conducted in 2001 at the St. Gabriel Research Station, St. Gabriel, Louisiana. †

Plant crop	April treatments (kg N/ha)	July treatments (kg N/ha)	Sugar yield (Estimated) (t/ha)	Cane yield (Estimated) (t/ha)	Sucrose content (g/kg)	Mean stalk weight (kg)	Stalk population at harvest (stalks/ha)	Fiber content ($g\ kg^{-1}$)	Stalk density (g/cm^3)
Mature stalks	56	-	11.7	103.8	112	1.09 B	75216	12.38	-
	112	-	10.9	106.6	102	1.11 B	79101	11.53	-
	168	-	10.7	106.0	101	1.07 B	78703	12.28	-
	224	-	11.2	106.8	105	1.12 B	81193	11.46	-
	112	56	10.0	105.5	95	1.10 B	79699	11.84	-
	168	56	11.2	105.7	106	1.29 A	75116	10.79	-
Significance			NS	NS	NS		NS	NS	
Suckers	56	-	0.00	0.63 C	3	0.20	2789	8.14	0.89
	112	-	0.00	0.71 BC	0	0.24	3387	8.55	1.00
	168	-	0.00	0.58 C	3	0.18	3088	8.28	1.06
	224	-	0.01	0.91 ABC	3	0.31	3088	8.11	1.00
	112	56	0.00	1.09 A	2	0.26	4184	8.78	0.99
	168	56	0.01	1.08 AB	9	0.39	3188	8.20	1.01
Significance			NS		NS	NS	NS	NS	NS

† Values in each column followed by the same letter are not significantly different at the P=0.05.

Table 10. T-test of soil samples taken for nitrate analysis in the plantcane crop of HoCP 85-845 before and after N application at an experiment Conducted in 2001 at the St. Gabriel Research Station, St. Gabriel, Louisiana.

Treatment numbers	April treatments (kg N/ha)	July treatments (kg N/ha)	Initial Soil Samples(Composite)	Final Soil Samples
			------------------------ppm	-----------------
1	56	-	<43	<41.6
2	112	-	<43	<41.0
3	168	-	<43	<41.7
4	224	-	<43	<40.5
5	112	56	<43	<40.6
6	168	56	<43	<40.9
Means			42.0 ± .4	41.1 ± 1.8
Pr>[t]			0.64	

CONCLUSION

Research has shown that suckers are physiologically immature and accumulate less sucrose and more water content compared to mature sugarcane stalks at the time of harvest. Therefore, suckers may affect productivity by increasing biomass while contributing little to sucrose content. Given the added costs of transportation and milling, suckers are likely to have an overall negative effect on sugar production. A good understanding of the environmental and cultural practice factors responsible for sugarcane sucker production in south Louisiana may be helpful in designing strategies to minimize the impact of suckers on Louisiana sugar industry.

Results for the 2000 plantcane experiment with variety HoCP 85-845 showed that increasing N fertilizer either as a single or split application had no effect on sugar yield, cane yield, sucrose content, mean stalk weight, stalk population or sucker population. The lack of significant fertilizer N treatment effects observed in this experiment could be explained by adverse weather conditions caused by Tropical Storm Allison in June, which produced in excess of 230 mm of rainfall. The high amount of rainfall received could have affected the experiment by N losses due to leaching, microbial immobilization, denitrification and/or volatilization. It is also not unusual to not see a fertilizer response in some plantcane crops in Louisiana. The crop remained erect with a closed canopy in this experiment and no suckers were produced in variety HoCP 85-845, a variety previously identified with a propensity for suckering.

The data from the 2001 first ratoon experiment revealed that fertilizer N treatments resulted in significant ($P \leq 0.05$) effects for mature stalk sucrose content. The highest sucrose yield was derived from the 56 kg N/ha treatment while the lowest sucrose yield was derived from the highest split treatment of 168 + 56 kg N/ha. Data from the 2001 plantcane experiment showed that increasing N fertilizer had significant ($P \leq 0.05$) effects on mature stalk weight and sucker cane yield. The highest stalk weights were recorded from the split treatment of 168 + 56 kg N/ha while the single application of 168 kg N/ha resulted in the lowest stalk weight. Stalk weight for the split treatment of 168 + 56 kg N/ha was significantly higher than all other treatments. The split treatment of 112 + 56 kg N/ha yielded significantly more sucker compared to the single application of 168 kg N/ha. There was no significant difference between the split application of 168 + 56 kg N/ha and the single application of 224 kg N/ha. The inconclusive results may be due to the high amounts of rainfall received at harvest particularly with the occurrence of Hurricane Lili producing 302.01 mm of rainfall and Tropical Storm Isidore producing 232.41 mm of rainfall in September and October of 2002, respectively.

Data from one ratoon and one plantcane experiments indicate that increased N fertilizers contributed to sucker production in sugarcane grown in Louisiana. Louisiana sugarcane growers should be careful to not exceed recommended N rates when applying fertilizer each spring.

REFERENCES

Berding, N. 2000. Potential versus realized CCS: Lessons for crop improvement. *In* Abstracts. 6th Breeding Workshop International Soc. Sugar Cane Technol., 13-17Nov. 2000, Barbados.

Berding, N., A.P. Hurney, B. Salter, and G.D. Bonnett. 2005. Agronomic impact of sucker development in sugarcane under different environmental conditions. Field Crops Res. 92:203-217.

Bieske, G.C. 1972. Split applications of nitrogen fertilizers on ratoon crops. Proc. Queensland Soc. Sugar Cane Technol. 39th Conf., p. 73-76.

Bonnett, G.D., B. Salter, and P.L. Albertson. 2001. Biology of suckers: late formed shoots in sugarcane. Ann. Appl. Biol. 138:17-26.

Bonnett, G.D., B. Salter, N. Berding, and A.P. Hurney. 2005. Environmental stimuli promoting sucker initiation in sugarcane. Field Crops Res. 92:219-230.

Borden, R.J. 1948. Nitrogen effects upon the yield and composition of sugar cane. Hawaii Plant Rec. 52:1-51.

Clarke, W.B., M.R. Player, and G.H. Weiss. 1988. Effect of extraneous matter on millers and growers costs. Proc. Aust. Soc. Sugar Cane Technol. 10:39-46.

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

Crooke, T.D., G.M. Pope, S.P. Staunton, and C.P. Norris. 1999. A survey of field CCS versus mill CCS. Proc. Aust. Soc. Sugar Cane Technol. 21:33-77.

Golden, L. E. 1969. The effect of early summer aerial application of fertilizer N on yields of sugarcane. Sugar Bull. 47(14):6-12.

Gravois, K.A. 1988. Path-coefficient analysis: Phenotypic, broad-sense and narrow sense variation in sugarcane. Ph.D. diss. Louisiana State Univ., Baton Rouge (Diss Abstr. 89-17818).

Gravois, K.A., B.L. Legendre, and K.P. Bischoff. 2002. Cultivar and crop effects of sugarcane bull shoots on sugarcane yield in Louisiana. J. Amer. Soc. Sugar Cane Technol. 22:42-52.

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

Griffee, Peter 2000. Entity Display: Saccharum officinarum. Food and Agriculture Organization of the United States. http://ecoport.org/ep?Plant=1884&entityType=PL****&entityDisplayCategory=full Accessed: Jan 2007

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

Hughes, R.M., and R.C. Muchow. 2000. Variation in sucrose concentrations with crop age in primary, sucker, and dead stalks in New South Wales environments. Proc. Aust. Soc. Sugar Cane Technol. 22:200-205.

Hurney, A.P., and N. Berding. 2000. Impact of suckering and lodging on productivity of cultivars in the wet tropics. Proc. Aust. Soc. Sugar Cane Technol. 22:328-333.

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

Jackson, P., G. Bonnett, P. Chudleigh, M. Hogarth, and A. Wood. 2000. The relative importance of cane yield and traits affecting CCS in sugarcane varieties. Proc. Aust. Soc. Sugar Cane Technol. 22:23-29.

Judice, W. 2005. Reduced tillage and residue management programs in sugarcane (*Saccharum* spp. hybrids). M.S. thesis Louisiana State Univ. Baton Rouge, LA.

Keating, B.A., I. Vallis, M. Hughes, and D.R. Ridge. 1993. Strategic directions for nitrogen research-a view from the south. Proc. Aust. Soc. Sugar Cane Technol. 15:276-284.

Keeney, D.R., and D.W. Nelson. 1982. Nitrogen – inorganic forms. pp. 643-698. *In*: A.L. Page (eds.) Methods of soil analysis. Part 2. Agron. Monogr. 9, 2nd ed. ASA and SSSA, Madison, WI.

Kennedy, C. W., and B. L. Legendre. 2005. Determination of optimum fertilizer nitrogen rates for LCP85-384 and other sugarcane varieties [on-line]. Available: http://www.lsuagcenter.com/impacts [2006, October 13].

Louisiana State University Agricultural Center. 1999. Louisiana sugarcane production processing [Online]. Available at http://www.lsuagcenter.com/subjects/sugarcane/industry.asp (version verified 3 Nov, 2006.)

Louisiana State University Agricultural Center. 2001. Louisiana sugarcane production processing [Online]. Available at http://www.lsuagcenter.com/subjects/sugarcane/history.asp (version verified 3 Nov, 2006.)

National Climatic Data Center. 2006. Climate data online extremes [online]. Available: http://cdo.ncdc.noaa.gov/CDO/cdoextremesdata.cmd [2006, September 18].

Prasad, R., and Power J.F. 1997. Soil Fertility Management for Sustainable Agriculture. CRC Press, Boca Raton, FL.

Richard, E.P. Jr. 1999. Management of chopper harvested-generated green cane trash blankets: A new concern for Louisiana. pp. 52-62. *In:* V. Singh and V. Kumar (eds.) Proc. Int. Soc. Sugar Cane Technol. 22Feb. – 26Feb., 1999. New Delhi, India.

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

SAS Institute. 2002. The SAS system for Windows Release 9.0. SAS Inst., Cary, NC.

Stevenson, G. G. 1965. Genetics and Breeding of Sugar Cane. Longmans, Green and Co. LTD, London.

Stubbs, W.C. 1897. Sugarcane. Sugar Experiment Station. 2:5-10.

Van Dillewijn, C. 1952. Botany of Sugar Cane. Chronica Botanica, Waltham, MA.

Wiedenfeld, R. 1997. Sugarcane response to N fertilizer application on clay soils. J. Amer. Soc. Sugar Cane Technol. 17:144-27.

Wilson, G.L., and J.K. Leslie. 1997. Productivity trends in sugarcane in the wet tropics. Proc. Aust. Soc. Sugar Cane Technol. 19:21-29

Yadava, R.L. 1991. Sugarcane Production Technology. Indian Inst. of Sugarcane Res.

VITA

John Eriton Richard was born in Opelousas, Louisiana, on 22 April 1976, the son of Belva J. Richard and Leon M. Richard. After graduating from Opelousas Senior High School in 1994, he went on to Southern University A&M College where he studied soil science and received his Bachelor of Science in December 2000. In August 2001, he began to pursue a Master of Science degree in the Department of Agronomy and Environmental Science at Louisiana State University. In June 2003, he began working as a Research Associate at the Louisiana State University Agricultural Center's Iberia Research Station in Jeanerette, Louisiana.