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Sugarcane growth, sucrose content, and yield response to the ripeners glyphosate and trinexapac-ethyl

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SUGARCANE GROWTH, SUCROSE CONTENT, AND YIELD RESPONSE TO THE RIPENERS GLYPHOSATE AND TRINEXAPAC-ETHYL

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ABSTRACT

Under Louisiana climatic conditions, production of sugarcane (*Saccharum* spp.) is limited to a maximum growth period of nine months. To increase sucrose concentration in the crop, ripener is applied prior to harvest. The chemical ripeners, glyphosate and trinexapac-ethyl were applied to the sugarcane cultivars HoCP 96-540, L 99-226, L 99-233, HoCP 00-950, and L 01-283 eight weeks prior to harvest. When glyphosate was applied at 210 g ae/ha, TRS for the cultivars was increased 10 to 28% compared with the nontreated. Increases in TRS with glyphosate were greatest for HoCP 96-540 and L 99-226 and least for HoCP 00-950 and L 01-283. Trinexapac-ethyl at 350 g ai/ha increased TRS for the cultivars 7 to 10% and increases were greatest for L 99-233 and least for HoCP 00-950. Sugarcane yield averaged across cultivars was reduced 9% with glyphosate and 7% for trinexapac-ethyl at 350 g/ha. An increase in sugar yield per hectare, a function of TRS and sugarcane yield, was observed only when glyphosate was applied to HoCP 96-540 (16% increase) and when trinexapac-ethyl at 300 g ai/ha was applied to L 01-283 (13% increase). In a second study where eight cultivars were harvested six weeks after glyphosate application, TRS for HoCP 96-540 was increased an average of 10% compared with the nontreated and sugarcane yield was decreased 17%; sugar yield was not affected.

In another study, sugarcane yield, TRS, and sugar yield were not affected by nitrogen rates of 67, 112, and 157 kg/ha. Six weeks after application of glyphosate at 210 g/ha TRS averaged across N rates was 11% greater than the nontreated and 9% greater than when trinexapac-ethyl was applied at 350 g/ha. TRS following trinexapac-ethyl was equivalent to the nontreated. Sugarcane yield and sugar yield were not affected by ripener application. In a separate study TRS and sugar yield were not affected when glyphosate or trinexapac-ethyl was applied in 75 and 150 L/ha spray volume or when none or 0.25% v/v surfactant was added to the spray

solution. Averaged across spray volume and surfactant treatments, TRS was as much as 8% greater for glyphosate compared with trinexapac-ethyl.

CHAPTER 1
INTRODUCTION

Sugarcane (*Saccharum* spp.), a C_4 perennial grass, is a member of the Gramineae family. Both sugarcane (*Saccharum* spp.) and sugar beets (*Beta vulgaris*) produce large quantities of the disaccharide, sucrose, which is processed and refined into granulated sugar. In 2007, 17.5% of the United States granulated sucrose was produced in Louisiana; roughly 1.46 million tons (96° pol) (Salassi and Legendre 2007). Approximately, 164,970 hectares in Louisiana produced 10.8 million tons of cane in 2011 (Salassi et al. 2011). Sugarcane is a major commodity for Louisiana farmers and in 2007 was the state’s most valuable row crop.

Many geographical regions that cultivate sugarcane have tropical climates, but the temperate climate of Louisiana experiences periods of freezing temperatures in the months of November, December, January, February, and March (Grymes 2007). Louisiana’s climate limits physiological growth of sugarcane to a maximum time span of 9 months before processing of the crop. In 1969, 44 Louisiana sugar mills processed 5.54 million metric tons of sugarcane (Anonymous 2009). From 1969 to 2008, 32 processers have closed sugar mill operations; however, the amount of cane processed during the 2008-2009 harvest season was 11.09 million metric tons, a 5.5 million metric ton increase compared to the 1969-1970 crop (Anonymous 2009). The amount of cane processed over the past 39 years has increased in spite of fewer mills; this has been achieved by increasing the sugar factories’ daily processing capacity and extending the harvest period.

Louisiana’s sugar factories begin processing sugarcane in late-September or early-October to avoid the threat of freezing temperatures. Once the milling process is initiated in Louisiana, harvest is continuous, regardless of precipitation events. Harvest is completed in late-December or early-January, depending on the crop tonnage and weather conditions.

SUCROSE TRANSPORT AND STORAGE

The ability of plants and some microbes to utilize atmospheric carbon dioxide and water to produce carbohydrates through photosynthesis provides the foundation for terrestrial energy transfer. Consumption of primary producers, namely plants and microbes, by heterotrophs provide the essential energy required by higher trophic levels. Chlorophyll in the mesophyll cells of the leaf utilizes sunlight photons to reduce carbon dioxide and water to make sugar and starch molecules. Sucrose synthase, sucrose-phosphate synthase, and fructose 1,6-bisphosphatase are key enzymes that control the sucrose synthesis pathway (Grof et al. 2006; Grof et al. 2007). According to Batta and Singh (1996) sucrose, glucose, and fructose are the only free sugars detected in leaf (source) and stem (sink) tissues of sugarcane. The complexity of sink-source relationships drives sucrose partitioning.

Current sucrose accumulation models are modifications of previous scientific efforts to explain sucrose accumulation and movement in sugarcane. Movement of carbohydrate from sources to sinks is controlled by points on the transport pathways; thus controlling the partitioning to tissue, cells, and subcellular compartments (Rae et al. 2005). Leaf sucrose is believed to be released from vascular parenchyma cells and moved into the phloem through the apoplast, rather than through symplastic plasmodesmata movement. Robinson-Beers and Evert (1991) found that sugarcane leaves lacked plasmodesmata connections between the leaf phloem and other conducting cells. The phloem transports sucrose molecules to sinks which are developing shoots, root apices, and storage organs (Rae et al 2005). Sucrose is transported to storage organelles in the internodal regions of the stem. The vacuoles of the internodes' parenchyma cells provide long term storage of sucrose.

Unloading of sucrose from phloem tubes is facilitated by symplastic plasmodesmata movement through the surrounding bundle sheath cells. The theory of apoplastic transportation

of sucrose through cell wall space was disproven by Walsh et al. (2005) when he showed that vascular bundles were encased by a fiberous sheath with lignified and/or suberised cell walls, thus inhibiting apoplastic movement.

Post bundle sheath cell movement of sucrose to parenchyma storage cells occurs through both apoplastic and symplastic mechanisms (Rae et al. 2005). Movement of sucrose molecules in the apoplast allows transport of sucrose from cell wall to cell wall or directly into the cytoplasm. In the cytoplasm, sucrose is metabolized for cellular energy needs, stored in vacuoles, or moves into the apoplast to maintain turgor.

The apoplastic spaces in both leaves and stems contain invertase enzymes. Invertase enzymes hydrolyze sucrose molecules into hexose molecules. Glasziou and Gayler (1972) suggested that the hexose/sucrose ratio in the extracellular space regulates the movement of sucrose from the leaf to the internodal parenchyma vacuole.

SUGARCANE RIPENERS

Climatic factors that influence the natural ripening of sugarcane clones in Louisiana have been investigated by Lengendre (1975). The most important factors affecting sucrose accumulation were incident sunlight and temperature. There was no relationship between natural ripening of sugarcane and excess or deficient moisture due to rainfall during the harvest period. Maturity curves from 1968 to 1972 for the five clones in the study showed lowest sucrose levels in late-September with an increase in sucrose as the season progressed, reaching the highest sucrose levels in December.

The use of chemicals to increase immature internodal sucrose levels in the early portion of the harvest season has received much attention since the 1970’s. Early season sucrose levels have been improved with the application of glyphosine, glyphosate, ethephon, fluazifop, haloxyfop and trinexapac-ethyl (McDonald et al. 2001). The ability of a synthetic chemical to

increase sucrose levels in sugarcane is dependent on the chemical mode of action and the crops ability to metabolize the chemical. Efficacy of glyphosate as a ripener is dependent on the application rate, metabolic rate within the plant, and harvest interval following application (Julien et al. 1980). Glyphosate, an amino acid synthesis inhibitor, and fluazifop and haloxyfop, lipid synthesis inhibitors, are classified as herbicides and are applied at sub-lethal doses to increase sucrose levels.

GLYPHOSINE AND GLYPHOSATE

In 1975, the first sugarcane ripener, glyphosine (Polaris), was registered with the Environmental Protection Agency in the United States (Martin et al. 1981). The ability of glyphosine [N-N-(bis-phosphonomethy) glycine] to artificially improve sucrose levels was investigated in Louisiana, Hawaii, Florida, Jamaica, and Maurtius. Rice et al. (1980) noted reduced growth rates for several cultivars after treatment with glyphosine and or glyphosate in Florida. Five weeks after treatment with glyphosine, 'Cl 54-378' terminal height was 28.7 cm less than the nontreated. Sucrose, purity, and yield was increased 1.01, 1.79, and 0.79 percentage points, respectively, over the nontreated. Increases in juice purity and pol % cane were also reported in natural rain fed ecosystems in Jamaica (McCatty 1980). Sugarcane treated with glyphosine had 4% higher purity and 7% higher pol % cane, statistically greater than nontreated controls. However, in arid regions of Jamaica where sugarcane was irrigated, increases in purity and pol % sucrose with glyphosine were not observed due to induced water stress (McCatty 1980). In Louisiana increases in sucrose concentration were not observed for several cultivars treated with glyphosine (Legendre and Martin 1977). A decrease in sugar per hectare with glyphosine was observed in 'CP 65-357' infected with Ratoon Stunt Disease in Louisiana (Martin et al. 1980). Non-infected CP 65-357 showed significant increases in sucrose, purity, and sugar per ton with changes of 12, 3, and 14 %, respectively.

Since 1980 glyphosate [N-(phosphonomethyl) glycine] has been the primary ripener used in the Louisiana sugarcane industry. In 2005, glyphosate was applied to approximately 62% of the total harvested hectares (Legendre et al. 2005). Polado-L®, Roundup WeatherMAX®, Roundup OrginalMax®, Touchdown Total® and Touchdown HiTech® are all glyphosate products available for use as a sugarcane ripener in Louisiana.

The shikimate pathway is deregulated by glyphosate (Amrhein et al. 1980). Glyphosate inhibits the binding of the enzyme 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS) with phosphoenolpyruvate; the glyphosate molecule occupies or changes the shape of the binding site on EPSPS (Baylis 2000; Sikorski and Gruys 1997). The shikimate pathway is associated with production of the aromatic amino acids tyrosine, tryptophan, and phenylalanine, and of auxin, phytoalexins, folic acid, lignin, and plastoquinones (Shaner 2006).

In laboratory and greenhouse experiments, Hilton et al. (1980) reported that glyphosate was translocated from sugarcane leaf blades to the apical region, stalk, and roots. Vegetative development is reduced after the application of glyphosate in sugarcane. Decreased levels of new cell wall fixed carbon and reducing sugars in immature internodes of glyphosate treated cane, as well as, decreased invertase activity in mature internodes were reported within 24 to 48 hours of glyphosate application (Hilton et al. 1980). Sucrose levels were increased and sucrose turnover was diminished in immature tissue.

Various formulations of glyphosate including Mon 2139, Mon 8000 (Polado) and, XHH 148 were evaluated as ripeners in the late 1970's. Glyphosate (Polado), a more efficient ripener than glyphosine (Polaris), consistently increased pol % cane and juice purity (Clowes 1980; Hilton et al. 1980; Mason 1980). Clowes (1980) partitioned stalks treated with Mon 8000 into the basel (0.8 m) internodes and upper internodes. Mon 8000 significantly improved sucrose in both the

lower and upper portions of the stalk. The lower internodes had an increase in sucrose % cane, but not in purity. This phenomenon was defined as “loading” by Clowes.

Averaged across 48 experiments throughout the South African cane region, sugarcane treated with glyphosate ripener increased recoverable sugar yield by 14% (Clowes 1980). In the Philippines, ‘Phil 56-226’ treated with glyphosate ripener yielded 15% more piculs sugar per ton cane, but tonnage was reduced by 5% (Tianco and Gonzales 1980). In Florida, application of glyphosate and glyphosine to sugarcane suckers with 2-4 internodes (bullshoots) increased sucrose content 313% above that of the control (Andrels and DeStefano 1980).

Common residual effects of glyphosate on the subsequent ratoon crop include leaf chlorosis, increased tillering, and reduced growth rates early in the growing season, but the effects are transient and do not affect subsequent ratoon crop yield for most cultivars (Clowes 1978; Donaldson and Inman-Bamber 1982l Mills 1980; Tianco and Gonzales 1980). Rice et al. (1984), however, reported in Florida reduced growth of the ratoon crop and yield reduction of 17.2 and 17.5 metric tons of cane per hectare when Glyphosate was applied the prior year to “Cl 54-378’ and ‘Cl 59-1052’, respectively.

TRINEXAPAC-ETHYL

Trinexapac-ethyl, a plant growth regulator, is commonly used in cereal crops to retard stem elongation, thus reducing the incidence of lodging (Rajala et al. 2002). Another common use of trinexapac-ethyl is in turf grass management to reduce shoot growth which reduces mowing frequency (Fagerness and Penner 1998).

Trinexapac-ethyl, an acylcyclohexanedione, interferes with the biosynthesis of gibberellins. Acylcyclohexanediones mimics 2-oxoglutaric acid late in gibberellin biosynthesis; thus interfering with the normal biosynthesis pathway where 2-oxoglutaric acid and dioxygenases, co-substrates, catalyze biological reactions (Rademacher 2000).

Experiments conducted by Fagerness and Penner (1998) with ^{14}C-trinexapac-ethyl showed greatest absorption to be in the leaf sheaths of Kentucky Bluegrass (*Poa pratensis* L.) compared to the leaf blade and roots. The absorption 24 hours post-treatment for the leaf sheaths, leaf blade, and roots were 94, 70, and 5%, respectively.

Moddus® (trinexapac-ethyl) has been used to ripen sugarcane in Brazil since 2000 (Resende et al. 2000). An average increase in sugar content of 10% for the 25 most important cultivars in Brazil was reported. Australian researchers also successfully ripened cane with Moddus® when applied at 200 g ai/ha (Kingston and Rixon 2007), but a 3 Mt/ha yield reduction was observed in subsequent crops of six clones. The clone 'Q205' was affected most, showing a statistically significant large negative effect on yield; 'Q188', 'Qs92-330', and 'QS93-286' showed small non-significant negative effects, and 'Q151' and 'Q225' showed small non-significant positive effects.

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CHAPTER 2
SUGARCANE CULTIVAR RESPONSE TO THE RIPENERS GLYPHOSATE AND TRINEXAPAC-ETHYL

INTRODUCTION

Sugarcane (*Saccharum* spp.) was the most valuable row crop commodity ($1.08 billion) and accounted for more than 10% of the total for all agricultural commodities produced in Louisiana for 2011 (Anonymous 2012a). Sugarcane cultivar development and improvement is an integral reason that the Louisiana sugar industry has remained competitive and profitable. In the early 1900's, sugarcane mosaic virus (SMV) became a major disease problem for Louisiana producers and sugarcane yield by 1926 was reduced by 88% (Riquelmy and Currie 2002). Introduction of germplasm from Java and India by the United States Department of Agriculture (USDA) provided the Louisiana sugarcane industry with cultivars resistant to SMV which was critical to the industry's survival. Cultivar development and testing programs were initiated by USDA at Canal Point, FL, in 1919 and at Houma, LA, in 1923. Beginning in the 1950's, breeding efforts focused on enhancing sucrose content, whereas previous breeding efforts had focused on disease resistance (Breaux 1984). Utilizing multiple cycles of recurrent selection, Louisiana sugarcane breeders were able to develop cultivars that yielded in excess of 100 kg of sugar per net tonne of cane. As a result of those efforts, Louisiana cultivars produce equivalent sucrose per net tonne of cane to that of tropical cultivated sugarcane. Bischoff and Gravois (2004) noted that breeding efforts in Louisiana also improved early maturation, resulting in improved sucrose level at the commencement of the harvest season.

Current variety development and testing in Louisiana is conducted cooperatively by the LSU AgCenter, USDA-ARS at Houma, LA, and the American Sugar Cane League. Cultivar development and testing is a 13-year process to evaluate cane yield, theoretical recoverable sugar, sugar yield, fiber, ratooning (stubbling) ability, erectness, and disease and insect

susceptibility. In year 11 of cultivar development and testing, advance cultivars are provided to Louisiana’s two clean seed sugarcane companies for micro-propagation to increase seedcane availably one year after release. In year 13, superior cultivars are provided to local growers for propagation.

In 1969, the Louisiana sugarcane industry had 44 sugar factories in operation (Anonymous 2012b). In 2011, 11 factories processed Louisiana’s entire sugarcane crop. The amount of sugarcane processed over the past 41years has increased, in spite of fewer factories, and this was accomplished by increasing the daily processing capacity and extending the harvest period. Louisiana’s sugar factories begin processing sugarcane in late September or early October in hopes of completion before freezing temperatures negatively affect juice and stalk quality. Legendre (1975) reported that sucrose levels are lowest in late-September but significantly increase as the season progresses, with highest levels occurring in December. With the short growing season in Louisiana, a large emphasis is placed on cultivars that accumulate high levels of sucrose early in the harvest season.

The use of chemicals to increase immature internodal sucrose levels has received much attention since the 1970’s. Glyphosine, glyphosate, ethephon, fluazifop, haloxyfop, and trinexapac-ethyl have been evaluated in sugar industries around the world to increase recoverable sugar per metric ton (Dalley and Richard 2010; McDonald et al. 2001). Chemical ripener effectiveness in respect to increasing sucrose can vary among cultivars and environmental conditions (Martin et al. 1981; Millhollon and Legendre 1996). Since 1980, glyphosate [N-(phosphonomethyl) glycine] has been an effective tool to improve early season recoverable sugar per ton of cane in Louisiana (Legendre et al. 2005). Roundup WeatherMAX®, Roundup Orginal Max®, Touchdown HiTech®, and Touchdown Total® are glyphosate-containing products available for use as a sugarcane ripener in Louisiana; however, usage is limited to ratoon

sugarcane only. The application rate for glyphosate in Louisiana is 157 to 489 g ae/ha with application 3 to 7 weeks prior to harvest.

Glyphosate is a systemic herbicide which enters through leaf blade, and is translocated to shoot and root meristematic tissue (Hilton et al. 1980). Glyphosate deregulates the shikimate pathway by inhibiting the binding of the enzyme 5-enolpyruvylshikimate 3-phosphate synthase (EPSPS) with phosphoenolpyruvate (Amrhein et al. 1980; Baylis 2000; Sikorski and Gruys 1997). Many essential biomolecules such as tyrosine, tryptophan, and phenylalanine, as well as, auxin, phytoalexins, folic acid, lignin, and plastoquinones are produced in the shikimate pathway (Shaner 2006).

Vegetative development is reduced after the application of glyphosate. Hilton et al. (1980) reported decreased levels of new cell wall fixed carbon and reducing sugars in immature internodes of glyphosate treated cane within 24 to 48 hours of glyphosate application, as well as, decreased invertase activity in mature internodes. Sucrose levels were increased and sucrose turnover was diminished in immature tissue.

Glyphosate has been shown to increase recoverable sugar yield in Louisiana (Martin et al. 1981; Millhollon and Legendre 1996; Legendre et al. 2005), Florida (Andrels and DeStefano 1980), South Africa (Clowes 1980), and the Philippines (Tianco and Gonzales 1980). Averaged across 48 experiments conducted throughout the South African cane belt, sugarcane treated with glyphosate as a ripener increased recoverable sugar yield by 14% (Clowes 1980). He also determined that 6 weeks was the optimal duration between application and harvest in order to maximize the ripening benefit of glyphosate and minimize negative effect of decreased tonnage. In the Philippines, the cultivar ‘Phil 56-226’ treated with 0.3 kg ai/ha glyphosate (Mon 2139) increased grams of sucrose per stalk by 26%, 6 weeks after treatment (WAT). However, stalk weight was reduced by 4% 8WAT (Tianco and Gonzales 1980). In Florida, application of

glyphosate and glyphosine to sugarcane with suckers having 2-4 internodes (bullshoots) increased sucrose content up to 313% above that of the control (Andrels and DeStefano 1980). Common residual effects of glyphosate on the subsequent ratoon crop include leaf chlorosis, increased tillering, and reduced growth rates early in the growing season, but the effects are transient and do not affect subsequent ratoon crop yield for most cultivars (Clowes 1980; Donaldson and Inman-Bamber 1982; Mills 1980; Tianco and Gonzales 1980). Rice et al. (1984) reported in Florida reduced growth of the ratoon crop and sugarcane yield reduction of 17.2 and 17.5 metric tons of cane per hectare when glyphosate was applied the prior year to ‘Cl 54-378’ and ‘Cl 59-1052’, respectively.

Trinexapac-ethyl, an acylcyclohexanedione, interferes with the biosynthesis of gibberellins. Acylcyclohexanediones mimic 2-oxoglutaric acid late in gibberellin biosynthesis, thus interfering with the normal gibberellin biosynthesis pathway where 2-oxoglutaric acid and dioxygenase co-substrates catalyze biological reactions (Rademacher 2000). Trinexapac-ethyl has been used successfully in Brazil (Resende et al. 2000) and Australia (Kingston and Rixon 2007) to ripen sugarcane. Resende et al. (2000) reported trinexapac-ethyl applied at 200 g ai/ha increased sugar content by 10% for the 25 most important cultivars in Brazil. It was determined that optimal treatment to harvest interval was 45 to 60 days. In Australia, six cultivars treated with trinexapac-ethyl at 200 g ai/ha were harvested at intervals between 6 and 10 weeks after application. Although trinexapac-ethyl improved sucrose levels above the nontreated, sugarcane yield for the cultivars Q 205, Q188, Qs92-330, and Qs93-286 was negatively impacted in the subsequent ratoon crop (Kingston and Rixon 2007). Trinexapac-ethyl has also been used as a growth retardant in Australia to shorten internode length and reduce the potential for lodging of sugarcane to be used for planting (Croft and Magnanini 2006).

Because of the short growing season in Louisiana and the diversity in genetics of sugarcane cultivars grown, research was conducted to compare glyphosate and trinexapac-ethyl as sugarcane ripeners when applied in plant-cane and second-ratoon crops of HoCP 96-540, L 99-226, L 99-233, HoCP 00-950, and L 01-283. In addition, a separate study was conducted to evaluate glyphosate response in the plant-cane crop of eight cultivars.

MATERIALS AND METHODS

Glyphosate and Trinexapac-ethyl Study. Research was conducted in 2009 and 2011 at the Sugar Research Station in St. Gabriel, LA. Sugarcane was planted on September 26, 2008, in a Commerce silt loam (fine-silty, mixed, nonacid, thermic Aeric Fluvaquent) soil. A randomized complete block experimental design with a sugarcane cultivar by ripener factorial treatment arrangement was used. Sugarcane cultivars included HoCP 96-540, L 99-226, L 99-233, HoCP 00-950, and L 01-283. Ripener treatments included glyphosate[1] at 210 g ae/ha and trinexapac-ethyl[2] at 300 and 350 g ai/ha, and a nontreated control. Treatments were replicated four times. For the 2011 second-ratoon crop, ripener treatments were applied to same plots treated the previous years (the first-ratoon experiment was not included because of severe lodging). Glyphosate and trinexapac-ethyl treatments were applied 46 cm above the crop canopy on August 24, 2009 and August 15, 2011 using a CO_2-pressurized backpack sprayer delivering 140 L/ha at 190 kPa. Plot size consisted of a single row 1.8 m wide by 15.2 m long. Each plot was separated by a 1.5 m alley. The adjacent rows on each side of the plot were planted with HoCP 96-540, and were used as a buffer to minimize potential off target drift. HoCP 96-540 was chosen to buffer treated plots due to its erect growth habit.

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[1] Touchdown Total, glyphosate N-(phosphonomethyl)glycine in the form of potassium salt. Syngenta Crop Protection, P. O. Box 18300, Greensboro, North Carolina 27419-8300

[2] Palisade, trinexapac-ethyl, Syngenta Crop Protection, P. O. Box 18300, Greensboro, North Carolina 27419-8300.

A 15-stalk sample from each plot was hand-harvested eight weeks after treatment (8 WAT) on October 19, 2009 and October 10, 201l, weighed, and processed at the Sugar Research Station Sucrose Lab in St. Gabriel, LA. Brix, pol (Z°), and % fiber were measured by NIR SpectraCane. Gravois et al. (2008) showed a high degree of relationship between NIR estimations and standard laboratory techniques for Brix ($R^2 = 0.96$), fiber content ($R^2 = 0.85$), moisture ($R^2 = 0.94$) and pol ($R^2 = 0.94$). Theoretical recoverable sugar (TRS) (sucrose content) was calculated using normal juice sucrose, Brix and fiber (TRS = 0.5(0.28 * Normal Juice Sucrose – 0.08 * Brix)(100 – (55.67 * Fiber)/(100 – Fiber)) (Gravois and Milligan 1992). Plots were harvested with a sugarcane combine and loaded into a wagon equipped with load cells to gain actual cane yield. Sugar yield per hectare was calculated by multiplying TRS by sugarcane yield per hectare.

Glyphosate Study. In 2010 and 2011, glyphosate ripener experiments were conducted at the Sugar Research Station in St. Gabriel, LA. The cultivars HoCP 96-540, L 99-226, L 99-233, HoCP 00-950, L 01-283, L 01-299, L 03-371, and HoCP 04-838 were planted on August 14, 2009, and September 9, 2010, in a Commerce silt loam (fine-silty, mixed, nonacid, thermic Aeric Fluvaquent) soil. Both experiments were arranged in a split block experimental design, and were replicated 3 times. Whole plots consisted of sugarcane cultivars and subplots treatments were glyphosate (Touchdown Total®)[1] ripener and a nontreated. Glyphosate at 210 g ae/ha was applied 46 cm above the crop canopy, using a broadcast boom sprayer delivering 74.8 L/ha at 221 kPa to the experiments on August 30, 2010, and August 29, 2011. Plot size consisted of a single row 1.8 m wide by 6.1 m long, separated by a 1.2 m alley between plots. The adjacent rows on each side of the plot were planted with HoCP 96-540, and were used as a buffer to minimize potential off target drift.

Six weeks after treatment (6 WAT) (October 12, 2010, and October 10, 2011), 10 stalks were hand-harvested from each plot and processed as described for the Glyphosate and Trinexapac-

ethyl Ripener Study. Plots were harvested to determine sugarcane yield and sugar yield was calculated as described previously.

Statistical Analysis. Data for both studies were analyzed using SAS v9.3 software (SAS Institute 2012), and were subjected to the Proc Mixed procedure where years/experiments are considered as random effects. Using this procedure does not allow for comparison of crop-year(s) or any interactions involving crop-year(s)/experiments. Treatment data for the Glyphosate and Trinexapac-ethyl Ripener Study were analyzed using the following linear model:

$Y_{ijkl}=\mu+C_i+R_{j(i)}+T_k+V_l+CT_{ik}+CV_{il}+CTV_{ikl}+E_{ijkl}$.

Y_{ijkl} is the observed response of crop-year i in replication j(i) of ripener k and cultivar l. μ is the overall mean; C_i is the crop-year effect; $R_{j(i)}$ is the replication effect nested in crop-year; T_k is the ripener treatment effect; V_l is the cultivar effect; CT_{ik} is the crop-year by ripener interaction; CV_{il} is the crop-year by cultivar interaction; CTV_{ikl} is the crop-year by ripener by cultivar interaction; E_{ijkl} is the experimental error.

Treatment data for the Glyphosate Ripener Study were analyzed using the following linear model:

$Y_{ijkl}=\mu+W_i+R_{j(i)}+G_k+RG_{j(i)k}+V_l+GV_{kl}+E_{ijkl}$.

Y_{ijkl} is the observed response of year i in replication j(i) of glyphosate treatment k and cultivar l. μ is the overall mean; W_i is the year effect; $R_{j(i)}$ is the replication effect nested in year; G_k is the ripener treatment effect; $RG_{j(i)k}$ is the replication(year) by glyphosate interaction; V_l is the cultivar effect; GV_{kl} is the glyphosate by cultivar interaction; E_{ijkl} is the experimental error. For both studies, least square means were calculated, and mean separation was performed using the PDIFF option ($P \leq 0.05$). Letter groupings were converted using the PDMIX800 (Saxton 1998).

RESULTS AND DISCUSSION

Glyphosate and Trinexapac-ethyl Study. Analysis of variance showed a significant ($P \leq 0.05$) sugarcane cultivar by ripener interaction eight weeks after treatment for stalk height, stalk weight, TRS, and sugar yield (Table 2.1). Glyphosate and trinexapac-ethyl treatments reduced stalk height compared to the respective nontreated controls for only L 99-226 (19 to 21%) and L 01-283 (10 to 13%) (Table 2.2). For L99-226, stalk height was greater for trinexapac-ethyl compared with glyphosate, but for L01-283, height was equivalent for the glyphosate and trinexapac-ethyl treatments. When either ripener was applied to HoCP 96-540, stalk height was equivalent to the nontreated. For L 99-233, stalk height when trinexapac-ethyl was applied was equivalent to the nontreated, but stalk height following glyphosate was reduced by 7%. For HoCP 00-950, stalk height was not reduced when glyphosate was applied compared with the nontreated, but was reduced at least 7% with trinexapac ethyl. Averaged across ripener treatments, stalk height ranged from 203 cm for HoCP 00-950 to 215 cm for L 99-233 (Table 2.2). Stalk height for L 99-233 was equivalent to that of HoCP 96-540 and L 99-226. Stalk height was equivalent for HoCP 00-950 and L 01-283 and averaged 12 cm less than for L 99-233. Averaged across cultivars, stalk height was reduced an average of 9% when glyphosate and trinexapac-ethyl were applied.

A significant sugarcane cultivar by ripener interaction was observed for stalk weight (Table 2.1). Ripener treatments reduced stalk weight 17 to 24% for L 99-226 and 11 to 17% for L 01-283 when compared to respective nontreated controls (Table 2.3). For L 99-226, stalk weight was 9% less for glyphosate compared with trinexapac-ethyl treatments, but for L 01-283, stalk weight for the ripener treatments was equivalent. For HoCP 96-540, glyphosate was the only ripener treatment that reduced stalk weight compared with the nontreated (15% reduction). Mean stalk weight of HoCP 96-540 for glyphosate treatment averaged 14% less than the trinexapac-

Table 2.1 Analysis of variance of fixed effects for plant-cane and second-ratoon crop experiments to evaluate ripener treatments and commercial sugarcane cultivars.[1]

Source of variation	Stalk height	Stalk weight	Sugarcane yield	TRS	Sugar yield
	P-value				
Crop	0.0273	<.0001	<.0001	0.0007	<.0001
Cultivar	0.0108	<.0001	<.0001	<.0001	<.0001
Crop*Cultivar	0.1122	<.0001	0.0276	0.0004	0.0013
Ripener	<.0001	<.0001	0.0060	<.0001	0.0632
Crop*Ripener	0.4166	0.2538	0.3905	0.0041	0.0133
Cultivar*Ripener	0.0008	<.0001	0.0574	0.0004	0.0041
Crop*Cultivar*Ripener	0.9748	0.9228	0.3857	0.0835	0.1142

[1]Crops = 2009 plant-cane and 2011 second-ratoon; ripener treatments = glyphosate at 210 g ae/ha, trinexapac-ethyl at 300 and 350 g ai/ha, and a nontreated; Cultivars = HoCP 96-540, L 99-226, L 99-233, HoCP 00-950, and L 01-283.

ethyl treatments. For L 99-233, stalk weight for all ripener treatments was equivalent to the nontreated, whereas for HoCP 00-950 stalk weight for only trinexapac-ethyl at the high rate was less than the nontreated. Stalk weight was equivalent for the glyphosate and trinexapac-ethyl treatments for L 99-233, but for HoCP 00-950, stalk weight averaged 11% less for trinexapac-ethyl at 350 g/ha compared with glyphosate and trinexapac-ethyl at 300 g/ha.

Averaged across ripener treatments, stalk weight was greatest for L 99-226 (1.06 kg) and lowest for L 99-233 (0.72 kg) (Table 2.3). Stalk weight was equivalent for HoCP 96-540 and HoCP 00-950 and greater than for L 01-283. Averaged across cultivars, ripening treatments reduced stalk weight 9 to 15% compared with the nontreated. Stalk weight averaged 6% less where glyphosate was applied compared with trinexapac-ethyl at 300 g/ha.

For sugarcane yield, the cultivar by ripener interaction was not significant (P= 0.0574), but significant cultivar and ripener effects were observed (Table 2.1). Averaged across ripener treatments, sugarcane yield ranged from 78.0 Mt/ha for HoCP 01-950 to 91 Mt/ha for L 01-283 (Table 2.4). Sugarcane yield for L 01-283 was equivalent to that of HoCP 96-540, but averaged 8 to 14% less for L 99-226, L 99-233, and HoCP 00-950. Averaged across cultivars, sugarcane

Table 2.2 Sugarcane stalk height of five commercial cultivars eight weeks after ripener application at St. Gabriel, Louisiana in 2009 and 2011.[1]

Ripener and rate	Cultivar					Ripener
	HoCP 96-540	L 99-226	L 99-233	HoCP 00-950	L 01-283	average[3]
	----------	----------	cm	----------	----------	----------
Nontreated	215 bcde[2]	239 a	224 ab	216 bcd	224 b	223 A
Glyphosate at 210 g ae/ha	203 defgh	189 h	209 cdef	207 cdefg	201 defgh	202 B
Trinexapac-ethyl at 300 g ai/ha	207 cdefg	206 cdefg	215 bcde	200 efgh	198 fgh	205 B
Trinexapac-ethyl at 350 g ai/ha	220 bc	207 cdefg	211 bcdef	190 h	194 gh	204 B
Cultivar average[4]	211 AB	210 ABC	215 A	203 C	204 BC	

[1] Ripener treatments applied August 24, 2009 and August 15, 2011, and sugarcane was harvested October 19, 2009, and October 10, 2011. Data averaged across plant-cane and second-ratoon crops.
[2] Cultivar by ripener means followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).
[3] Ripener means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).
[4] Cultivar means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).

Table 2.3 Sugarcane stalk weight of five commercial cultivars eight weeks after ripener application at St. Gabriel, Louisiana in 2009 and 2011.[1]

Ripener and rate	Cultivar					Ripener
	HoCP 96-540	L 99-226	L 99-233	HoCP 00-950	L 01-283	average[3]
	----------	----------	kg	----------	----------	----------
Nontreated	0.97 bcd[2]	1.23 a	0.73 ij	0.96 cde	0.90 def	0.96 A
Glyphosate at 210 g ae/ha	0.82 fgh	0.93 de	0.68 j	0.88 efg	0.80 ghi	0.82 C
Trinexapac-ethyl at 300 g ai/ha	0.95 cde	1.04 b	0.71 j	0.89 def	0.76 hij	0.87 B
Trinexapac-ethyl at 350 g ai/ha	0.94 de	1.02 bc	0.74 hij	0.79 hi	0.75 hij	0.85 BC
Cultivar average[4]	0.92 B	1.06 A	0.72 D	0.88 B	0.80 C	

[1] Ripener treatments applied August 24, 2009 and August 15, 2011, and sugarcane was harvested October 19, 2009, and October 10, 2011. Data averaged across plant-cane and second-ratoon crops.
[2] Cultivar by ripener means followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).
[3] Ripener means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).
[4] Cultivar means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).

yield was equivalent for the glyphosate and trinexapac-ethyl treatments (80.9 to 83.8 Mt/ha) and averaged 7% less than the nontreated. A reduction in sugarcane yield for glyphosate treated sugarcane has also been reported by Dusky et al. (1986), Millhollon and Legendre (1996), Richard et al. (2006), and Tianco and Gonzales (1980).

A significant cultivar by ripener interaction was observed for TRS (Table 2.1). Compared with the nontreated, an increase in TRS occurred when glyphosate and both rates of trinexapac-ethyl were applied to L 99-226 (9 to 28%) and L 01-283 (9%) (Table 2.5). For L 99-226, TRS when glyphosate was applied was 129 g/kg and averaged 15% more than trinexapac-ethyl at both rates. For L 01-283, TRS was equivalent for the glyphosate and trinexapac-ethyl treatments (average of 114 g/kg). In contrast, TRS for HoCP 96-540, L 99-233, and HoCP 00-950 was greater than the nontreated for only glyphosate and 350 g/ha of trinexapac-ethyl. TRS was increased 21% for glyphosate and 8% for trinexapac-ethyl for HoCP 96-540; 17% for glyphosate and 10% for trinexapac-ethyl for L 99-233; and 11% for glyphosate and 7% for trinexapac-ethyl for HoCP 00-950. TRS was greater for glyphosate compared with the high rate of trinexapac-ethyl for HoCP 96-540 but was equivalent for the ripener treatments for L 99-233 and HoCP 00-950. Resende et al. (2000) reported that trinexapac-ethyl at 200 g ai/ha increased pol% cane for most of the cultivars evaluated. Kingston and Rixon (2007) reported variable response among cultivars to trinexapac-ethyl at 200 g ai/ha, and most cultivars showed a positive response in commercial cane sugar (CCS).

Averaged across ripener treatments, TRS ranged from 106 g/kg for L 99-233 to 117 g/kg for HoCP 00-950 (Table 2.5). TRS for HoCP 00-950 was equivalent to L 99-226, but averaged 4 to 9% less for HoCP 96-540, L 99-233, and L 01-283. Averaged across cultivars, TRS was 121 g/kg for glyphosate (18% greater than the nontreated) and 110 and 113 g/kg for the trinexapac-

Table 2.4 Sugarcane yield of five commercial cultivars eight weeks after ripener application at St. Gabriel, Louisiana 2009 and 2011.[1]

Ripener and rate	Cultivar HoCP 96-540	L 99-226	L 99-233	HoCP 00-950	L 01-283	Ripener average[2]
	Mt/ha					
Nontreated	92.1	91.0	83.7	82.5	95.7	89.0 A
Glyphosate at 210 g ae/ha	85.7	77.2	75.4	75.7	90.6	80.9 B
Trinexapac-ethyl at 300 g ai/ha	84.8	83.6	75.8	75.7	99.0	83.8 B
Trinexapac-ethyl at 350 g ai/ha	90.7	82.0	83.8	78.0	78.9	82.7 B
Cultivar average[3]	88.3 AB	83.4 BC	79.7 CD	78.0 D	91.0 A	

[1] Ripener treatments applied August 24, 2009 and August 15, 2011, and sugarcane was harvested October 19, 2009, and October 10, 2011. Data averaged across plant-cane and second-ratoon crops.

[2] Ripener means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).

[3] Cultivar means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).

Table 2.5 Theoretical recoverable sugar (TRS) of five commercial sugarcane cultivars eight weeks after ripener application at St. Gabriel, Louisiana in 2009 and 2011.[1]

Ripener and rate	Cultivar HoCP 96-540	L 99-226	L 99-233	HoCP 00-950	L 01-283	Ripener average[3]
	g/kg					
Nontreated	103 fg[2]	101 g	98 g	111de	105 efg	103 C
Glyphosate at 210 g ae/ha	125 ab	129 a	115 cd	123 ab	115 cd	121 A
Trinexapac-ethyl at 300 g ai/ha	101 g	115 cd	105 efg	115 cd	114 cd	110 B
Trinexapac-ethyl at 350 g ai/ha	111 cde	110 de	108 def	119 bc	114 cd	113 B
Cultivar average[4]	110 CD	114 AB	106 D	117 A	112 BC	

[1] Ripener treatments applied August 24, 2009 and August 15, 2011, and sugarcane was harvested October 19, 2009, and October 10, 2011. Data averaged across plant-cane and second-ratoon crops.

[2] Cultivar by ripener means followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).

[3] Ripener means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).

[4] Cultivar means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).

ethyl treatments (7 and 10% greater than the nontreated), respectively. TRS was equivalent for both rates of trinexapac-ethyl, but averaged 7% less than for glyphosate.

For sugar yield, a significant cultivar by ripener interaction was noted (Table 2.1). Of the five sugarcane cultivars evaluated, an increase in sugar yield due to ripener application was noted only for HoCP 96-540 treated with glyphosate (16% increase) and for L 01-283 treated with trinexapac-ethyl at 300 g/ha (13% increase). Sugar yield for HoCP 96-540 was 2,648 kg/ha greater for glyphosate than for trinexapac-ethyl at 300 g/ha and 512 kg/ha greater than for trinexapac-ethyl at 350 g/ha. For L 99-226, L 99-233, and HoCP 00-950, sugar yield was equivalent for the glyphosate and trinexapac-ethyl treatments. For L 01-283, sugar yield was equivalent for glyphosate and trinexapac-ethyl at 300 g/ha, but for 350 g/ha of trinexapac-ethyl, sugar yield was less than for both glyphosate and the lower rate of trinexapac-ethyl. An explanation for this response is not apparent.

Averaged across ripener treatments, sugar yield ranged from 8,471 kg/ha for L 99-233 to 10,057 kg/ha for L 01-283 (Table 2.6). Sugar yield for L 01-283 was equivalent to HoCP 96-540 and L 99-226, but averaged 19% more than L 99-233 and 13% more than HoCP 00-950. Averaged across cultivars, sugar yield for glyphosate was 9,771 kg/ha, 7% greater than the nontreated and 8% greater than trinexapac-ethyl at 300 g/ha. Sugar yield was equivalent for the two rates of trinexapac-ethyl.

A significant sugarcane crop by ripener interaction for TRS and sugar yield was also observed (Table 2.1). TRS in nontreated plant-cane was less than for nontreated second-ratoon sugarcane (98 vs.109 g/kg) (Table 2.7). An increase in TRS was observed following glyphosate and trinexapac-ethyl treatments compared to the nontreated in both sugarcane crops. TRS following glyphosate application was equal for the plant-cane and second-ratoon crops (average of 122 g/kg) but for trinexapac-ethyl, TRS averaged 8% greater in the second-ratoon crop. In

Table 2.6 Sugar yield of five commercial sugarcane cultivars eight weeks after ripener application at St. Gabriel, Louisiana in 2009 and 2011.[1]

Ripener and rate	Cultivar					Ripener average[3]
	HoCP 96-540	L 99-226	L 99-233	HoCP 00-950	L 01-283	
	kg/ha					
Nontreated	9269 cdef[2]	9036 cdef	8177 f	9121 cdef	9888 bcd	9098 B
Glyphosate at 210 g ae/ha	10721 ab	10019 abcd	8714 def	9202 cdef	10201 abc	9771 A
Trinexapac-ethyl at 300 g ai/ha	8073 f	9590 bcde	8044 f	8345 ef	11201 a	9059 B
Trinexapac-ethyl at 350 g ai/ha	10209 cdef	8976 cdef	8948 cdef	8970 cdef	8896 cdef	9200 AB
Cultivar average[4]	9568 AB	9405 AB	8471 C	8909 BC	10057 A	

[1] Ripener treatments applied August 24, 2009 and August 15, 2011, and sugarcane was harvested October 19, 2009, and October 10, 2011. Data averaged across plant-cane and second-ratoon crops.

[2] Cultivar by ripener means followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).

[3] Ripener means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).

[4] Cultivar means followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).

Table 2.7 Ripener treatment means for sugarcane stalk height, stalk weight, sugarcane yield, TRS, and sugar yield averaged across five commercial cultivars for plant-cane and second-ratoon crops eight weeks after ripener application at St. Gabriel, Louisiana in 2009 and 2011.[1]

	Stalk height (cm)		Stalk weight (kg)		Sugarcane yield (Mt/ha)		TRS (g/kg)		Sugar yield (kg/ha)	
Ripener and rate	Plant cane	Second ratoon	Plant cane	Second ratoon	Plant cane	Second ratoon	Plant cane	Second ratoon	Plant cane	Second ratoon
Nontreated	238 a[2]	209 a	1.16 a	0.75 a	113.1 a	65.0 a	98 d	109 c	11107 b	7090 c
Glyphosate at 210 g ae/ha	213 a	191 a	1.01 a	0.64 a	105.2 a	56.6 a	121 a	122 a	12656 a	6887 c
Trinexapac-ethyl at 300 g ai/ha	220 a	190 a	1.09 a	0.65 a	110.3 a	57.2 a	106 c	114 b	11556 b	6562 c
Trinexapac-ethyl at 350 g ai/ha	221 a	188 a	1.07 a	0.63 a	105.2 a	60.1 a	107 c	118 ab	11263 b	7136 c
Ripener average[3]	223 A	194 B	1.08 A	0.67 B	108.5 A	59.7 B	108 B	116 A	11646 A	6919 B

[1] Ripener treatments applied August 24, 2009 and August 15, 2011, and sugarcane was harvested October 19, 2009, and October 10, 2011.

[2] Crop by ripener means averaged across five sugarcane cultivars for each parameter. Means followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).

[3] Crop means for each parameter followed by the same uppercase letter are not significantly different using Fisher's protected LSD (P>0.05).

plant-cane, TRS averaged 13% greater for glyphosate compared with trinexapac-ethyl. In second-ratoon, TRS was equal for glyphosate and trinexapac-ethyl at 350 g ai/ha, but was 7% greater for glyphosate compared with trinexapac-ethyl at 300 g/ha. In both plant-cane and second-ratoon, TRS was equivalent for the trinexapac-ethyl treatments. Sugar yield was greater for all ripener treatments applied to plant-cane compared with second-ratoon (Table 2.7). In plant-cane, sugar yield where glyphosate was applied averaged 14% greater than the nontreated and 11% greater than the trinexapac-ethyl treatments. Sugar yield was equivalent for both rates of trinexapac-ethyl. In second-ratoon, sugar yield was equivalent for the ripener treatments and none of the treatments increased sugar yield compared with the nontreated.

Averaged across ripener treatments, stalk height, stalk weight, sugarcane yield, and sugar yield were greatest in the plant-cane crop (Table 2.7). The highly significant sugarcane crop and sugarcane crop by ripener effects observed for most of the parameters measured (Table 2.1) warrant further discussion in regard to rainfall in the plant-cane and second-ratoon crops. For the plant-cane crop in 2009, rainfall received from the time ripener was applied in late-August until harvest in mid-October totaled 23.9 cm (Table 2.8). For the second-ratoon crop in 2011, rainfall totaled 3.5 cm for the period between ripener application in mid-August and harvest in early-October. It would be expected that greater rainfall during the application to harvest period would result in increased stalk height, stalk weight, and sugarcane yield. The effect on sugar yield, however, would be dependent on the magnitude of increase in cane yield in relation to the change in TRS. Even though rainfall during the application to harvest period was greater in the plant-cane crop, TRS when glyphosate was applied was equivalent for both plant-cane and second-ratoon crops (average of 122 g/kg) and was greater than for the nontreated (Table 2.7). The large decrease in tonnage in the second-ratoon crop, however, offset the increase in TRS observed where glyphosate was applied resulting in sugar yield equal to that of the nontreated. In

contrast to glyphosate, when trinexapac-ethyl was applied, TRS was higher in the second-ratoon crop showing greater inconsistency between years in ripening ability.

Table 2.8. Rainfall received from August through October in 2009, 2010, and 2011 at the Ben Hur Research Farm located 8 miles north of the Sugar Research Station.[1]

	Rainfall (cm)		
Date	2009	2010	2011
August 1-15	4.0	9.6	0.6
August 16-31	1.5	14.1	2.5
September 1-15	7.2	1.3	0.0
September 16-30	2.3	0.2	0.7
October 1-15	14.4	4.2	0.3
October 16-31	6.5	0.4	0.6

[1] For the glyphosate and trinexapac-ethyl study, treatments were applied August 24, 2009 (plant-cane) and August 15, 2011 (second-ratoon) and sugarcane was harvested October 19, 2009, and October 10, 2011. For the glyphosate study, glyphosate was applied August 30, 2010 (plant-cane) and August 29, 2011 (plant-cane) and sugarcane was harvested October 12, 2010 and October 10, 2011.

Glyphosate Study. Analysis of variance did not show a significant ripener by cultivar interaction for any of the parameters measured (Table 2.9). Significant ripener and cultivar effects, however, were noted 6 weeks after treatment for stalk weight, fiber, sugarcane yield, and TRS; a significant cultivar effect was observed for sugar yield. Averaged across eight sugarcane cultivars, glyphosate application reduced stalk weight 8%, fiber 5%, and sugarcane yield 17%, but increased TRS 10% (Table 2.10). The increase in TRS with glyphosate was offset by the decrease in sugarcane yield and sugar yield was equivalent for glyphosate and the nontreated. Fiber and TRS response to glyphosate in this study is consistent with findings reported by Osgood et al. (1981). Averaged across ripener treatments, stalk weight ranged from 0.91 kg for L 99-233 to 1.29 kg for L 99-226 (Table 2.11). Stalk weight of L 99-226 was greater than all other cultivars and stalk weight of L 99-233 was equivalent to that for HoCP 00-950, L 01-283, and L 01-299. Fiber was highest and at least 12.3% for L 99-233 and HoCP 04-838; fiber was

Table 2.9 Analysis of variance of fixed effects for plant-cane crop experiments to evaluate ripener treatments and commercial sugarcane cultivars.[1]

Source of variation	Stalk weight	Fiber	Sugarcane yield	TRS	Sugar yield
	-----------------------------------		P-value		-----------------------------------
Ripener	0.0195	0.0238	0.0035	0.0004	0.1417
Cultivar	<.0001	<.0001	0.0002	0.0007	<.0001
Ripener*Cultivar	0.2367	0.3071	0.3281	0.2580	0.0601

[1] Ripener treatments = glyphosate 210 g ae/ha and nontreated; Cultivars = HoCP 96-540, L 99-226, L 99-233, HoCP 00-950, L 01-283, L 01-299, L 03-371, HoCP 04-838.

Table 2.10 Ripener treatment means for stalk weight, fiber, sugarcane yield, TRS, and sugar yield averaged across eight sugarcane cultivars for plant-cane experiments conducted at St. Gabriel, Louisiana in 2010 and 2011.[1]

Ripener	Stalk weight (kg)	Fiber (%)	Sugarcane yield (Mt/ha)	TRS (g/kg)	Sugar yield (kg/ha)
Nontreated	1.07 a[2]	11.6 a	108.1 a	113 b	12248 a
Glyphosate	0.98 b	11.0 b	89.9 b	124 a	11212 a

[1] Glyphosate at 210 g ae/ha was applied August 30, 2010, and August 29, 2011. Sugarcane harvested October 12, 2010 and October 10, 2011.

[2] Means within a column followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).

Table 2.11 Sugarcane cultivar means for stalk weight, fiber, sugarcane yield, TRS, and sugar yield averaged across ripener treatments for plant-cane experiments conducted at St. Gabriel, Louisiana at 2010 and 2011.[1]

Cultivar	Stalk weight (kg)	Fiber (%)	Sugarcane yield (Mt/ha)	TRS (g/kg)	Sugar yield (kg/ha)
HoCP 96-540	1.13 b[2]	11.5 c	106.8 ab	117 bcd	12443 ab
L 99-226	1.29 a	11.4 c	108.9 a	125 a	13552 a
L 99-233	0.91 e	12.8 a	96.7 cd	113 d	10822 cd
HoCP 00-950	0.99 cde	10.7 d	98.6 bcd	122 ab	11956 bc
L 01-283	0.94 de	10.8 d	92.6 de	117 bcd	10834 cd
L 01-299	0.92 e	11.7 bc	87.1 e	121 abc	10584 d
L 03-371	1.04 bc	9.6 e	97.2 cd	119 bc	11494 bcd
HoCP 04-838	1.01 cd	12.3 ab	104.2 abc	117 cd	12151 b

[1] Ripener treatments = Glyphosate at 210 g ae/ha and a nontreated; Ripener treatment applied August 30, 2010 and August 29, 2011. Sugarcane harvested October 12, 2010 and October 10, 2011.

[2] Means within a column followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).

lowest for L 03-371, HoCP 00-950, and L 01-283 (9.6 to 10.8%). Fiber levels for HoCP 96-540, L 99-226, and L 01-299 were intermediate and ranged from 11.4 to 11.7%.

Sugarcane yield averaged across ripener treatments ranged from 104.2 to 108.9 Mt/ha for HoCP 96-540, L 99-226, and HoCP 04-838 (Table 2.11). Lowest sugarcane yield was noted for L 01-299 (87.1 Mt/ha). Average TRS was 121 to 125 g/kg for L 99-226, HoCP 00-950, and L 01-299 and was 113 to 119 g/kg for HoCP 96-540, L 99-233, L 01-283, L 03-371, and HoCP 04-838 (Table 2.11). Highest average sugar yield was observed for L 99-226 (13,552 kg/ha), which was equivalent to that for HoCP 96-540 (12,443 kg/ha). Lowest sugar yield was noted for L 01-299 (10,584 kg/ha) which was equivalent to that for L 99-233, L 01-283, and L 03-371. Sugar yield for HoCP 00-950 (11,956 kg/ha) and HoCP 04-838 (12,151kg/ha) were equivalent to that of HoCP 96-540.

For the glyphosate study, rainfall received from ripener application in late-August until harvest in mid-October totaled 5.7 cm in 2010 and 1.0 cm in 2011 (Table 2.8). In 2010, 14.1 cm of rain were received during the two-week period prior to ripener application, whereas only 2.5 cm was received during the same time period in 2011. Rainfall was limiting to sugarcane growth in 2011 and probably accounts for the reduction in sugarcane yield that year.

The label for glyphosate ripener states that sugarcane should be harvested 3 to 7 weeks after application. It is expected that use of ripener will increase TRS but will also decrease tonnage. The hope is that any reduction in sugarcane yield will be more than offset by an increase in TRS, resulting in greater or equivalent sugar yield per hectare. Each year, glyphosate ripener recommendations are distributed to Louisiana sugarcane producers through the LSU AgCenter Cooperative Extension Service (Legendre and Gravois 2011). At the beginning of the harvest season from September 15 to October 15 when significant vegetative growth of sugarcane is expected, the recommended interval from glyphosate ripener application to harvest is 4 to 5

weeks. As the harvest season progresses beyond October 15, less vegetative growth is expected and for sugarcane harvested from October 15 to November 15, the recommended ripener application to harvest interval is 4 to 6 weeks. As sugarcane harvest is further delayed until November 15 to December 1, a 5 to 7 week application to harvest interval is recommended.

Preliminary sugarcane research conducted in Louisiana, with trinexapac-ethyl suggests that a minimum of 8 weeks may be needed to obtain gains in TRS comparable to glyphosate (Orgeron et al. 2010). Palisade (trinexapac-ethyl) is now labeled as a ripener in Louisiana and the label states that harvest should be made 4 to 8 weeks after application. In the initial plans for the glyphosate and trinexapac-ethyl study, sugarcane was scheduled to be hand-harvested at 4, 6, and 8 weeks after treatment (WAT) and plots were to be combine-harvested 8 WAT. The previously described harvest schedule was prevented due to excessive lodging. In 2009, 5 WAT lodging was caused by high wind and rain, similarly in 2011, high wind and rain caused lodging 3 WAT. The use of a sugarcane combine harvester 8 WAT allowed for proper plot sampling. It was expected that the delay in harvest until 8 weeks after application would be beneficial to trinexapac-ethyl, but could have a negative effect on sugarcane response to glyphosate. It was important, however, that glyphosate and trinexapac-ethyl be compared in the same study under the same environmental conditions.

Since there is no way of knowing the nature of environmental conditions prior to and following ripener application or how such conditions might affect sugarcane growth, the choice to use a ripener should be based on consistency in elevating TRS. When sugarcane was harvested 8 WAT glyphosate at 210 g/ha and of trinexapac-ethyl at 350 g/ha in the first study, TRS was increased for HoCP 96-540, L 99-226, L 99-233, HoCP 00-950, and L 01-283. Sugarcane yield was reduced an average of 9% for glyphosate and as much as 7% for trinexapac-ethyl treatments. When sugarcane was harvested six weeks after glyphosate application in the second study, TRS

was increased for HoCP 96-540, L 99-226, L 99-233, HoCP 00-950, L 01-283, L 01-299, L 03-371, and HoCP 04-838 and sugarcane yield was reduced an average of 17%. Based on TRS response to glyphosate for the two studies, a general conclusion can be made that HoCP 96-540 and L 99-226 are most responsive to glyphosate ripener and HoCP 00-950 and L 01-283 are least responsive. The other cultivars, L 99-233, L 01-299, L 03-371, and HoCP 04-838, would be classified as intermediate in response until more definitive research is conducted.

For the glyphosate and trinexapac-ethyl study, a significant sugar yield increase due to glyphosate application was observed for only HoCP 96-540 (16% increase). However, numerical increases in sugar yield due to glyphosate application were observed for L 99-226, L 99-233, HoCP 00-950, and L 01-283. Averaged across cultivars, a significant increase in sugar yield of 7% was observed. In comparison, sugar yield increase due to trinexapac-ethyl application was observed for only L 01-283 treated with 300 g/ha (13% increase). When averaged across cultivars, however, neither rate of trinexapac-ethyl increased sugar yield per hectare. An increase in sugar per hectare, therefore, would be directly dependent on ripener selection and growing conditions (temperature and rainfall) prior to and after ripener application, as well as the interval between ripener application and harvest.

The inability of ripener to increase sugar yield per hectare is not uncommon. Richard et al. (2006) reported an increase in TRS six weeks after glyphosate application in late August/early September, but sugar yield for LCP 85-384, HoCP 85-845, HoCP 91-555, HoCP 96-540, and L 99-233 was not increased compared with the respective nontreated controls. The reduction in sugar yield was attributed to reduced sugarcane yield. In Brazil, trinexapac-ethyl at 200 g/ha increased sugar content by 10% for 25 cultivars (Resende et al. 2000). A rate of 300 g/ha trinexapac-ethyl in the present study increased TRS for only two of five cultivars harvested 8WAT. Resend et al. (2000) reported that for trinexapac-ethyl, the optimal treatment to harvest

interval was 45 to 60 days (6.4 to 8.6 weeks). Kingston and Rixon (2007) in Australia reported improved sucrose levels in several cultivars treated with trinexapac-ethyl at 200 g/ha and harvested 6 and 10 WAT.

In a Florida study, Brix, apparent sucrose, and theoretical yield were not affected by glyphosate or trinexapac-ethyl six weeks after application (Rainbolt et al. 2005). They concluded that although trinexapac-ethyl can ripen sugarcane similar to glyphosate, sugarcane response to glyphosate was more consistent. In the present study where ripener was applied to plant-cane and second-ratoon crops and where sugarcane growth was greatly affected by rainfall, TRS response was consistent for glyphosate but not for trinexapac-ethyl.

This research shows that both glyphosate and trinexapac-ethyl can increase TRS in sugarcane cultivars presently being grown or slated to become available to Louisiana producers. Glyphosate has been a mainstay for use as a ripener in Louisiana since 1980 and will continue to serve a major role in a sugarcane production system. For trinexapac-ethyl, questions remain in regard to application rate, harvest interval, and environmental conditions and the role of these factors in consistency in TRS response. Although trinexapac-ethyl is labeled for use as ripener, there has been no definitive statement made concerning cost.

In Louisiana the desire of the factories to process high sucrose sugarcane with harvest beginnings in September has prompted use of ripener to enhance natural ripening of sugarcane. Even though factories will cover the cost of ripener, the value to the grower through increased sugar per hectare is not always realized.

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CHAPTER 3
INFLUENCE OF NITROGEN FERTILIZATION ON SUGARCANE RESPONSE TO THE RIPENERS GLYPHOSATE AND TRINEXAPAC-ETHYL

INTRODUCTION

Sugarcane (*Saccharum* spp.) is a C_4 perennial grass which stores large quantities of sucrose in parenchyma storage cells (Rae et al. 2005). In Louisiana, sugarcane is annually cultivated on 164,970 hectares, and is the most valuable row crop commodity in the state (Salassi et al. 2011). Unlike more traditional sugarcane producing areas in the world, the climate in Louisiana is temperate. The northern boundary of the sugarcane growing region is in Cheneyville, LA, (latitude: 31.01N, longitude: -92.28W) and the southern boundary is in Theriot, LA, (latitude: 29.35N, longitude: -90.83W). Louisiana experiences periods of freezing temperatures in the months of January, February, and March (Grymes 2007), which limits the growth period of sugarcane to a maximum of 9 months.

To avoid the threat of freezing temperatures Louisiana's sugar factories begin processing sugarcane in late-September or early-October. Sugarcane maturity, in terms of sucrose content (Theoretical Recoverable Sugar/Ton Cane or TRS/TC) accumulation is lowest at the onset of the harvest and subsequently increases throughout the harvest period for most cultivars. Ripener is commonly applied during the first sixty days of the harvest season to increase sucrose concentration within immature portions of the stalk. Since 1980, glyphosate [N-(phosphonomethyl) glycine] has been the primary ripener used in the Louisiana sugarcane industry, with 62% of the total harvested hectares treated in 2005 (Legendre et al. 2005).

Glyphosate is a systemic herbicide which enters the plant through the leaf blade, and is translocated to the shoot and root meristematic tissue (Hilton et al. 1980). Sugarcane treated with glyphosate ripener showed decreased levels of new cell wall production and of reducing sugars within immature internodes, as well as decreased invertase activity in mature internodes within

24 to 48 hours of glyphosate application, resulting in retarded vegetative growth (Hilton et al. 1980).

Trinexapac-ethyl has been shown to be an effective sugarcane ripening agent in Brazil (Resende et al. 2000) and Australia (Kingston and Rixon 2007). Trinexapac-ethyl applied at 200 g ai/ha increased sugar content by 10% for the 25 most important sugarcane cultivars in Brazil (Resende et al. 2000); the optimal treatment to harvest interval was 45 to 60 days. In Australia, six cultivars were treated with trinexapac-ethyl at 200 g ai/ha and were harvested between 6 and 10 weeks after application (Kingston and Rixon 2007). Trinexapac-ethyl improved sucrose levels above nontreated sugarcane, but sugarcane yield in the subsequent ratoon crop for the cultivars Q 205, Q188, Qs92-330, and Qs93-286 was negatively affected. Trinexapac-ethyl has also been used as a growth retardant in Australia to shorten internode length, and reduce the potential for lodging of sugarcane to be used for planting (Croft and Magnanini 2006). In 2012, the United States Environmental Protection Agency (EPA) approved trinexapac-ethyl (Palisade 2EC®) for use as a sugarcane ripener and growth retardant in the U.S. Trinexapac-ethyl can be applied at 204 to 352 g a.i/ha in both plant-cane and ratoon crops.

Unlike glyphosate which limits aromatic amino acid synthesis, trinexapac-ethyl interferes with a plant hormone biosynthesis, namely gibberellic acid 1 (GA1). Trinexapac-ethyl, an acylcyclohexanedione, mimics 2-oxoglutaric acid late in gibberellin biosynthesis pathway where co-substrates 2-oxoglutaric acid and dioxygenases, catalyze biological reactions (Rademacher 2000).

In sugarcane, stalk sucrose concentration has been shown to be related to nitrogen availability and uptake (Tubaña et al. 2007). Nitrogen, an essential plant nutrient, is a constituent of chlorophyll, amino acids, proteins, and other biochemical plant compounds (Foth and Ellis 1997). In Louisiana, nitrogen recommendations for sugarcane are based on soil texture and crop

age. Nitrogen levels range from 67 to 90 kg/ha for the plant-cane crop on light- and medium-textured soils and 90 to 134 kg/ha for ratoon crops on light- and heavy-textured soils (Gravois 2010). Previous research indicates a direct relationship between nitrogen rate and cane yield, and nitrogen rate and stalk sucrose concentration (Borden 1942; Chapman et al. 1994; Das 1936; Muchow et al. 1996; and Wiedenfeld 1995). Applying excessive nitrogen to sugarcane, especially in the ratoon crop, often has a positive impact on sugarcane yield, but usually decreases sucrose content of sugarcane, whereas, moderate nitrogen levels affect sugarcane yield to a lesser extent, but increase intermodal stalk sucrose levels.

Clowes and Inman-Bamber (1980) conducted trials evaluating moisture regime, nitrogen, and glyphosate ripener. They concluded that nitrogen level did not affect sugarcane response when treated with glyphosate ripener in South Africa. In Louisiana, sugarcane fertilization levels can vary greatly from farm to farm. With more than 62% of the harvested hectares treated with glyphosate (Legendre 2005) and with the availability of trinexapac-ethyl as an alternative ripener to glyphosate, research was conducted to evaluate ripener response at different nitrogen rates.

MATERIALS AND METHODS

A nitrogen rate and ripener study was conducted in 2010 and 2011 at the Sugar Research Station in St. Gabriel, LA, on a Commerce silt loam (Fine-silty, mixed, nonacid, thermic Aeric Fluvaquent) soil. Nitrogen at rates of 67, 112, and 157 kg/ha were applied to the sugarcane cultivar HoCP 96-540 (plant-cane) on March 27, 2010, and April 20, 2011. Liquid, 32% urea-ammonium nitrate, fertilizer was applied using knives, one on each side of the sugarcane drill spaced 71 cm apart and placed 10 cm deep. Experiments were arranged in a split block experimental design, and were replicated three times. Whole plots consisted of nitrogen rates and

subplots were ripener treatments. Ripener treatments included glyphosate (Touchdown Total®)[1] at 210 g ae/ha, trinexapac-ethyl (Palisade EC®)[2] at 350 g ai/ha, and a nontreated control. Glyphosate and trinexapac-ethyl were applied above the canopy using a CO_2-pressurized backpack sprayer delivering 140 L/ha at 190 kPa on August 20, 2010, and August 24, 2011. Subplot size consisted of a single row 1.8 m wide by 6.1 m long. Each plot was separated by a 1.5 m nontreated buffer. Six weeks after ripener application on September 30, 2010, and October 5, 201l, a 10-stalk sample from each plot was hand-harvested from each plot. Samples were weighed and processed at the Sugar Research Station Sucrose Lab in St. Gabriel, LA. Brix, (Z°) pol, and percent fiber were measured by NIR SpectraCane (Gravois et al. 2008). Gravois et al. (2008) showed a high degree of relationship between NIR estimations and standard laboratory techniques for Brix (R^2 = 0.96), fiber content (R^2 = 0.85), moisture (R^2 = 0.94) and pol (R^2 = 0.94). Theoretical recoverable sugar (TRS) (sucrose content) was calculated using normal juice sucrose, Brix and fiber (TRS = 0.5(0.28 * Normal Juice Sucrose – 0.08 * Brix)(100 – (55.67 * Fiber)/(100 – Fiber)) (Gravois and Milligan 1992). Plots were harvested with a sugarcane combine and loaded into a wagon equipped with load cells to gain actual cane yield. Sugar yield was calculated by multiplying plot TRS by cane yield.

Data were analyzed using SAS v9.3 software (SAS Institute 2012), and were subjected to the Proc Mixed procedure using the following linear model.

$Y_{ijkl}=\mu+W_i+R_j(_i)+P_k+RP_j(_i)_k+N_l+GN_{kl}+E_{ijkl}$.

Y_{ijkl} is the observed response of year $_i$ in replication $_{j(i)}$ of ripener treatment $_k$ and nitrogen $_l$. μ is the overall mean; W_i is the year effect; $R_j(_i)$ is the replication effect nested within year; P_k is the ripener treatment effect; $RP_j(_i)_k$ is the replication(year) by ripener interaction; N_l is the

[1] Touchdown Total, glyphosate N-(phosphonomethyl)glycine in the form of potassium salt. Syngenta Crop Protection, P. O. Box 18300, Greensboro, North Carolina 27419-8300.
[2] Palisade 2 EC, trinexapac-ethyl, Syngenta Crop Protection, P. O. Box 18300, Greensboro, North Carolina 27419-8300.

nitrogen effect; PN_{kl} is the ripener by nitrogen interaction; E_{ijkl} is the experimental error. Least square means were calculated, and mean separation was performed using the PDIFF option ($P \leq 0.05$). Letter groupings were converted using the PDMIX800 macro (Saxton 1998).

RESULTS AND DISCUSSION

Analysis of variance showed a significant ($P \leq 0.05$) ripener effect 6 WAT for only stalk weight and TRS (Table 3.1). There were no significant effects due to nitrogen rate or for nitrogen rate x ripener treatment for any of the parameters measured.

Table 3.1 Analysis of variance of fixed effects for the 2010 and 2011 plant-cane experiments with HoCP 96-540 to evaluate ripener treatments and nitrogen rates.[1]

Source of variance	Stalk weight	Fiber %	Sugarcane yield	TRS	Sugar yield
	-----------------------------------P-value-----------------------------------				
Nitrogen	0.6615	0.2160	0.5390	0.8614	0.5290
Ripener	0.0436	0.2188	0.5652	0.0002	0.3139
Nitrogen*Ripener	0.4771	0.3369	0.8823	0.4068	0.8269

[1] Ripener treatments = glyphosate 210 g ae/ha and trinexapac-ethyl 350 g ai/ha; Nitrogen rate= 67, 112, and 157 kg N/ha.

Averaged across nitrogen treatments, sugarcane stalk weight 6 WAT for HoCP 96-540 was reduced 8 and 7% when glyphosate at 210 g ae/ha and trinexapac-ethyl at 350 g ai/ha treatments were applied, respectively, compared with nontreated sugarcane (1.07 kg) (Table 3.2). Millhollon and Legendre (1996) reported decreased stalk weight in as few as 27 days after glyphosate treatment. Legendre et al. (2001) reported that glyphosate (210 g ai/ha) had no effect on sugarcane stalk weight of LCP 85-384 at 5 or 6 WAT, but stalk weight was reduced 7 WAT. Results of sugarcane ripener research conducted with trinexapac-ethyl and reported by Resende et al. (2000) in Brazil and Kingston and Rixon (2007) in Australia did not include data showing the effect of trinexapac-ethyl on stalk weight, but focused on improvement in pol percent, a measure of stalk sucrose concentration.

TRS, averaged across nitrogen treatments, was 120 g/kg when glyphosate was applied, an 11% increase compared to the nontreated (108 g/kg) and 9% greater than trinexapac-ethyl (110 g/kg) (Table3.2). Numerous researchers have demonstrated the ability of glyphosate to increase TRS (Hilton et al. 1980; Tianco and Gonzales 1980; Martin et al. 1981; Millhollon and Legendre 1996; Legendre et al. 2001). The inability of trinexapac-ethyl in the present study to increase TRS is in contrast to that observed by Resende et al. (2000) and Kingston and Rixon (2007). Resende et al. (2000) reported an average increase in sugar content of 10% for the 25 most important cutivars in Brazil. Similarly, trinexapac-ethyl increased sucrose levels for many of the cultivars tested in Australia (Kingston and Rixon 2007). Averaged across ripener treatments (glyphosate, trinexapac-ethyl, and non-treated), percent fiber averaged 10.8%, sugarcane yield 62.3 Mt/ha, and sugar yield 7046 kg/ha (Table 3.2).

Table 3.2 Ripener treatment means averaged across three nitrogen rates for the plant-cane experiments with HoCP 96-540 conducted in St. Gabriel, Louisiana in 2010 and 2011.[1]

Ripener	Stalk weight (kg)	Fiber (%)	Sugarcane yield (Mt/ha)	TRS (g/kg)	Sugar yield (kg/ha)
Nontreated	1.07 a[2]	11.0 a	65.0 a	108 b	7153 a
Glyphosate	0.98 b	10.6 a	60.9 a	120 a	7333 a
Trinexapac-ethyl	1.00 b	10.8 a	61.1 a	110 b	6652 a

[1] Ripener treatments were applied August 20, 2010 and August 24, 2011. Sugarcane harvested September 30, 2010 and October 5, 2011. Nitrogen Rate = 67, 112, and 157 kg N/ha.
[2] Means within a column followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).

This study also evaluated the effect of nitrogen fertilizer at rates of 67,112, and 157 kg/ha. Stalk weight, percent fiber, sugarcane yield, TRS, and sugar yield were not affected by nitrogen fertilizer rate, showing that 67 kg/ha was as effective as the 157 kg/ha rate. These findings are in agreement with those reported by Tubaña et al. (2007) for sugarcane yield, TRS, and sugar yield.

Managing early season sucrose concentration is vital to the profitability of the Louisiana sugarcane industry. In considering the cost of sugarcane ripeners, producers and sugarcane factory managers should both benefit economically from ripener use. In this study, the focus was on the possible interaction between nitrogen fertilizer rates and sugarcane ripeners, and also on the comparison of the ripeners glyphosate and trinexapac-ethyl. Results showed that sugarcane response to ripener was not affected by nitrogen rate for HoCP 96-540 plant-cane. The finding that increasing nitrogen rate did not lead to increases in TRS, sugarcane yield, or sugar yield further substantiated results of other research in Louisiana (Tubaña et al 2007). The consistency in TRS response in sugarcane treated with glyphosate ripener in previous research Hilton et al. 1980; Tianco and Gonzales 1980; Martin et al. 1981; Millhollon and Legendre 1996; Legendre et al. 2001 was also observed in the present study. Application of trinexapac-ethyl at 350 g ai/ha decreased sugarcane stalk weight, as did glyphosate, but trinexapac-ethyl did not improve TRS 6 weeks after application.

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CHAPTER 4
INFLUENCE OF SPRAY VOLUME AND SURFACTANT ADDITION ON SUGARCANE RESPONSE TO THE RIPENERS GLYPHOSATE AND TRINEXAPAC-ETHYL

INTRODUCTION

Sugarcane (*Saccharum* spp.) is a major commodity in Louisiana, and directly contributed over one billion dollars to the state's economy in 2011 (Salassi et al. 2011). Sugarcane was cultivated on 164,970 hectares in Louisiana in 2011, of which 153,780 were processed by the state's 11 sugar factories. Over 1.274 million metric tons of sugar were produced in Louisiana in 2011 (Anonymous 2012).

Commercial sugarcane production in not unique to Louisiana, however, the climatic environment in which sugarcane is produced in Louisiana is unique. Unlike tropical climates, vegetative growth of sugarcane is limited to a maximum of 9 months in Louisiana due to freezing temperatures in the months of January, February, and March. Due to the short growing season, cultivars must accumulate large quantities of biomass and sucrose within a 7 month period. Typically, Louisiana sugar factories begin processing sugarcane in late-September to avoid the threat of freezing temperatures. Sugarcane maturity, in terms of sucrose content (theoretical recoverable sugar), is lowest at the beginning of the harvest season and subsequently increases throughout the harvest season.

Since 1948, the United States Department of Agriculture (USDA) has evaluated compounds to enhance natural sucrose concentration of sugarcane stalks (Dalley and Richard 2010). Many of the compounds are classified as herbicides, but others including plant hormones and nutrients have also been evaluated. Glyphosate [N-(phosphonomethyl) glycine], a nonselective systemic herbicide, has been utilized since 1980 as a sugarcane ripener in Louisiana. Sub-lethal doses of

glyphosate are applied by aircraft four to six weeks prior to harvest. In 2005, 62% of Louisiana's sugarcane hectarage was treated with glyphosate ripener (Legendre et al. 2005).

In recent years, Louisiana sugarcane producers have become increasingly concerned with possible deleterious effects of glyphosate ripener on subsequent ratoon crops, mainly, retardation of regrowth, leaf chlorosis, and reduced shoot population. Recently trinexapac-ethyl has been shown to be an effective ripening agent in Brazil (Resende et al. 2000) and Australia (Kingston and Rixon 2007). Unlike glyphosate, trinexapac-ethyl interferes with plant hormone biosynthesis, namely, gibberellins. In Brazil, trinexapac-ethyl (200 g ai/ha) was reported to increase sugarcane sucrose concentration by 10%, 45 to 60 days after application (Resende et al. 2000). In 2012, the United States Environmental Protection Agency (EPA) approved trinexapac-ethyl (Palisade 2EC®) for use as a sugarcane ripener.

In order for a sugarcane ripener to increase sucrose content, it must be absorbed by the leaf and translocated to site of action within the sugarcane plant. Several factors can affect efficacy of herbicides to include spray deposition and leaf retention and uptake and translocation within the plant (Zabkiewicz 2000). Research to evaluate potential increase in ripener uptake and improved ripener efficacy through addition of surfactants has not been reported. Surfactants are one category of adjuvants which reduce the surface tension of the spray droplet on leaves; therefore potentially increasing the quantity of sugarcane ripener absorbed. Current glyphosate formulations labeled for use as a sugarcane ripener from both Monsanto Company and Syngenta Crop Protection are formulated with surfactant; however, trinexapac-ethyl is not formulated with surfactant. Since surfactants are added to spray solutions as a percentage of the total spray volume, the proportion of surfactant would be disproportionally greater for lower spray volumes as would be the case for an aerial application compared with ground application. Upon reviewing 110 studies, Knoche (1994) reported in terms of herbicide performance, that carrier volume

(spray volume) is important, but of more importance is droplet size. It was also noted that efficacy of some herbicides were noticeably affected by carrier volume, whereas, others were not. Knoche (1994) noted improved performance of glyphosate at lower spray volumes due to less interaction of calcium and magnesium ions with glyphosate.

The objective of this research was to compare the effectiveness of the sugarcane ripeners glyphosate and trinexapac-ethyl, and to evaluate the effect of spray volume and surfactant addition on sugarcane growth, sugar accumulation, and yield.

MATERIALS AND METHODS

Sugarcane ripener, spray volume, and surfactant experiments were conducted in 2010 and 2011 at the Sugar Research Station in St. Gabriel, LA, on a Commerce silt loam (fine-silty, mixed, nonacid, thermic Aeric Fluvaquent) soil. A randomized complete block design was used. and treatments were replicated four times. In 2010, a second-ratoon field of L 99-226 and in 2011, a plant-cane field of HoCP 96-540 were used to evaluate the ripener treatments, glyphosate (210 g ae/ha), trinexapac-ethyl (350 g ai/ha), and a nontreated control. Glyphosate[1] and trinexapac-ethyl[2] were applied in 75 and 150 L/ha spray volume at a pressure of 190 kPa. The non-ionic surfactant Induce[3] was added to the spray solution at either 0 or 0.25% v/v. In each experiment, a randomized complete block designed was used where treatments were arranged as an unbalanced factorial; spray volume and surfactant treatments were not included for the nontreated/no ripener treatment. Glyphosate and trinexapac-ethyl were applied 46 cm above the crop canopy on September 30, 2010, and August 24, 2011. Plot size consisted of a single row 1.8 m wide by 10.7 m long. Each plot was separated by a 1.5 m unplanted buffer. Adjacent rows on

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[1] Touchdown Total, glyphosate N-(phosphonomethyl)glycine in the form of potassium salt. Syngenta Crop Protection, P. O. Box 18300, Greensboro, North Carolina 27419-8300.

[2] Palisade 2 EC, trinexapac-ethyl, Syngenta Crop Protection, P. O. Box 18300, Greensboro, North Carolina 27419-8300.

[3] Induce, nonionic surfactant, alkyl aryl polyoxylkane ethers, alkanolamides, dimethyl siloxane, and free fatty acids, Helena Chemical Company, 225 Schilling Boulevard, Suite 300, Collierville, Tennessee 38017.

each side of the treated row were also used as buffers to reduce potential off target drift. A 10-stalk sample from each plot was hand-harvested on November 11, 2010, and October 5, 201l (6 weeks after ripener application), weighed, and processed at the Sugar Research Station Sucrose Lab in St. Gabriel, LA. Brix, percent pol, and percent fiber were measured by NIR SpectraCane (Gravois et al. 2008). Gravois et al. (2008) reported a high degree of relationship between NIR estimations and standard laboratory techniques for Brix (R^2 = 0.96), fiber content (R^2 = 0.85), moisture (R^2 = 0.94) and pol (R^2 = 0.94). Theoretical recoverable sugar (TRS) was calculated using normal juice sucrose, Brix and fiber (TRS = 0.5(0.28 * Normal Juice Sucrose – 0.08 * Brix)(100 – (55.67 * Fiber)/(100 – Fiber)) (Gravois and Milligan 1992). Plots were harvested with a sugarcane combine and loaded into a wagon equipped with load cells to gain actual cane yield. Sugar yield was calculated by multiplying plot TRS by cane yield.

Data were analyzed using SAS v9.3 software (SAS Institute 2012), and were subjected to the Proc Mixed procedure. Due to the lack of availability of sugarcane fields containing the same cultivar and ratoon age, data were analyzed separately for the plant-cane and second-ratoon experiments using the following linear model.

$Y_{ijkl}=\mu + R_i+P_j+V_k+S_l+P_jV_k+P_jS_l+V_kS_l+P_jV_kS_l+E_{ijkl}$.

Y_{ijkl} is the observed response of replication i, of ripener treatment j, of spray volume k, and surfactant l. μ is the overall mean; R_i is the replication effect; P_j is the ripener treatment effect; V_k is the spray volume effect; S_l is the surfactant effect; P_jV_k is the ripener by spray volume interaction; P_jS_l is the ripener by surfactant interaction; V_kS_l is the spray volume by surfactant interaction; $P_jV_kS_l$ is the ripener by spray volume by surfactant interaction; E_{ijkl} is the experimental error. Least square means were calculated, and mean separation was performed using the PDIFF option ($P \leq 0.05$). Letter groupings were converted using the PDMIX800 macro (Saxton 1998).

To properly evaluate this unbalanced factorial, only the $P_jV_kS_l$ interaction was used to evaluate ripener treatments including the nontreated control. For 2-way interaction and main effect sources of variation, the nontreated was excluded from data analysis which allowed for comparison of only the glyphosate and trinexapac-ethyl treatments.

RESULTS AND DISCUSSION

Second-Ratoon Experiment. Analysis of variance showed a significant ($P \leq 0.05$) ripener by spray volume by surfactant interaction for TRS in L 99-226, when data were analyzed as a unbalanced factorial, but significance was not observed for stalk weight, fiber, sugarcane yield, and sugar yield (Table 4.1). When glyphosate was applied in 75 or 150 L/ha spray volume with or without surfactant, TRS ranged from 150 to 154 g/kg and averaged at least 9% more than the nontreated control (138 g/kg) (Table 4.2). TRS for sugarcane following all glyphosate treatments, regardless of spray volume or surfactant treatment was equal. When trinexapac-ethyl was applied in 75 and 150 L/ha with or without surfactant, TRS for sugarcane was equivalent and ranged from 142 to 146 g/kg. When trinexapac-ethyl was applied in a spray volume of 75 L/ha, TRS was equal to that of the nontreated, but TRS was greater than the nontreated when applied in 150 L/ha. The explanation for the response is not apparent. For all trinexapac-ethyl treatments TRS was lower compared with glyphosate applied in 75 L/ha with or without surfactant and 150 L/ha without surfactant (an average of144 vs. 153g/kg).

Analysis of variance of fixed effects excluding the nontreated control (balanced factorial) for the second ratoon experiment showed a significant ($P \leq 0.05$) ripener effect for TRS, but not for stalk weight, fiber, sugarcane yield or sugar yield (Table 4.3). Significance was not observed for any of the other sources of variation and parameters. Averaged across spray volume and surfactant treatments TRS for glyphosate treated sugarcane averaged 6% greater than for

Table 4.1 Analysis of variance of fixed effects for the L 99-226 second-ratoon experiment conducted in St. Gabriel, LA in 2010 to evaluate ripener treatment, spray volume, and surfactant addition.[1]

Source of variance	Stalk weight	Fiber %	Sugarcane yield	TRS	Sugar yield
	----------------------------------	------------	P-value	------------	----------------------------------
Ripener*Spray vol.*Surf	0.7198	0.6543	0.9715	<.0001	0.9456

[1] Ripener treatments = glyphosate 210 g ae/ha, trinexapac-ethyl 350 g ai/ha, and a nontreated; Spray volumes = 75 L/ha and 150 L/ha; Surfactant = 0.25% v/v addition or no addition.

Table 4.2 Theoretical recoverable sugar means influenced by the interaction of spray volume and surfactant addition for the L 99-226 second-ratoon experiment conducted in St. Gabriel, LA in 2010.[1]

Treatment	Spray Volume (L/ha)	Surfactant (0.25% v/v)	TRS (g/kg)
Nontreated	-	-	138 d[2]
Glyphosate	75	No	152 a
@ 210 g ae/ha	75	Yes	153 a
	150	No	154 a
	150	Yes	150 ab
Trinexapac-ethyl	75	No	143 cd
@ 350 g ai/ha	75	Yes	142 cd
	150	No	146 bc
	150	Yes	145 bc

[1] Ripener treatments were applied September 30, 2010. Sugarcane harvested November11, 2010.
[2] Means within a column followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).

trinexapac-ethyl (Table 4.4). Stalk weight, fiber, sugarcane yield, and sugar yield were each equivalent for the glyphosate and trinexapac-ethyl treatments and averaged 1.15 kg, 12.1%, 54.2 Mt/a, and 8012 kg/ha, respectively.

Plant-Cane Experiment. A significant ripener by spray volume by surfactant interaction for HoCP 96-540 was not observed for stalk weight, percent fiber, sugarcane yield, TRS, and sugar yield when data were analyzed as an unbalanced factorial with the nontreated included (Table 4.5) or as a balanced factorial where the nontreated was not included as a treatment (Table 4.6).

Table 4.3 Analysis of variance of fixed effects excluding the nontreated control for the L 99-226 second-ratoon experiment conducted in St. Gabriel, LA in 2010 to evaluate ripener treatment, spray volume, and surfactant addition.[1]

Source of variance	Stalk weight	Fiber %	Sugarcane yield	TRS	Sugar yield
	----------	----------	P-value	----------	----------
Ripener	0.3717	0.6561	0.9296	<.0001	0.5253
Spray volume	0.6419	0.4419	0.5133	0.5025	0.4794
Ripener*Spray vol.	0.1205	0.1480	0.5573	0.1567	0.4621
Sur	0.4337	0.8265	0.2184	0.3082	0.2674
Ripener*Sur	0.6174	0.1763	0.6107	0.9062	0.5670
Spray vol.*Sur	0.8583	0.4934	0.7875	0.3710	0.8543
Ripener*Spray vol.*Sur	0.4287	0.2108	0.8369	0.3017	0.7294

[1] Ripener treatments = glyphosate 210 g ae/ha and trinexapac-ethyl 350 g ai/ha; Spray volumes = 75 L/ha and 150 L/ha; Surfactant = 0.25% v/v addition or no addition.

Table 4.4 Ripener treatment means averaged across spray volumes and surfactant addition for the L 99-226 second-ratoon experiment conducted in St. Gabriel, LA in 2010.[1]

Ripener	Stalk weight (kg)	Fiber (%)	Sugarcane yield (Mt/ha)	TRS (g/kg)	Sugar yield (kg/ha)
Glyphosate	1.13 a[2]	12.0 a	54.0 a	152 a	8205 a
Trinexapac-ethyl	1.16 a	12.1 a	54.3 a	144 b	7818 a

[1] Ripener treatments were applied September 30, 2010 using a broadcast boom sprayer delivering 75 L/ha and 150 L/ha at 190 kPa. Glyphosate was applied at 210 g ae/ha and trinexapac-ethyl 350 g ai/ha. Surfactant treatments were added to spray mix at 0.25% v/v or not included. Sugarcane harvested November 11, 2010.

[2] Means within a column followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).

In the plant-cane experiment, neither glyphosate nor trinexapac-ethyl were not affected by spray volume or surfactant addition.

Analysis of variance of fixed effects showed a significant ($P \leq 0.05$) ripener effect for percent fiber, sugarcane yield, and TRS, but not for sugar yield (Table 4.6). Averaged across spray volume and surfactant treatments, sugarcane treated with glyphosate had 0.5% less fiber and 8% greater TRS compared with sugarcane treated with trinexapac-ethyl (Table 4.7). Sugarcane yield, however, averaged 11% less when glyphosate was applied compared with trinexapac-ethyl.

Table 4.5 Analysis of variance of fixed effects for the HoCP 96-540 plant-cane experiment conducted in St. Gabriel, LA in 2010 to evaluate ripener treatment, spray volume, and surfactant addition.[1]

Source of variance	Stalk weight	Fiber %	Sugarcane yield	TRS	Sugar yield
	----------------------------------P-value----------------------------------				
Ripener*Spray vol.*Sur	0.7885	0.1208	0.2587	0.1562	0.5357

[1] Ripener treatments = glyphosate 210 g ae/ha, trinexapac-ethyl 350 g ai/ha, and a nontreated; Spray volumes = 75 L/ha and 150 L/ha; Surfactant = 0.25% v/v addition or no addition.

Table 4.6 Analysis of variance of fixed effects excluding nontreated control for the HoCP 96-540 plant-cane experiment conducted in St. Gabriel, LA in 2011 to evaluate ripener treatment, spray volume, and surfactant addition.[1]

Source of variance	Stalk weight	Fiber %	Sugarcane yield	TRS	Sugar yield
	----------------------------------P-value----------------------------------				
Ripener	0.6802	0.0217	0.0074	0.0038	0.4186
Spray volume	0.8530	0.0958	0.3490	0.0902	0.0665
Ripener*Spray vol.	0.5714	0.4648	0.7269	0.3110	0.4066
Sur	0.6323	0.1625	0.5130	0.6590	0.8602
Ripener*Sur	0.9227	0.0769	0.4527	0.5362	0.8350
Spray vol.*Sur	0.2002	0.9287	0.5932	0.8134	0.5509
Ripener*Spray vol.*Sur	0.7695	0.9855	0.3216	0.1593	0.9173

[1] Ripener treatments = glyphosate 210 g ae/ha and trinexapac-ethyl 350 g ai/ha; Spray volumes = 75 L/ha and 150 L/ha; Surfactant = 0.25% v/v addition or no addition.

Table 4.7 Ripener treatment means averaged across spray volumes and surfactant addition for the HoCP 96-540 plant-cane experiment conducted in St. Gabriel, LA in 2011[1].

Ripener	Stalk weight (kg)	Fiber (%)	Sugarcane yield (Mt/ha)	TRS (g/kg)	Sugar yield (kg/ha)
Glyphosate	1.00 a[2]	9.9 b	83.7 b	117 a	9845 a
Trinexapac-ethyl	0.99 a	10.4 a	94.2 a	108 b	10193 a

[1] Ripener treatments were applied August 24, 2011 using a broadcast boom sprayer delivering 75 L/ha and 150 L/ha at 190 kPa. Glyphosate was applied at 210 g ae/ha and trinexapac-ethyl 350 g ai/ha. Surfactant treatments were added to spray mix at 0.25% v/v or not included. Sugarcane harvested October 5, 2011.

[2] Means within a column followed by the same lowercase letter are not significantly different using Fisher's protected LSD (P>0.05).

Sugarcane stalk weight and sugar yield were each equivalent for the ripener treatments and averaged 1 kg and 10,019 kg/ha, respectively.

Previous research has consistently shown increased stalk sucrose concentration when glyphosate is used as a sugarcane ripener (Andrels and DeStefano 1980; Clowes 1980; Martin et al. 1981; Millhollon and Legendre 1996; Legendre et al. 2005; Tianco and Gonzales 1980). The present research shows an average increase in TRS six weeks after application of glyphosate ripener of 10% in second-ratoon.

This research also addressed the impact of spray volume and surfactant addition on sugarcane response to glyphosate and trinexapac-ethyl application. In both the second-ratoon and plant-cane experiments, spray volume and addition of surfactant to glyphosate and trinexapac-ethyl treatments did not affect sugarcane response in TRS. This research also shows that TRS 6 WAT for glyphosate application averaged 6% greater in second-ratoon and 8% greater in the plant-cane compared with trinexapac-ethyl. Neither glyphosate nor trinexapac-ethyl improved sugar yield per hectare, which for sugarcane producers would be the primary criteria for ripener use.

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CHAPTER 5
CONCLUSIONS

At the onset of the sugarcane harvest season in mid-September in Louisiana, sugarcane maturity in terms of sucrose accumulation is at its lowest and increases as the season progresses through natural ripening. Application of ripening agents target biochemical processes within the sugarcane plant, resulting in a redistribution of fixed carbon and a shifting of resources into sucrose storage. Use of chemical ripening agents to improve early season sucrose concentration is of critical importance to Louisiana sugarcane processors through improve efficiency and increased daily mill capacity by reducing fiber concentration.

Glyphosate has been used as a ripener in Louisiana since 1980 and has become an important component of sugarcane production management. However, sugarcane producers have become increasingly concerned with the possible deleterious effects of glyphosate ripener on subsequent ratoon crops; mainly, retardation of regrowth, leaf chlorosis, and reduced shoot population. Therefore, there is interest in evaluating alternatives to glyphosate for use in sugarcane production programs.

In 2012, the United States Environmental Protection Agency (EPA) granted registration of trinexapac-ethyl (Palisade 2EC®) as a sugarcane ripener. The label states that sugarcane should be harvested 28 to 60 days after trinexapac-ethyl application. For glyphosate sugarcane should be harvested 21 to 49 days after application. Trinexapac-ethyl has been an effective ripener in Brazil and Australia. Unlike glyphosate, trinexapac-ethyl is classified as a plant growth regulator targeting gibberellin biosynthesis that would not be expected to have any effect on subsequent crops.

Because of the diversity in genetics in commercial sugarcane cultivars, responsiveness to glyphosate can be variable. In the glyphosate and trinexapac-ethyl ripener by cultivar study,

glyphosate applied at 210 g ae/ha and harvested 8-weeks after treatment (8WAT), increased TRS by an average of 18% for the 5 cultivars evaluated. These cultivars are currently grown on 84% of Louisiana's sugarcane area. In contrast, trinexapac-ethyl applied at 350 g ai/ha increased TRS an average of 10%. When applied at 300 g ai/ha, however, trinexapac-ethyl failed to improve TRS compared to the nontreated for the cultivars HoCP96-540, L 99-233, and HoCP 00-950. Sugar yield, the product of TRS and sugarcane yield, was increased 16% for HoCP 96-540 treated with glyphosate and 13% for L01-283 treated with trinexapac-ethyl at 300 g ai/ha.

In the nitrogen study, sugarcane stalk weight, percent fiber, sugarcane yield, TRS, and sugar yield were not affected by changes in nitrogen rates of 67, 112, 157 kg/ha in plant-cane. Previous nitrogen fertility research in Louisiana has shown that high nitrogen fertilizer rate can increase sugarcane yield, but can also reduce TRS. It has been speculated that glyphosate ripener is ineffective in increasing TRS when sugarcane is heavily fertilized, due to the excessive vegetative growth. In this study, for TRS, nitrogen rate did not affect performance for either ripener. Averaged across nitrogen rates TRS was increased 11% when glyphosate was applied. In the spray volume and surfactant study, sugarcane response in TRS from glyphosate and trinexapac-ethyl application was not affected by spray volume of 75 and 150 L/ha or by the addition of surfactant (0.25%v/v).

As a result of the short growing season (March-November) and limited daily processing capacity for Louisiana sugarcane factories, sugarcane harvest is initiated well before a large portion of sugarcane crop reaches its maximum yield potential both in terms of sugarcane yield, TRS, and sugar yield. At the beginning of the harvest season in Louisiana, sucrose content may be at levels that are not profitable for processing. The need to increase TRS prompted the use of ripeners. Previous research has shown that glyphosate often reduces sugarcane yield, and the treatment to harvest interval is critical to managing sugarcane yield loss potential. In the cultivar

study, the average loss of sugarcane yield for the five cultivars was 8.1 Mt/ha when treated with glyphosate and harvested eight weeks after glyphosate treatment. In contrast, trinexapac-ethyl at 350 g ai/ha reduced sugarcane yield 6.3 Mt/ha. This shows that both glyphosate and trinexapac-ethyl negatively impacted sugarcane yield.

At nine of the 11 sugarcane factories in Louisiana, producers are compensated solely on total sugar yield. It is important to recognize that neither glyphosate nor trinexapac-ethyl consistently increased sugar yield above the nontreated control; however, just as importantly, for both ripeners, a reduction in sugar yield per hectare was not observed.

For the other two factories, producers are not only compensated for total sugar yield, but are penalized or rewarded for their daily TRS level as compared to the factory average. For these producers delivering sugarcane to these factories, ripener usage is critically important to ensure that a penalty for low TRS is not imposed.

In all of the studies conducted, an increase in TRS of 8 to 18% was observed when glyphosate was applied. Response in TRS with trinexapac-ethyl was inconsistent, and the increase in TRS ranged from 3 to 11%. Based on the results of these studies, trinexapac-ethyl is not a viable ripener option for the Louisiana sugarcane industry.

Sugarcane ripener benefits sugarcane processor by increasing early season sucrose levels, thus reducing fixed cost associated with processing of sugarcane. Even though factories will cover the cost of ripener, the value to the producer through increased sugar yield per hectare is not always realized. For trinexapac-ethyl, questions still remain in regard to the role of application rate, harvest interval, and environmental conditions in promoting consistent TRS response.

VITA

Albert Joseph Orgeron is the oldest child of Alvin and the late Maryann Orgeron. He was born on August 17, 1977, in Raceland, Louisiana. The family resided in Cut Off, Louisiana and he attended South Lafourche High School and graduated in 1995. Albert began his college education at Nicholls State University in the fall of 1995. He transferred to Louisiana State University in January 1997, and completed a Bachelor of Science Degree in dairy science in August 2000. Upon graduation, Albert began working for the LSU AgCenter's Sugar Research Station as a research associate. Albert then earned a Master of Science degree in agronomy from Louisiana State University in August 2003. Following graduation, Albert began working for Helena Chemical Company as sugarcane seed specialist for SugarTech, a new enterprise focusing on disease free sugarcane propagation and seedcane production. In 2007, Albert began working for the LSU AgCenter's Cooperative Extension Service as a county agent in St. James parish, focusing on sugarcane producer education. In 2008, he began working towards a Doctorate of Philosophy in agronomy under the direction of Dr. Jim Griffin. Following graduation, Albert plans to continue his career with the LSU AgCenter's Extension Service.