

## **EFFECTS OF GREEN HARVESTING VS BURNING ON SOIL PROPERTIES, GROWTH AND YIELD OF SUGARCANE IN SOUTH TEXAS**

**Bob Wiedenfeld**

Texas AgriLife Research, Texas A&M University Research and Extension Center  
2415 East Highway 83, Weslaco, TX 78596

**Corresponding author:** b-wiedenfeld@tamu.edu

### **ABSTRACT**

Harvesting of sugarcane green without burning to remove leaves and tops is increasing due to environmental concerns. Information is needed on the effects of the residues that remain on soil properties and crop growth. This study was conducted to compare the effects of green harvesting followed by partial incorporation of residues vs preharvest burning in semiarid South Texas. Soil organic matter content after three years was increased by green harvesting compared to burning prior to harvest. Very few other differences in soil chemical properties were found. Harvesting green compared to burning caused a 20% reduction in yield in the 2<sup>nd</sup> ratoon and a slight reduction in crop growth but an 8% increase in sucrose content in the 3<sup>rd</sup> ratoon crop. While the effects due to green harvesting on soil properties and crop growth were relatively minor, the residue remaining on the soil presents considerable challenges in cultivation, weed control and irrigation.

### **INTRODUCTION**

Traditionally, sugarcane has been burned prior to harvest in order to eliminate leafy non-sucrose containing material so that it does not have to be transported and milled. This burn, while quick, efficient and relatively clean in terms of air quality effects, has caused concern regarding the impact of smoke and ash on adjacent urban areas. In the past, harvesting equipment was not very efficient in removing the leaves from the stalks and leaving this dry mater in the field. Until recently green harvesting was not a practical alternative for South Texas (Rozeff 1993). However, modern harvesters can separate trash from the millable cane much more efficiently. Approximately 25% of the sugarcane crop in the Lower Rio Grande Valley of Texas is currently harvested green. Now the challenge is how to manage the trash and what impact this residue left in the field will have on the soil and on subsequent crops.

Retention of sugarcane residue in the field potentially has several effects both positive and negative. Burning can be detrimental to soil structure and nutrient availability due to the loss of soil organic matter. Retention of unburned residues can increase nutrient conservation, reduce weed growth, and conserve soil moisture. Substantial losses of C and N due to sugarcane residue burning have been reported (Ball-Coelho et al. 1993). However, the retained mulch makes tillage operations more difficult, interferes with fertilizer and herbicide applications and can immobilize N and P (Ng Kee Kwong et al. 1987). Extracts from sugarcane postharvest residue were found to increase bud germination at low concentrations, but delayed early leaf development at high concentrations on a subsequent sugarcane crop (Viator et al. 2006). Furrow irrigation is more difficult when residues remain on the soil surface. Fire may play a role in controlling insect populations and diseases.

Management of residue after harvest will affect the impact on the subsequent sugarcane crop. In high rainfall areas the trash can be left on the surface since it decomposes quickly (Spain and Hodgen 1994). Incorporation of the residue is difficult and energy intensive. Residues left on the surface have been found to improve organic matter content and soil moisture holding capacity long term compared to incorporation (Samuels et al. 1952). Chopping the residue into finer particles and soil incorporation have been found to increase decomposition rates and increase yields (Kennedy and Arceneaux 2006).

Differences in sugarcane yields due to harvesting green vs preharvest burning have been inconsistent. In Brazil unburned mulching resulted in an increase in sugarcane yield in the subsequent crop which was attributed to increased soil moisture retention (Ball-Coelho et al. 1993). Samuels et al. (1952) in Puerto Rico found no differences in yield between burned and green harvesting until the 5<sup>th</sup> and 6<sup>th</sup> ratoons at which point they suggested that improvements and soil physical properties were beginning to have beneficial effects. In Louisiana residues left on the surface had no effect on yields, but incorporation increased yields compared to burning over two years (Kennedy and Arceneaux 2006). Residues incorporated into the soil at levels up to double the amount that would normally remain after green cane harvesting had no effect on yields or two sugarcane cultivars over four years in Texas (Wiedenfeld et al. 1985).

In semiarid South Texas residues from green harvested sugarcane are typically chopped using some type of roller chopper, and partially incorporated using a cultivator. These operations are done to stimulate decomposition in order to facilitate furrow irrigation, and to allow herbicide and fertilizer applications. The effectiveness of these operations are quite variable, but usually poor. The objective of this study was to compare effects of green harvesting with partial incorporation of residues vs preharvest burning on sugarcane growth and yield in a semiarid environment.

## MATERIALS AND METHODS

A field study was conducted in the South Texas, an area with a subtropical, semiarid climate (23.0 °C average daily temperature, 635 mm average annual rainfall). The study site was on the AgriLife Research and Extension Center, Weslaco, TX (26° 12' 15" N, 97° 56' 57" W, elevation 20 m) on a Hidalgo fine sandy loam soil (Fine-loamy, mixed, hyperthermic, Typic Calciustolls). The study area was prepared into raised beds spaced 76 cm apart. Sugarcane was planted on 21 Oct 2004 by placing stalk pieces in every other furrow at approximately double overlap, then covering with soil to a depth of 15 to 20 cm, giving a final row spacing of 152 cm. Cultivar TCP93-4245 was chosen because it has been found to produce more leafy trash than other sugarcane cultivars.

Treatments consisted of burning the crop prior to harvest, or harvesting green and returning the leaves and tops to the soil surface. Retained residues were chopped with an offset chopper disk (model DC2-242424, Rome Plow Equipment Co., LLC, Cedartown, GA 30125) and mixed with the soil using a Lilliston rolling cultivator. Even though multiple passes were made with both implements, approximately 50% of the residues initially remained on the soil surface following this procedure each year. Treatments were applied in plots 18.2 m wide (12 rows) by 37 or 43 m in length and separated by 6.1 m allies on all sides, and were replicated four times in a randomized block design.

Weed control was accomplished using annual pre-emergence applications of atrazine and pendimethalin, spot treatment throughout the season with glyphosate, and mechanical

cultivation. No pesticide applications were used for insect control. Nitrogen fertilizer was not applied to the plant crop, was applied at the rate of 112 kg N ha<sup>-1</sup> to the 1<sup>st</sup> ratoon crop, and at the rate of 202 kg N ha<sup>-1</sup> to the 2<sup>nd</sup> and 3<sup>rd</sup> ratoon crops, by banding liquid N-32 (32-0-0) into the shoulder of the bed.

The study was irrigated using a linear move overhead sprinkler system. Water application rates were determined using Penman-Monteith reference evapotranspiration calculated using meteorological data from a Campbell Scientific model ET-106 weather station and FAO crop coefficients (Allen et al. 1998) adjusted to local conditions. A water balance approach was used based on the moisture holding capacity of the soil, inputs including effective rainfall and irrigation, and crop water use.

Parameters measured included annual soil chemical properties, plant growth over time, and sugarcane yield. Soil samples were taken initially in each block, and annually after all harvests in each plot by taking samples at 10 to 12 random locations to a depth of 15 cm within a sampling unit and compositing to give a representative sample. Soil samples were dried, ground, and analyzed for pH and electrical conductivity in a 1:2 soil to water extract; for NO<sub>3</sub>-N spectrophotometrically in a 1 N KCl extract using Cd reduction; for P, K, Ca, Mg, Na and S in a dilute acid-fluoride-EDTA solution at pH 2.5 (Mehlich III) using ICP; and for organic matter using a combustion procedure (Texas Cooperative Extension 2005). Organic matter content was determined only following the 1<sup>st</sup> through 3<sup>rd</sup> ratoon crops.

Plant growth was estimated by measuring leaf area index (LAI) in each plot beginning in April each year and continuing at approximately weekly intervals using a plant canopy analyzer (LAI-2000, Li-Cor Biosciences, Lincoln, NE).

Cane and sugar yields were determined annually on 3 Feb 2006, 2 Mar 2007, 3 Jan 2008 and 30 Jan 2009 for each plot. Plots were burned or left green prior to harvest according to the treatment plan. Each row in each plot was harvested using a commercial chopper harvester with the weight determined using a weigh wagon equipped with a load cell which could be tared after each plot row. A stalk subsample was taken from each plot and a juice sample obtained using a roller mill. Juice samples were analyzed for total dissolved solids (brix) using a refractometer (PR-101, Atago USA, Bellevue, WA), sucrose content (Pol) using a saccharimeter (Autopol IIS/589-10, Rudolph Research Analytical, Hackettstown, NJ) and electrical conductivity. Commercially recoverable sucrose (CRS) content and sugar yields were calculated using the Winter-Carp formula (Chen and Chou 1993).

Data were analyzed statistically using analysis of variance with the GLM procedure of the SAS for Windows software version 9.1 (Copyright 2002-2003, SAS Institute, Cary, NC). For soil parameters, block, date and treatment were used as independent variables. Mean comparisons between dates were made using Duncan's multiple range test. LAI, sugarcane yield, sucrose content and sugar yield were analyzed separately for each year with block and treatment as the independent variables. Differences in soil parameters, daily and season long average LAI were considered statistically significant at the 5% level. Sugarcane yield and juice quality data were obtained by taking measurements on a large area 673 or 783 m<sup>2</sup> in size, therefore differences were considered statistically significant at the 10% level.

## RESULTS AND DISCUSSION

The soil in the study area initially had a pH of 8.2, very low NO<sub>3</sub>-N levels, high or very high levels of all other plant nutrients, and no salinity hazard (Table 1). These conditions are

typical of soils in the Lower Rio Grande Valley of Texas.

In soil samples taken annually following the sugarcane crops grown, differences between year were significant for all of the soil chemical parameters measured, but no significant differences due to treatment occurred for any parameter, therefore the annual levels reported in table 1 are averaged for the burned vs green harvested treatments. Annual variations in soil fertility parameters can generally be attributed to recent rainfall patterns prior to sampling. Soil salinity as well as most individual nutrients were higher following all sugarcane crops than they were initially (Table 1). The method used to determine irrigation requirements was designed to meet crop water requirements as efficiently as possible, therefore no excess water was applied to facilitate leaching of salts. The irrigation water used in South Texas contains approximately 850 mg kg<sup>-1</sup> total salt, therefore salt buildup is a risk.

**Table 1. Soil fertility status (mg/kg) prior to initiation of the study and following each sugarcane crop.**

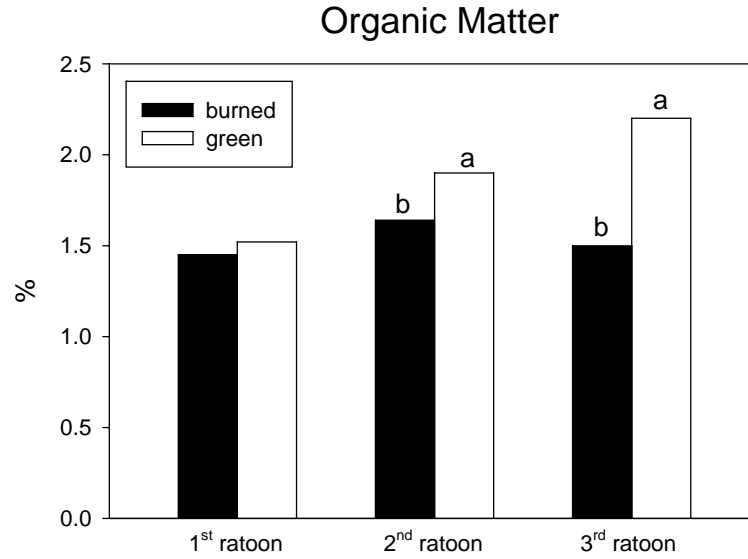
Crop	pH	NO <sub>3</sub> -N	P	K	Ca	Mg	S	Na	Salinity
preplant	8.2 a	5.6 a	50 b	425 c	4,367 d	441 b	16 d	175 c	191 d
plant	8.1 b	5.8 a	47 bc	588 b	5,121 bc	455 b	57 a	292 a	421 b
1st ratoon	7.7 d	2.3 b	50 b	863 a	5,849 a	540 a	40 bc	231 b	333 c
2nd ratoon	7.9 c	4.3 a	56 a	813 a	5,717 ab	529 a	48 ab	267 ab	575 a
3rd ratoon	7.7 d	4.6 a	43 c	622 b	4,787 b	445 b	34 c	149 c	412 b

Means in each column followed by the same letter are not significantly different at the 5% significance level.

Soil organic matter content showed no significant difference due to burning vs green harvesting after the 1<sup>st</sup> ratoon crop, but then the difference between treatments increased following the 2<sup>nd</sup> and 3<sup>rd</sup> ratoon crops (Fig. 1). This increase in soil organic matter content is consistent with what would be expected for green harvesting, although other increases in soil mineral levels might have been expected due to the ash from burning as well.

Over the three years of this study, differences in LAI due to the green harvesting vs burning treatments were significant on less than 3% of the sampling dates. Season long average LAI over time showed no differences due to the green harvesting vs burning before harvesting in the 1<sup>st</sup> and 2<sup>nd</sup> ratoon crops; however, in the 3<sup>rd</sup> ratoon crop season long average LAI for green harvesting was significantly lower than for burning. This difference occurred primarily during and after the grand growth period from September on (Fig. 2). This indicates that in one of three years green harvesting resulted in reduced plant growth.

Cane sucrose content in the plant crop was about 6% lower for green harvesting than for burning (Table 2,  $p = 0.09$ ). Since this was the 1<sup>st</sup> harvest no residue treatments had been applied to this crop, therefore this difference was the effect of the preharvest treatment on harvest efficiency only. Cane and sugar yields in the 2<sup>nd</sup> ratoon crop were lower for green harvesting vs burning (cane:  $p = 0.08$ , sugar:  $p = 0.07$ ), but yields in the 1<sup>st</sup> and 3<sup>rd</sup> ratoons were not affected by residue treatment. In the 3<sup>rd</sup> ratoon crop cane sucrose content was significantly higher for green harvested vs burned ( $p = 0.02$ ).



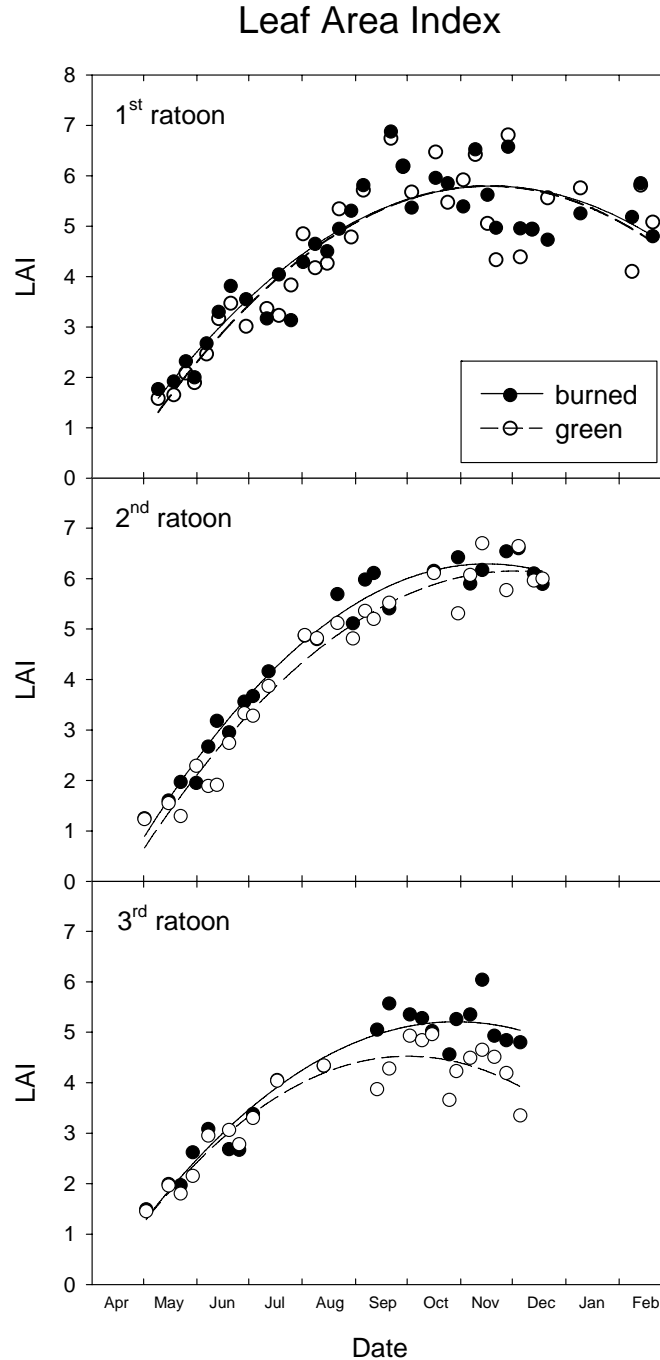
**Figure 1.** Soil organic matter content for preharvest burning vs green harvesting for three sugarcane crops. Different letters above bars indicate that treatment means for each crop were different at the 5% significance level.

**Table 2. Sugarcane yields and sucrose content for burned vs green harvested for four crops.**

Crop	Treatment	Cane yield Mg/ha	Sucrose kg/Mg	Sugar yield Mg/ha
Plant	Burned	125.5	132	16.4
	Green	122.6	124	15.2
		ns	S <sup>.09</sup>	ns
1 <sup>st</sup> ratoon	Burned	89.9	112	10.1
	Green	91.9	108	9.9
		ns	ns	ns
2 <sup>nd</sup> ratoon	Burned	76.0	125	9.4
	Green	60.5	126	7.6
		S <sup>.08</sup>	ns	S <sup>.07</sup>
3 <sup>rd</sup> ratoon	Burned	62.5	115	7.3
	Green	61.6	124	7.7
		ns	S <sup>.02</sup>	ns

Differences between treatment means in each column for each crop are not significant at the 10% level (ns), or significant (S) at the level indicated.

Agronomically the effects of green harvesting followed by partial incorporation of the residue vs burning prior to harvest were relatively minor, resulting in differences in sugarcane growth, yield and quality that were not significant every year. The only effect of green vs burned harvesting on soil properties was the increasing difference in soil organic matter content



**Figure 2.** Sugarcane leaf area index over time for burned vs green harvested for three ratoon crops.

each year, however, this difference was not enough to have much of an effect on the sugarcane crop.

The main concern for green cane harvesting in semiarid South Texas will be handling of residues. Up to  $25 \text{ Mg ha}^{-1}$  of dry matter are returned to the soil annually. The mechanical operations that were used in this study to try to break down and incorporate the crop residues that remained were only partially effective. Residue remaining following green harvesting is usually

perceived to be a big problem for furrow irrigation, although that was not a concern in this study since overhead irrigation was used. Preemerge herbicide applications made to the green harvested plots were found in this study to be much less effective due to the residues that remained on the surface than herbicide applied to burned plots. Boring insects have also been found to over-winter and reproduce in the residues that remain. While several of the positive effects of green cane harvesting that have been suggested such as improved moisture holding capacity or nutrient availability did not seem to provide much benefit in the three years of this study, negative effects on crop growth and yield were minimal as well. The biggest challenge is probably the increased expense associated with handling the residues in the field. The tools currently available to do this are not very efficient or economical.

## CONCLUSIONS

Green sugarcane harvesting has only minor effects on soil properties which affect crop growth and yield. Any differences due to changes in nutrient availability, soil moisture holding capacity or soil temperature are probably not large enough or not long lasting. Sugarcane, like many agronomic crops in a subtropical environment, can compensate for these effects as soil differences disappear over time during the long growing season. The biggest challenge is to figure out how to handle and manage large amounts of residue efficiently and economically.

## ACKNOWLEDGMENTS

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