

## EFFECT OF HARVEST METHOD ON MICROCLIMATE AND SUGARCANE YIELD IN FLORIDA AND COSTA RICA

By

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**KEYWORDS: Green Cane, Burning, Soil Temperature, Crop Residue, Tiller Population.**

### Abstract

THERE IS worldwide pressure on sugarcane industries to adopt 'green cane' harvesting systems that do not involve burning. The objective of this study was to compare the effect of sugarcane harvest methods on cane productivity and microclimate in Florida, U.S.A. and Costa Rica. The treatments included 1) burnt cane, 2) green cane, and 3) green cane with residue management. These treatments were implemented at three sites: A) Everglades Research and Education Center (EREC), Belle Glade, Florida on a muck Histosol with high organic matter, B) Hilliard Brothers Farms, Florida on an Entisol with sandy texture, and C) Azucarera El Viejo mill in Guanacaste, Costa Rica on a clay loam Inceptisol. The green cane residue provided a buffering effect on soil temperatures (15–cm depth) at the Florida muck site. There was a trend for higher biomass yields in burnt cane when harvested early (Nov – early Jan), and a significant cumulative 3-year difference of 22 t/ha of cane favouring burnt vs. green cane treatments. However, cane yields were not different when harvested late in the season (mid-February – March). On the Florida sand site, a decline in tiller population, particularly in green cane, was linked to frost events in February, 2006. Air temperatures at 10-cm aboveground were lower in green cane during frosts, which led to significantly lower tiller population in green cane in the first ratoon crop. Cane biomass yields on sand followed similar trends to those on the muck soil with burnt cane recording higher yields when harvested early but not significantly different when harvested late. At the Inceptisol site in Costa Rica, trash content, biomass and sucrose yields were not significantly different in green vs. burnt cane in the plant cane and first ratoon crops. In Costa Rica, cane residues reduced maximum soil temperatures by 5–10°C for 3 months from harvest to canopy closure. Our results indicate that green cane residues have a significant effect on microclimate and that green cane harvest in Florida would be better suited for late rather than early harvest time periods.

### Introduction

In burnt sugarcane systems, the crop is harvested annually in a process that utilises controlled fires prior to harvest to remove excess, adhering leaves on the standing stalks. The juices

of the sugarcane stalk contain the majority of sugar in the plant, whereas the topmost growing point and leaves (both green and senesced) have much lower sucrose contents. Furthermore, as much as 25 to 30 percent of the above-ground biomass in sugarcane is present as leaves and tops (commonly referred to by sugarcane growers as the cane trash) and is undesirable from the standpoint of processing for sugar and molasses. Pre-harvest burning destroys the trash, and increases the efficiency and profitability of the harvesting process (Meyer *et al.*, 2005).

There are sound reasons based on conservation and agricultural science to effectively utilise crop residues by returning them to the soil if feasible. Important among these are the conservation and recycling of nutrients and organic matter, and the reduction of soil erosion and runoff in agricultural systems (Dominy *et al.*, 2002).

As a result, there are incentives to experiment with alternative systems of harvesting unburned sugarcane which may show potential environmental and agronomic benefits (Kingston *et al.*, 2005). Some of the potential benefits include: 1) improved air quality, 2) greenhouse gas reductions, 3) rainfall conservation (Morandini *et al.*, 2005), 4) reduced soil erosion, herbicide usage and runoff (Makepeace and Williams, 1988; Prove *et al.*, 1986), and 5) improved soil quality and nutrient recycling (Barzegar *et al.*, 2000; Graham *et al.*, 2002).

In green cane harvest systems, the non-commercial residues are conserved as surface mulches. Despite this benefit, there are major agricultural concerns with the green cane system because, under specific conditions, it has been shown to reduce sugarcane biomass and sugar yields due to excessive soil wetness, lower soil temperatures (Oliviera *et al.*, 2001), slower ratoon crop re-growth rates, and possible allelopathic effects (Cock *et al.*, 1997; Kingston *et al.*, 2005). Heavy crop residues left on the fields may facilitate higher pathogen and pest pressures (Liu and Allsopp, 1996).

Additionally, trash residues generally impede effective cultivation. As a consequence, many sugarcane growers disk green cane residues into the soil following harvest. Modifying harvest practices at this scale could significantly impact the economics of producing and harvesting the sugarcane crop, as well as the entire agro-ecosystem of sugarcane fields.

However, agricultural, environmental, and social pressures are continuing to push sugarcane farming operations towards higher adoption of green cane harvesting systems, and many of the potential limitations may be solved or minimised through a multidisciplinary research team approach.

The Costa Rican sugarcane industry differs from the Florida industry in that the number of mills is greater (16 *vs.* 4) whereas the amount of sugar produced is smaller (380 000 *vs.* 1 520 000 tonnes in 2006/2007). The Costa Rican industry also is widely dispersed throughout the country while the Florida industry is concentrated south of Lake Okeechobee.

However, both industries are facing threats from increased urbanisation and environmental regulation that may push them towards greater implementation of green cane harvesting. Thus, it is important to generate sound scientific data on the benefits and disadvantages of green cane for both industries.

The objectives of this study were to determine the effect of different harvest management strategies (burnt cane, green cane, and green cane with residue management) in Florida and Costa Rica on sugarcane growth, yield and microclimate. An additional goal was to determine the effect of early *vs.* late harvest dates in Florida on sugarcane growth and yield under different harvest management.

## Materials and methods

Harvest management experiments were established at 3 locations (Table 1): Everglades Research and Education Center (EREC) in Belle Glade, Florida; Hilliard Brothers Farms in

Clewiston, Florida; and Azucarera El Viejo in Guanacaste, Costa Rica. The EREC and Hilliard Brothers sites were harvested both early and late in the season whereas the El Viejo site was harvested once per season. All sites imposed different harvest management treatments including burning, green cane, and green cane with harvest residue management. The residue management treatments differed by location due to grower preference, and included raking from the crop row (EREC and Hilliard Brothers), disking between rows (Hilliard Brothers), and complete residue removal from the field (El Viejo). Due to different burn regulations between sites, the burnt treatment was implemented during daylight hours at EREC and Hilliard Brothers, whereas burns were conducted at night at El Viejo.

**Table 1**—Soil type, cultivar, planting and harvest dates for the 3 sites included in the study. PC, 1R and 2R refer to plant cane, first ratoon and second ratoon crops, respectively.

Site	Soil type	Cultivar	Planting date	Harvest dates
EREC	Histosol (muck)	CP 80-1743	15/11/03	30/11/04 (Early PC) 23/03/05 (Late PC) 13/12/05 (Early 1R) 28/02/06 (Late 1R) 03/01/07 (Early 2R) 07/03/07 (Late 2R)
Hilliard Brothers	Entisol (sand)	CP 78-1628	15/08/04	20/12/05 (Early PC) 25/02/06 (Late PC) 18/12/06 (Late 1R) 23/02/07 (Late 1R) 10/12/07 (Early 2R) 12/02/08 (Late 2R)
El Viejo	Inceptisol (clay loam)	B 80-689	04/03/07	12/03/08 (PC) 18/03/09 (1R)

Measurements at all sites included crop residue ('trash') dry weights taken immediately after harvest, tiller population counts at monthly intervals, and whole-plot sugarcane biomass weights.

Plot sizes at all locations were at least 12 m wide x 300 m long to allow for adequate burning and also for efficient commercial-scale mechanical harvest and transport, as well as uniform trash deposition in the green cane treatments.

Cane yields were calculated from trailer or rail car weights recorded at the mill. Sucrose yields were calculated by established methods (Gilbert *et al.*, 2006). Soil temperatures were recorded at 15-minute intervals at 15-cm depth within the row in Florida and at 2 and 10 cm in Costa Rica throughout the growing season. In addition, air temperature at 10-cm height above the row was recorded at 15-minute intervals from January–May at the two Florida locations.

## Results and discussion

Sugarcane harvest management had a highly significant effect on crop residue deposited on the field (Table 2). Burning in standing cane resulted in 2.0–3.4 t/ha of residue whereas green cane harvest averaged 10.2–18.1 t/ha of residue remaining in the field.

The amount of residue declined in the ratoon crops at all locations, consistent with decreasing total crop biomass in the ratoons compared to the plant cane crops. There was a significant increase in residue production during late harvest at EREC but no significant difference in residue production due to harvest date at Hilliard Brothers (Table 2).

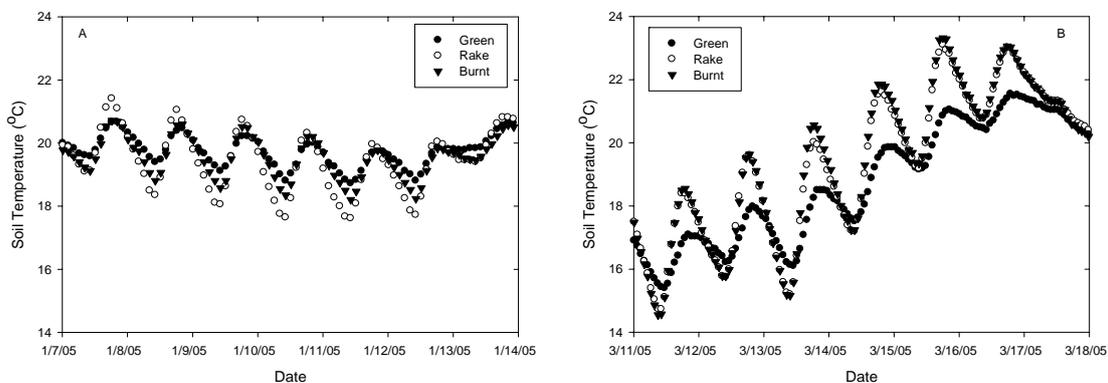
The residue levels obtained in the green cane treatments were similar to the 7–16 t/ha recorded in Argentina (Romero *et al.*, 2007) and 7–12 t/ha obtained in Australia (Robertson and

Thorburn, 2007), but lower than reported in Columbia (Cock *et al.*, 1997) and greater than estimated in Louisiana (Johnson *et al.*, 2007).

**Table 2**—Crop residue dry weights at three sites. Data presented are mean values for harvest management treatment, crop class and date of harvest.

Treatment	Residue t/ha	Crop class	Residue t/ha	Harvest date	Residue t/ha
EREC					
Rake	18.1 a	Plant cane	16.7 a	Late	14.0 a
Green	17.3 a	1 <sup>st</sup> ratoon	11.9 b	Early	10.9 b
Burnt	2.0 b	2 <sup>nd</sup> ratoon	8.8 c		
<i>P</i>	<0.001	<i>P</i>	<0.001	<i>P</i>	0.002
Hilliard Brothers					
Rake	17.6 a	Plant cane	15.4 a	Late	13.2 a
Green	16.2 a	1 <sup>st</sup> ratoon	12.8 b	Early	13.3 a
Disk	15.9 a	2 <sup>nd</sup> ratoon	11.6 b		
Burnt	3.4 b				
<i>P</i>	<0.001	<i>P</i>	0.001	<i>P</i>	0.78
El Viejo					
Remove	10.8 a	Plant cane	10.4 a		
Green	10.2 a	1 <sup>st</sup> ratoon	5.2 b		
Burnt	2.4 b				
<i>P</i>	<0.0001	<i>P</i>	<0.0001		

Soil temperature (15-cm depth) was significantly affected by harvest management at the EREC site. During cool periods early in the growing season, the presence of green cane residue led to higher minimum soil temperatures (Figure 1A), whereas, later in the season as air temperatures increased, the green cane plots recorded lower maximum soil temperatures (Figure 1B). Thus, the green cane systems led to a buffering of soil temperatures on both a diurnal and a seasonal basis. Leaf area indices were higher for the burnt treatment on muck, particularly when harvested early, which could have been due to lower soil temperatures early in the season leading to delayed emergence and growth. The buffering of soil temperature in green cane in our study concurs with soil temperature data reported from Louisiana (Viator *et al.*, 2005), Argentina (Morandini *et al.*, 2005) and Brazil (Oliviera *et al.*, 2001).



**Fig. 1**—Soil temperature (averaged over 15-min periods) at 15-cm depth as affected by harvest management at the EREC site during A) Early-season: January 7–13, 2005 and B) Late-season: March 11–17, 2005.

Burnt cane treatments recorded higher cane yields (cane t/ha; TCH) than the green cane or raked treatments when harvested early at EREC; however, there were no significant yield differences between harvest management treatments when harvested late (Figure 2). Green cane harvest can be either beneficial or detrimental to sugarcane yield. Sugarcane yield increases under green cane have been documented in Brazil (Ball-Coelho *et al.*, 1993) and Mexico (Toledo *et al.*, 2005), whereas yield losses have been reported from Louisiana (Viator *et al.*, 2008). In general, green cane harvest appears to be most detrimental to cane yield in cool and wet environments (Kingston *et al.*, 2005).

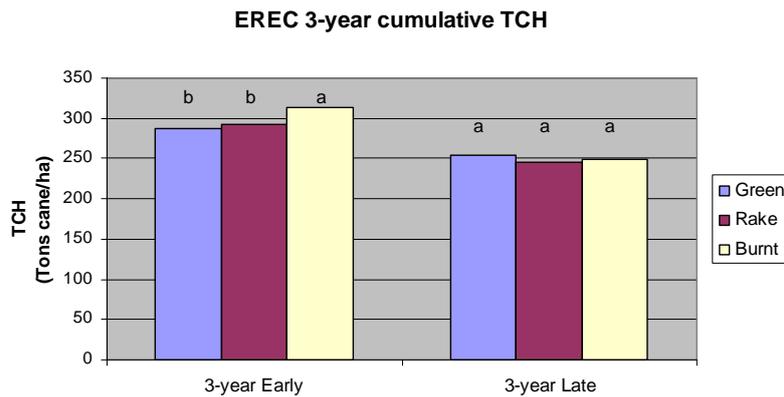


Fig. 2—Sugarcane 3-year cumulative cane yields at the EREC, Florida site as affected by sugarcane harvest management.

Air temperatures during two freeze events in Feb, 2006 at the Hilliard Brothers site are presented in Figure 3. During cold nights, when air temperature declined below 5°C, the green cane treatments consistently recorded air temperatures that were 2–3°C lower than air temperatures in the burnt cane treatments. Lower air temperatures for a longer duration can have significant effects on plant growth if they cause freezing of plant tissue. We should note that the burnt cane treatments also recorded below-freezing temperatures on February 14, during an extremely cold freeze event. However, under the milder conditions recorded on February 13, sugarcane in the green cane plots would have been frozen whereas burnt cane would not.

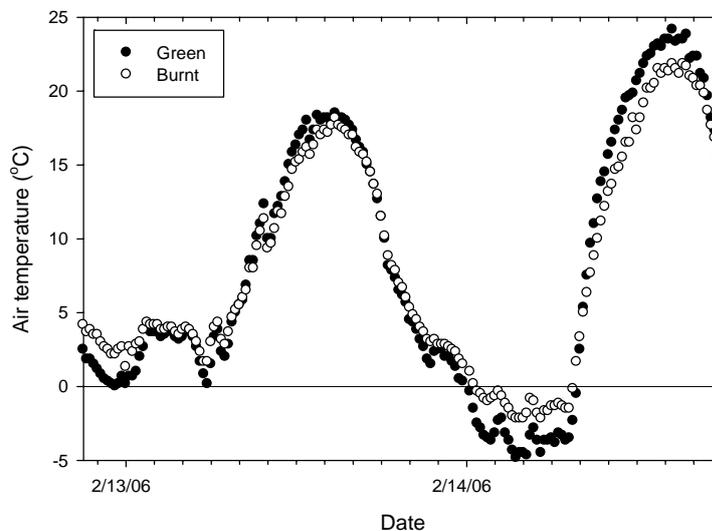


Fig. 3—Air temperatures by harvest management treatment at the Hilliard Brothers, Florida site on February 12–14, 2006. Temperature was monitored at 10-cm height within the row.

The lower minimum air temperatures recorded in green cane are most likely due to trash reflectance leading to lower soil heat flux during the day, and thus less re-radiation of heat from the soil at night in the green cane treatments. This hypothesis would be supported by the higher maximum daytime temperature recorded in green cane for Feb 13 and 14 (Figure 3). To our knowledge, this is the first report of the effect of green cane residue on air temperatures within sugarcane fields.

The freeze events recorded in February, 2006 at the Hilliard Brothers site had a significant effect on tiller populations (Figure 4). Tiller populations in all treatments declined following the freezes, but the green and between-row disking treatments were most severely affected and took the longest to recover. These tiller population data can be explained by the air temperatures which reflect increased number and severity of freeze events when residue was allowed to remain within the row early in the growing season.

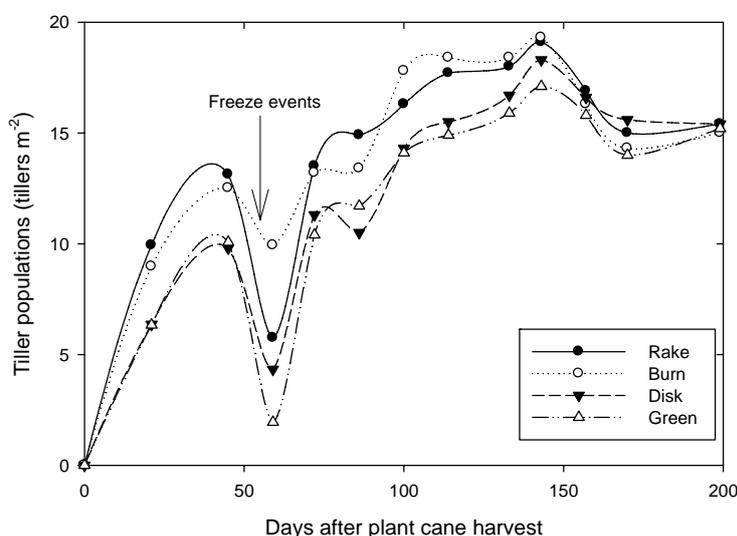


Fig. 4—Tiller population for the different harvest management treatment for the first ratoon crop at the Hilliard Brothers site.

The freeze events recorded in the first ratoon crop led to significantly higher cane (TCH) and sucrose (TSH) yields in burnt cane compared to the other harvest management treatments at the Hilliard Brothers site. However, 3-year cumulative yields across plant cane through to second ratoon crops were not significantly different (Table 3).

**Table 3**—Sugarcane cane yield (cane t/ha; TCH) and sucrose yield (sucrose t/ha; TSH) under different harvest management treatments at the Hilliard Brothers, Florida site.

Treatment	First ratoon early TCH	First ratoon early TSH	3-year cumulative TCH	3-yea cumulative TSH
Burnt	76 a	8.9 a	204	23.0
Rake	71 b	8.1 b	207	22.8
Green	69 b	8.0 b	198	22.1
Disk	69 b	7.9 b	205	22.6
<i>P</i>	0.04	0.008	NS	NS

There was no significant effect on cane yields from harvest management treatments for plant cane or first ratoon at El Viejo, Costa Rica (Figure 5A), although there was a trend ( $P=0.09$ ) towards higher sucrose yields in the first ratoon crop in burnt cane (Figure 5B). Overall, yields were lower across treatments in the first ratoon crop primarily due to flooding of the fields in October, 2008.

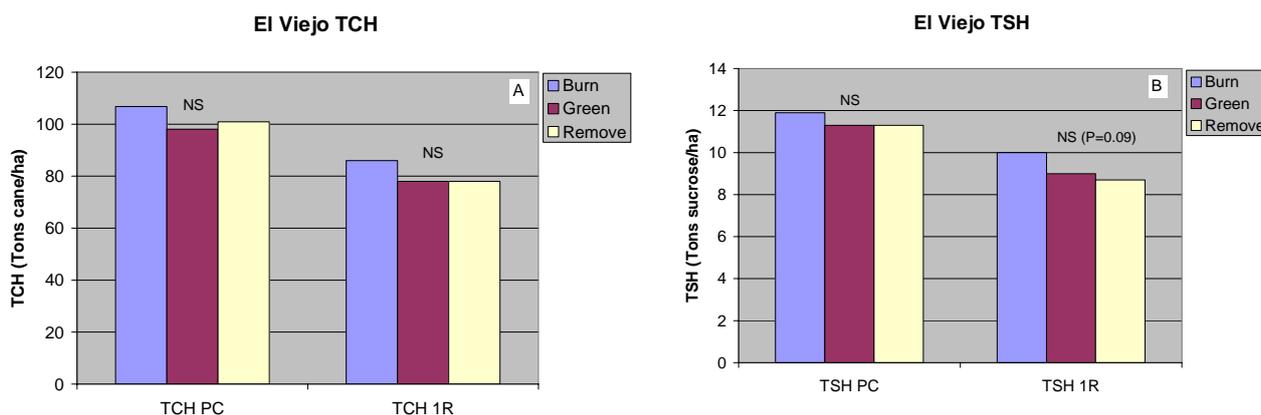


Fig. 5—Cane A) and sucrose B) yield for different harvest management treatments for the plant cane (PC) and first ratoon (1R) crops at the El Viejo, Costa Rica site.

The presence of crop residues also buffered soil temperature at the El Viejo, Costa Rica site. From harvest in March to canopy closure in July, crop residue reduced maximum soil temperatures by 5– 10°C at 2-cm depth (Figure 6A) and by 2–5°C at 10-cm depth (Figure 6B).

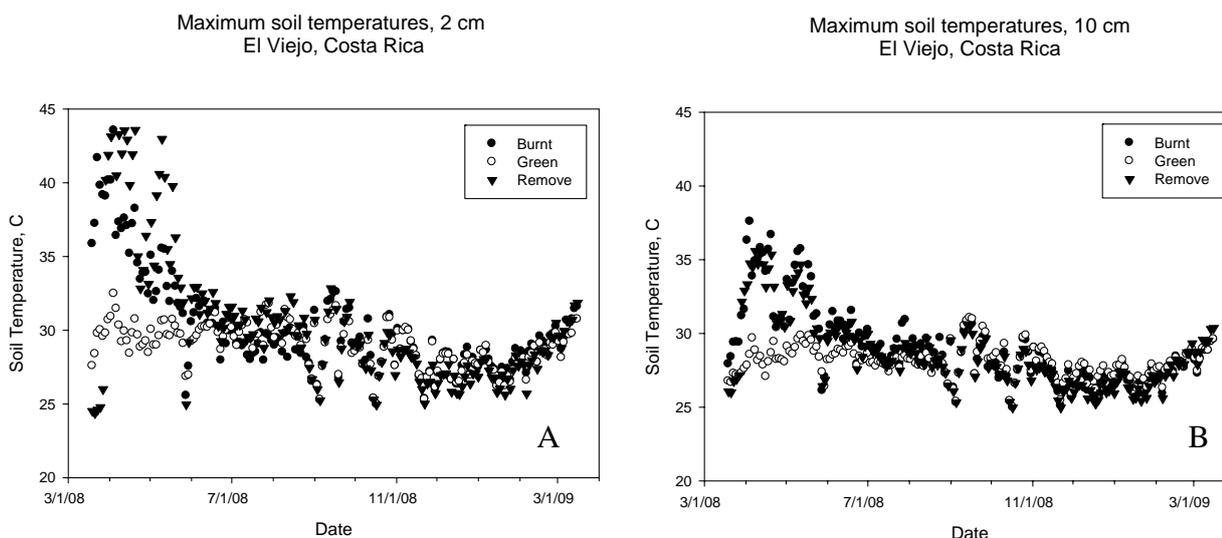


Fig. 6—Daily maximum soil temperatures for different harvest management treatments at 2 (A) and 10-cm depth (B) at the El Viejo, Costa Rica site.

**Conclusions**

Green cane harvest buffered soil temperatures in 3 different soil types (Histosol, Entisol and Inceptisol), and also led to lower air temperatures during freeze events in Florida, indicating significant effect of harvest methods on microclimate. These microclimate effects led to significant reductions in sugarcane tiller populations and plant growth in green *v.* burnt cane following freeze events in Florida. Our results indicated a yield penalty in green cane systems in Florida when harvested early in the season; thus, green cane harvest should be recommended for later harvest periods. In Costa Rica, there were no significant differences in sugarcane growth and yield in green *v.* burnt cane in the plant cane and first ratoon crop.

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## EFFET DE LA MÉTHODE DE RECOLTE SUR LE MICROCLIMAT ET LE RENDEMENT DE LA CANNE À SUCRE EN FLORIDE ET AU COSTA RICA

Par

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**MOTS-CLÉS: Canne Verte, Canne Brûlée, Température du Sol, Résidus de Récolte, Population de Tiges.**

### Résumé

DANS LE MONDE entier, les industries de canne à sucre sont contraintes d'adopter les systèmes de récolte en canne verte qui évitent de brûler la canne. L'objectif de cette étude était de comparer les effets des différentes méthodes de récolte sur la productivité et le microclimat de canne en Floride et au Costa Rica. Les traitements incluaient 1) la canne brûlée, 2) la canne 2 verte et 3) la canne verte avec gestion des résidus. Ces traitements ont été appliqués sur 3 sites : A) au Centre de Recherche et de Formation des Everglades (EREC), Belle Glade, Floride sur un Histosol noir riche en matière organique, B) sur les exploitations Hilliard Brothers, Floride sur un Entisol à texture sableuse, et C) sur l'exploitation de l'usine sucrière EL Viejo, à Guanacaste, Costa Rica sur un Inceptisol argilolimonieux. Les résidus de canne récoltée en vert ont provoqué un effet tampon sur les températures du sol (à 15 cm de profondeur) sur le sol noir organique de Floride. Les cannes brûlées récoltées en début de campagne (Nov.- début Janvier) produisent généralement des rendements plus élevés, avec une différence significative de 22T/ha en cumulé sur 3 ans par rapport à la canne récoltée en vert. Cependant, les rendements ne furent pas différents sur les récoltes de fin de campagne (mi-février–mars). Sur le site sableux de Floride, la diminution de la population de tiges, en particulier sur canne récoltée en vert, fut causée par les gelées de Février 2006. Les températures de l'air à 10 centimètres au dessus de la surface furent inférieures en canne verte durant les gels, ce qui a diminué significativement la population de tiges en canne verte lors de la récolte de la première repousse. Les rendements canne sur sol sableux ont suivi des tendances similaires à ceux sur le sol noir organique avec des rendements plus élevés en canne brûlée pour les récoltes de début de campagne et pas de différence pour les récoltes de fin de campagne. Sur l'Inceptisol du Costa Rica, les teneurs en résidus, les rendements canne et sucre ne furent pas différents entre canne verte et brûlée en canne plantée et repousse. Au Costa Rica, les résidus de récoltes réduisirent les températures maxima du sol de 5 à 10°C pendant 3 mois, de la récolte à la fermeture du couvert. Ces résultats montrent que les résidus de canne verte ont un effet significatif sur le microclimat et que la récolte de la canne en vert en Floride serait plus adaptée en fin plutôt qu'en début de campagne.

## EFFECTO DEL METODO DE COSECHA SOBRE EL MICROCLIMA Y LA PRODUCTIVIDAD DE LA CAÑA DE AZÚCAR EN LA FLORIDA Y COSTA RICA

By

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**PALABRAS CLAVE: Caña Verde, Quema, Temperatura del Suelo, Residuos de Cosecha, Población de Tallos.**

### Resumen

Hay presión sobre la industria azucarera mundial para que se adopten sistemas de cosecha de “caña verde” que no involucren quemado. El objetivo de este estudio fue comparar el efecto de los métodos de cosecha de caña de azúcar de caña sobre la productividad y el microclima en Florida, EE.UU. y Costa Rica. Los tratamientos incluyeron 1) caña quemada, 2) caña verde, y 3) la caña verde con manejo de residuos. Estos tratamientos se establecieron en tres lugares: A) En Everglades Research and Education Center (EREC), Belle Glade, Florida en un Histosol, B) En Hilliard Brothers Farms, Florida, en un Entisol con textura arenosa, y C) Azucarera El Molino Viejo, en Guanacaste, Costa Rica en un Inceptisol franco-arcilloso. El residuo de la caña verde proporcionó un efecto amortiguador de las temperaturas del suelo (15 cm de profundidad) en el suelo pesado de la Florida. Hubo una tendencia a mayor rendimiento de biomasa en la caña quemada con cosecha temprana (noviembre–principios de enero), y una diferencia significativa de 22 t/ha en el acumulado de 3 años favoreciendo los tratamientos de caña quemada *vs* los de caña verde. Sin embargo, los rendimientos de caña no fueron diferentes cuando se cosechó al final de la temporada (mitad de febrero-marzo). En el sitio arenoso de la Florida, la disminución de la población de tallos, particularmente en caña verde, estuvo ligada a heladas que se presentaron en febrero de 2006. Las temperaturas del aire a 10-cm sobre el suelo durante las heladas fueron más bajas en caña verde que en caña quemada, lo que condujo a una significativamente menor población de tallos durante la primera soca de la caña verde. El rendimiento de biomasa de la caña en el suelo arenoso siguió tendencias similares a las de la caña quemada en el suelo pesado registrando mayor rendimiento con cosecha temprana, pero sin diferencias significativas cuando se realizó la cosecha tardía. En el suelo Inceptisol en Costa Rica, el contenido de los residuos, la biomasa y los rendimientos de sacarosa no fueron significativamente diferentes en caña verde *vs*. quemada en la platilla y la primera soca. En Costa Rica, los residuos de caña redujeron las temperaturas máximas del suelo de 5-10 °C durante el periodo de 3 meses que va desde la cosecha hasta el cierre del dosel. Nuestros resultados indican que los residuos de la caña verde tienen un efecto significativo en el microclima y que la cosecha de caña verde en la Florida sería más adecuada para cosecha tardía que temprana.