CHALLENGES OF POST-HARVEST RESIDUE MANAGEMENT IN THE LOUISIANA SUGARCANE INDUSTRY

By

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Abstract

FROM a global perspective, Louisiana's nine-month sugarcane growing season is extremely short. Post-harvest residues can decrease cane yield by 4.5-13.5 t/ha. Studies were implemented in the fall of 1998 to identify the reasons for this yield loss and to assess cultural practices that might mitigate against this loss. Soil moisture and temperature were monitored in a replicated study designed to compare the effects of residue removal through burning or mechanical means, versus a non-removal control. Four commercially popular Louisiana sugarcane cultivars were grown with and without residue to determine differences in tolerance to the residue layer. Date and methods of residue removal were also investigated to determine optimal management practices. During winter months, soil temperatures ranged from 8.4 to 26.0°C (mean = 16.8°C) for the non-removal treatment and from 7.6 to 27.3°C (17.5 average) when residues were removed. Soil moisture ranged from 2.0 to 33.3 kPa (mean = 8.0 kPa) for the non-removal treatment compared to 3.4 to 45.0 kPa (mean = 12.4 kPa) when residues were removed. Most varieties responded similarly to residue conditions. Under the non-removal treatment, sugar yields declined by 0.7 t/ha compared to treatments with a January residue removal event. The effects of mechanical removal proved similar to burning in terms of yield. Sugar yields declined by 1.2 t/ha when residues were burned after January. To avoid yield losses, producers should remove residues in January through either burning or mechanical means. If residues are removed after January, mechanical methods should be used instead of burning. Increased soil moisture and lower soil temperatures associated with a residue cover appear to be related to sugarcane yield losses in Louisiana where excessive, rather than inadequate, moisture is a limiting factor for growth. Residue removal is particularly critical during cold and wet conditions since these environmental factors typically delay the re-emergence of the ratoon crop, which is problematic, given the short Louisiana growing season.

Introduction

Sugarcane (Saccharum spp.) production systems often include preharvest or post-harvest burning strategies to remove leafy biomass residues (Ball-Coelho et al., 1993). However, a number of research studies suggest that biomass residues can be beneficial. Sugarcane residue has been shown to decrease pest populations such as nematodes and weeds (Akhtar, 1993; Samules et al., 1952), while increasing beneficial arthropods such as fire ants (Ali et al., 1986). The residue layer also enhances root development in the upper soil profile, increases soil water retention, and reduces soil compaction (Ball-Coelho et al., 1992; Barzegar et al., 2000; Graham et al., 2002; Juo and Lal, 1977). Ball-Coelho et al. (1993) reported that cane yields increase by 46% when residues are not removed with burning due to increased soil water retention and weed suppression in Brazil.

Long-term studies have demonstrated that greater inputs of organic matter lead to increased benefits from crop residues and cause an increase in the size of the readily decomposable portion of organic matter in the top 10 cm. of soil (Graham et al., 2002). Increased organic matter contents in the soil can also lead to decreased fertiliser requirements (Graham et al., 2002). Furthermore, Ball-Coelho et al. (1993) noted that preharvest burning results in nutrient losses of 17 kg N/ha and 1 kg P/ha due to convection while post-harvest burning results in losses of 42 kg N/ha with negligible P losses. Research in Brazil indicates that green cane harvesting followed by residue retention leads to more efficient recycling of the N applied to the system and therefore reduces fertiliser-N needs (Basanta et al., 2003). However, this improvement in
soil N status often takes several years. Following three years of residue retention, soil organic carbon
increases by 0.13% in the top 15 cm of soil, while available N and P increases by 37 and 10 kg/ha,
respectively. By improving the soil organic carbon status, residue retention also increases N uptake and
recovery of applied N by the crop (Yadav et al., 1994). Green-cane harvest residue retention associated
with reduced or zero tillage offers considerable cost savings for growers due to decreased input costs

Some studies also reveal negative aspects associated with non-removal of residue. If cultivation is
required, residue retention makes this difficult, especially if the cultivation is performed without the
appropriate equipment, and may decrease N, P, and K availability during the season (White and Ayoub,
1983). Waterlogging and N losses have been encountered under the residue layer in wetter climates with
poorly drained clay soils (Wood, 1991). Similar conditions are frequently encountered in the Louisiana
sugarcane industry, and yield losses associated with residue retention have been reported (Richard,
1999). At present, the relationship between crop residue management and its effect on sugarcane yield potential is
not well understood. For this reason, a series of experiments was initiated in the fall of 2000 to investigate
residue management factors that might cause yield losses and also to identify improved cultural practices
that might mitigate these losses.

Materials and methods

Three different experiments were conducted to determine what was causing the yield loss associated
with residue retention and to determine any solutions to this yield loss by either cultural practices or cultivar selection. The specific objectives of these experiments were to determine: a) the effects of
the residue on soil temperature and moisture; b) if currently grown cultivars have different tolerance to the
residue; and c) if timing and method of residue removal influence yields.

Experiment 1: Temperature and moisture

The soil temperature and moisture experiment was initiated in 2003 at the USDA Ardyone farm
near Schriever, LA. Treatments included no-removal (control), removal through burning, and partial
removal from the row top through brushing (mechanical removal). These treatments were replicated six
times in a randomised complete block design. Soil temperature was monitored using Spectrum
Technologies 450 Watchdog temperature sensors. Measurements were taken every 30 minutes throughout
February, March, and April. Soil moisture was recorded concurrently using Spectrum Technologies TDR
100 soil moisture probes with Spectrum Technologies 450 data loggers.

Experiment 2: Cultivar tolerance

Common commercial cultivars, including HoCP 70-321, LCP 85-384, HoCP 85-845, and HoCP
91-555, were assessed for residue tolerance in first-ratoon crops after being harvested in December.
Residue treatments consisted of no-removal (control), mechanical removal from the row top with a garden
rake in January, and removal through burning in January or March. The experimental design was a
randomised complete block with six replications, and the experiment was repeated at two locations. Cane in
each plot was mechanically harvested with a chopper harvester and cane yields (t/ha) were determined
using a wagon equipped with electronic load cells. The weigh wagon also contained a billet sampler
capable of collecting about 10 kg of billets as they were being harvested from the plot rows. The billets
contained in each sample were chipped. A 1000 g subsample was removed and pressed at 17 200 kPa for 2
minutes.

Theoretically recoverible sugar (TRS) levels in the expressed juice were determined using
standard analytical techniques (Mead and Chen, 1977). Sugar yield (t/ha) is the product of cane yield and
TRS levels. Data were analysed with SAS software using PROC GLM with specified error terms as
described in McIntosh (1983). Means of significant effects were separated using Fisher’s Protected LSD at
p ≤ 0.05.

Experiment 3: Removal dates and methods

After a December harvest, cane residues were removed either in March or April through burning,
manual raking, or machine shaving, which is a revolving blade that removes the top 2–3 cm of the row top.
Raking and shaving removed the residues from the row top and placed them in the wheel furrows. A
control (no-removal) was also included. The experimental design consisted of a randomised complete block
with six replications. This experiment was repeated at three locations with first-ratoon crops of either LCP
85-384, LCP 82-089, or HoCP 70-321. Stalk population, height, and weight were recorded at harvest. Plots
were mechanically harvested, billet samples were processed, and data were analysed using the same
procedure as previously described in the cultivar tolerance study.
Results

Temperature and moisture

Soil moisture ranged from 2.0 to 33.3 kPa (mean = 8.0 kPa) in plots with residue compared to 3.0-45.0 kPa (mean=12.4 kPa) in plots without residue (Figure 1). Soil temperatures ranged from 8.4–26.0°C (mean=16.8°C) in plots where residues were not removed and from 7.6–27.3°C (mean=17.5°C) where residues were removed (Figures 2, 3 and 4).

Fig. 1—Effect of sugarcane residue removal method (no removal, burn, and brush) on soil moisture (Feb-April 2003).

Fig. 2—Effect of sugarcane residue removal method (no removal, burn, and brush) on soil temperature (2-1-2003–2-28-2003).
During winter months, the residue layer served as an insulator against cold temperatures. Winter soil temperatures in plots with residues averaged 0.8°C warmer than in plots with no residues. However, this insulation effect also reduced soil warming in the spring, whereby plots with residues reflected average soil temperatures that were 1.3°C cooler than plots with no residues. Slight temperature differences such as these can lead to delayed emergence and slower growth.

The minimum temperature for cane emergence is 18.3°C (Mather, 1941). During the period for cane emergence in Louisiana (February 14–March 31), soil temperatures reached this minimum temperature for 15, 20, and 24 days for the no-removal, burned, and brush treatments, respectively (Figures 2 and 3).
**Cultivar tolerance**

With the exception of HoCP 91-555, all cultivars reflected decreased sugar yields when the residue was not removed in January by either burning or mechanical removal (Table 1). Both removal methods in January resulted in 0.7 t/ha more sugar than the control. Averaged across all cultivars, late residue removal with a March burning event resulted in yield reductions of 0.5 and 1.2 t/ha compared to the control and January residue removals, respectively.

**Table 1—Effect of residue removal method and residue removal date on sugar yield for four commercial cultivars.**

<table>
<thead>
<tr>
<th>Removal method</th>
<th>Removal date</th>
<th>HoCP70-321</th>
<th>LCP85-384</th>
<th>HoCP85-845</th>
<th>HoCP91-555</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>No removal</td>
<td>–</td>
<td>3.7b†‡</td>
<td>6.2b</td>
<td>6.5b</td>
<td>7.4a</td>
<td>5.9b</td>
</tr>
<tr>
<td>Rake</td>
<td>January</td>
<td>4.3a</td>
<td>7.4a</td>
<td>7.2a</td>
<td>7.5a</td>
<td>6.6a</td>
</tr>
<tr>
<td>Burn</td>
<td>January</td>
<td>4.2a</td>
<td>7.4a</td>
<td>6.9a</td>
<td>8.0a</td>
<td>6.6a</td>
</tr>
<tr>
<td>Burn</td>
<td>March</td>
<td>3.7b</td>
<td>6.4b</td>
<td>4.9c</td>
<td>6.4b</td>
<td>5.4c</td>
</tr>
</tbody>
</table>

†Values are means of all six replications for two trials.
‡Means within a column followed by the same letter are not significantly different at $p = 0.05$.

**Removal dates and methods**

There was a significant date of removal by method of removal interaction but the main effect for date of removal was much larger than the interaction. Therefore, the date of removal was pooled over all residue removal methods.

Over all residue removal methods, an earlier residue removal event in March supported increased cane height, stalk weight, cane yield, and sugar yield compared to a later removal event in April (Table 2). March residue removal led to increased cane height (30 mm) and stalk weight (0.11 kg/stalk), although shoot populations were not affected.

Compared to the April residue removal event, the earlier residue removal in March increased cane tonnage by 5.6 t/ha and sugar yield by 0.8 t/ha.

**Table 2—Effect of residue removal date on sugarcane stalk height, population, and height, TRS, and cane and sugar yields.**

<table>
<thead>
<tr>
<th></th>
<th>March</th>
<th>April</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stalk height (m)</td>
<td>2.48a †‡</td>
<td>2.45b</td>
</tr>
<tr>
<td>Stalk pop. (shoots/ha)</td>
<td>89 000a</td>
<td>88 000a</td>
</tr>
<tr>
<td>Stalk weight (kg/stalk)</td>
<td>0.92a</td>
<td>0.81b</td>
</tr>
<tr>
<td>TRS (kg/t)</td>
<td>106a</td>
<td>103a</td>
</tr>
<tr>
<td>Cane yield (t/ha)</td>
<td>82.7a</td>
<td>77.1b</td>
</tr>
<tr>
<td>Sugar yield (t/ha)</td>
<td>8.8a</td>
<td>8.0b</td>
</tr>
</tbody>
</table>

†Values are means of all six replications for three trials.
‡Means within a row within a removal date followed by the same letter are not significantly different at $p=0.05$.

As previously stated, there was a significant date of removal by method of removal interaction. However, since the main effect for residue removal methods was smaller in magnitude than the interaction, the method data are presented separately for each removal date (Table 3).

With the March removal, there were no differences between the control (no removal), raked, shaved, or burned treatments in terms of stalk population, height, and weight and TRS, cane yield, or sugar yield (Table 3). On the other hand, delaying residue removal until April resulted in 2000 fewer shoots/ha where the residue was burned compared to the control. With the April removal event, average stalk weight declined by 0.09 kg/stalk under shaving and burning removal strategies relative to the control. Furthermore,
shaving reduced cane yield and sugar yield by 10.1 and 1.2 t/ha, while burning reduced cane and sugar yield by 9.2 and 1.4 t/ha compared to the control.

Table 3—Removal method effects on stalk height, population, and weight, TRS, and cane and sugar yields.

<table>
<thead>
<tr>
<th></th>
<th>March</th>
<th>April</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>Raked</td>
</tr>
<tr>
<td>Stalk height (m)</td>
<td>2.48 a††</td>
<td>2.50 a</td>
</tr>
<tr>
<td>Stalk pop. (shoots/ha)</td>
<td>87 000 a</td>
<td>91 000 a</td>
</tr>
<tr>
<td>Stalk weight (kg/stalk)</td>
<td>0.94 a</td>
<td>0.92 a</td>
</tr>
<tr>
<td>TRS (kg/t)</td>
<td>107 a</td>
<td>105 a</td>
</tr>
<tr>
<td>Cane yield (t/ha)</td>
<td>83.2 a</td>
<td>85.2 a</td>
</tr>
<tr>
<td>Sugar yield (t/ha)</td>
<td>8.9 a</td>
<td>8.4 a</td>
</tr>
</tbody>
</table>

†Values are means of all six replications for three trials.
‡Means within a row within a removal date followed by the same letter are not significantly different at p = 0.05.

Discussion and conclusions
As hypothesised, the presence of a post-harvest residue blanket resulted in higher soil temperatures during the winter, but cooler temperatures in the spring. This treatment also resulted in increased soil saturation. Mather (1941) reported that the minimum temperature for ratoon cane emergence following harvest was 18.3°C. During the period of cane emergence in Louisiana (February 14–March 31), soil temperatures reached this minimum temperature on 15, 20, and 24 days for the no-removal, burned (complete removal), and brush/raked (partial removal) treatments (Figures 2 and 3).

Both low soil temperature (Zhang et al., 2003) and high soil moisture can reduce plant growth (Glaz et al., 2002) and can also increase cane infection by facultative parasitic soil fungi (Samules et al., 1952). Furthermore, low soil temperatures can reduce sugarcane net assimilation rate (Venkatasamana et al., 1984). It has been previously reported that retention of post-harvest residues can increase soil moisture, decrease soil temperature, and reduce cane yields (Wood, 1991).

Moreover, other research in semi-arid climates showed that full irrigation on fields with post-harvest residue resulted in a substantial yield depression (Gosnell and Lonsdale, 1977). Most currently grown cultivars in Louisiana do not tolerate the environmental conditions created by post-harvest residue. Research in Florida has reported cultivars that appear tolerant to saturated soils (Glaz et al., 2002).

Future research in Louisiana should focus on the development of cultivars that exhibit reduced leafy material at harvest and tolerance to cool, wet soils in the spring.

Early-season (no later than January) residue removal from the row top through either brushing or raking or complete removal of the residue from the field through burning increased sugar yields compared with no removal, consistent with previous reports from other sugarcane growing areas (Samules et al., 1952).

Removal of the material mechanically or by burning in the late winter appears to be the best time to remove the residue in Louisiana, since later burning in the spring (March/April) resulted in decreased cane population, stalk weight, biomass, and sugar yield.

Furthermore, shaving in April also reduced yields due to damage to emerged shoots. Research in Brazil, conducted under conditions with marginal moisture, has shown an increase in cane yield with residue retention due to moisture conservation (Korndörfer et al., 2003).

In Louisiana, increased soil moisture and lower soil temperatures that prevail under the residue blanket during the winter and early spring months are associated with yield loss, where excess rather than inadequate moisture, is a limiting factor for growth.
Removal of the residue at least from the row top above the planted line of sugarcane will be especially critical during cold and wet periods because, in these environmental conditions, the ratoon crop will be slow to re-emerge; a disadvantage, given the short nine-month Louisiana sugarcane growing season.

REFERENCES


DESAFIOS DE LA GESTION DE RESIDUO DE POST-COSECHA EN LA INDUSTRIA DE CAÑA DE AZÚCAR EN LOUISIANA

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PALABRAS CLAVES: Remoción Mecánica, Efectos del Suelo, Cosecha de Caña Verde.

Resumen

Desde una perspectiva global, la estación de crecimiento de caña de azúcar de nueve meses en Louisiana es sumamente corta. Los residuos post-cosecha pueden disminuir el rendimiento de caña de 4.5 - 13.5 t/ha. Se hicieron estudios en el otoño de 1998 para identificar las razones para esta pérdida de rendimiento y evaluar prácticas agrícolas que pudieran mitigar esta pérdida. Fue controlada la humedad y temperatura del suelo en un estudio reproducido, hecho para comparar los efectos de la remoción de residuo a través de quema o de medios mecánicos, contra un control sin remoción. Cuatro variedades de caña de azúcar comercialmente populares de Louisiana se cultivaron con y sin residuo, para determinar las diferencias en la tolerancia a la capa de residuo. También se investigaron la fecha y los métodos de remoción de residuo, para determinar las mejores prácticas de gestión. Durante los meses de invierno, las temperaturas del suelo fueron de 8.4 a 26.0°C (media = 16.8°C) para el tratamiento sin remoción y de 7.6 a 27.3°C (17.5° promedio) cuando se removían los residuos. La humedad del suelo fue de 2.0 a 33.3 kPa (kPa medio = 8.0) para el tratamiento sin remoción comparado a 3.4 a 45.0 kPa (kPa medio = 12.4) cuando se removían los residuos. La mayoría de las variedades respondió semejantemente a las condiciones de residuo. Bajo el tratamiento sin remoción, los rendimientos de azúcar bajaron de 0.7 t/ha comparados a los tratamientos con un evento de remoción de residuos en enero. Los efectos de la remoción mecánica se mostraron similares a quemar, en lo que se refiere al rendimiento. Los rendimientos de azúcar bajaron de 1.2 t/ha cuando se quemaron los residuos, después de enero. Para evitar las pérdidas de rendimiento, los productores deben quitar los residuos en enero a través de quema o de medios mecánicos. Si los residuos se remueven después de enero, deben usarse los métodos mecánicos en lugar de quemarlos. La mayor humedad del suelo y las temperaturas más bajas del suelo, asociadas con una capa de residuo parecen estar relacionadas a las pérdidas de producción de caña de azúcar en Louisiana, donde la humedad excesiva, además de inadecuada, es un factor limitante al crecimiento. La remoción de residuo es particularmente crítica durante las húmedas y frías condiciones, ya que estos factores ambientales típicamente retrasan el rebrote de la cosecha de caña, que es problemática, considerándose la corta estación de cultivo de Louisiana.