Full retention of sugarcane (interspecific hybrids of *Saccharum* spp.) postharvest residue may reduce ratoon crop yields. The objective of this study was to determine the effects of different residue removal timings and methods on sugarcane yield. A two-factor (timing and method) experiment was conducted on both clay and silt loam soils in southeastern Louisiana. Removal timings consisted of the following physiological stages: predormancy, complete dormancy, intermediate dormancy, and postdormancy. Removal methods consisted of partial removal from the row top by mechanical means, complete removal by burning, and no removal (control) applied to first, second, and third ratoons. Sugar yields following burning at predormancy (6800 kg ha⁻¹), complete dormancy (6610 kg ha⁻¹), and mechanical removal at predormancy (6500 kg ha⁻¹) were greater than the control (6190 kg ha⁻¹) for all ratoons. Burning at postdormancy decreased sugar yields by 440 kg ha⁻¹ relative to the control. Ratoons responded similarly to the residue management practices evaluated, and effects were consistent on both clay and silt loam soils. Results show that the residue generated during the green-cane harvesting of sugarcane in Louisiana should be removed from harvested fields as soon after harvest as possible to ensure optimum yields of subsequent ratoon crops.

**Scheme:**

- Full retention of sugarcane postharvest residue may reduce ratoon crop yields.
- The objective of the study was to determine the effects of different residue removal timings and methods on sugarcane yield.
- The study was conducted on clay and silt loam soils in southeastern Louisiana.
- Removal timings included predormancy, complete dormancy, intermediate dormancy, and postdormancy.
- Removal methods included partial removal from the row top by mechanical means, complete removal by burning, and no removal (control).
- Sugar yields following burning at predormancy, complete dormancy, and mechanical removal at predormancy were greater than the control for all ratoons.
- Ratoons responded similarly to the residue management practices evaluated, and effects were consistent on both clay and silt loam soils.
- The residue generated during green-cane harvesting should be removed from harvested fields as soon after harvest as possible.
P increased by 37 and 10 kg ha\(^{-1}\), respectively. By improving the soil organic carbon status, residue retention also increases N uptake and recovery of applied N by the crop, leading to a more efficient recycling of the N applied to the system, and therefore reduces fertilizer-N needs (Basantla et al., 2003).

Some studies, however, revealed negative aspects associated with residue retention. Residue retention makes cultivation difficult and may decrease N, P, and K availability (White and Ayoub, 1983). Monzon (1956) reported reduced cane tillering with residue retention. Moreover, allelochemicals have been reported in sugarcane residue, including 2,4-dihydroxy-1,4-benzoxazin-3-one, 2-benzoxazolinone, 3-(4-hydroxy-3-methoxy-phenyl) prop-2-enolic, 4-hydroxy-3-methoxybenzoic, 4-hydroxy-3,5-dimethoxybenzoic, and benzene carboxylic acids (Sampietro et al., 2006), and some of these substances are autotoxic to sugarcane buds, reducing germination by 30% (Viator et al., 2006). Waterlogging and N losses have been encountered under the residue layer in wetter climates with poorly drained clay soils (Wood, 1991). Waterlogging is frequently encountered in the temperate climate of Louisiana, especially on clay soils, and yield losses associated with residue retention have been reported (Viator et al., 2005a). These yield losses are associated with cool, wet soil conditions, along with autotoxicity during crop emergence and tillering (Viator et al., 2005a, 2006).

The benefits and challenges of residue retention are highly influenced by climate. Most of the benefits from residue retention are in tropical areas where moisture is periodically a limiting factor and where cane is grown for 12 to 24 mo before harvest (Ball-Coelho et al., 1993; Wood et al., 1996). In these climates, crop stresses imposed during the tillering phase have little impact on final yield because of the compensatory ability of the crop due to the long growing season (Robertson et al., 1999). For example, in the tropical climate of Colombia, negative effects of residue retention have been reported, but growth suppression caused by the residue was overcome after 6 mo of growth (Torres and Villegas, 1995). Moreover, in these tropical climates frost damage does not damage the ratoon crop (Lingle, 1999). In contrast, Louisiana often receives excess precipitation for adequate growth, and sugarcane is grown for 7 to 9 mo before harvest, limiting the ability of the crop to overcome early-season stresses.

Louisiana’s temperate climate is unique compared with most other sugar-producing areas. In tropical climates, the sugarcane plant does not undergo a dormant growth stage due to low soil temperatures. In a temperate climate, the crop does reemerge after harvest (predormancy) but is killed due to frost events (Lingle, 1999). The crop remains dormant (complete dormancy) until soil temperatures exceed 18°C (Mongelard and Mimurma, 1972). As soils warm beyond this threshold, primary tillers emerge (intermediate dormancy) and then secondary tillers (postdormancy). Louisiana also has unique cultural practices, such as postharvest burning, because most other industries employ preharvest burning. Postharvest burning is conducted to reduce airborne soot and increase the degree of residue removal relative to preharvest burning. Postharvest burning, though, can also result in increased damage to the ratoon crops especially if conducted after emergence.

Preliminary data in Louisiana indicate that residue retention reduced yields 10 to 20% greater on clay soils than on silt loam soils and that older ratoons are more sensitive to residue retention. It is hypothesized that the extended residue decomposition period (October–March) in the third ratoon may lead to more autotoxic leachates and N immobilization than younger ratoons with shorter decomposition periods. At present, the relationship between crop residue management and the yield potential of subsequent ratoon crops in Louisiana is not well understood. For this reason, an experiment was initiated to investigate postharvest residue management practices in the temperate climate of Louisiana. Experiments were conducted to determine the effects of different removal methods and timings on growth and yield of the subsequent ratoon crop, to determine if residue management effects are consistent across ratoon crops of various ages grown on contrasting soil types, and to determine the rate of residue decomposition during the time period when treatments were applied.

**MATERIALS AND METHODS**

An experiment was initiated in October 2003 on producer fields located within Louisiana’s Barrataria-Terrebonne National Estuary. All fields received similar agronomic inputs throughout the growing season according to Louisiana Cooperative Extension Service recommendations (Legendre, 2001). Second-ratoon, first-ratoon, and plant-cane crops of ‘LCP 85-384’ (Milligan et al., 1994) grown on Sharkey clay (very-fine, montmorillonitic, nonacid, thermic Vertic Hapludalfs) and Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaqupts) soils were harvested in mid-October, November, and December, 2003 and 2004, respectively. LCP 85-384 was planted to 91% of the sugarcane acreage in Louisiana in 2004 (Legendre and Gravois, 2004). Chemical properties of the soils used in this study were previously described (Viator et al., 2006).

The residue generated during harvest was collected by hand from three 1-m\(^2\) row sections from each plot designated for complete removal; this was repeated in plots designated for complete removal until the final removal date to determine percent decomposition. Samples were air-dried for 7 d at 50°C, and dry weight was recorded. Percent decomposition was calculated by dividing the dry weight difference of samples collected at two different dates by the dry weight of samples collected at the first removal date and then multiplying by 100. Residue removal methods consisted of partial removal (mechanical removal of residue from the row top by brushing
to the wheel furrow), complete removal by burning, and no removal (control). Removal timings were conducted at predormancy, complete dormancy, intermediate dormancy, and postdormancy. Plot size was three rows 1.8 m wide by 15.2 m long. All treatments were replicated four times in a randomized complete block design. The two factors were studied as an incomplete factorial design (all method and timing combinations except for the control), and the experiments were conducted in 2003–2004 and 2004–2005.

The response of the subsequent crops to the various residue treatments was assessed by determining yield and yield parameters. Populations of harvestable stalks (>1.4 m) for the entire plot and stalk heights (10 randomly selected stalks per plot) were determined in mid-August. Cane yield (Mg ha⁻¹) was determined by mechanically harvesting plots with a chopper harvester and weighing the harvested stalks with a modified dump field transportation wagon equipped with electronic load cells (Johnson and Richard, 2005). Theoretical recoverable sucrose (TRS) (kg Mg⁻¹) was assessed from a randomly collected billet sample from each plot using the core press method (Johnson and Richard, 2005). Sucrose yield (kg ha⁻¹) was determined by multiplying cane yield by TRS.

Data were initially analyzed with PROC MIXED (SAS Institute, 2001) with year and replications as random variables and soil type, removal method, removal timing, and ratoon age as fixed variables. Data were then analyzed with several different spatial models as described by Bajwa and Mozaffari (2006) to determine if error could be reduced by modeling the spatial covariance within the data. Parallel trend analysis coupled with perpendicular trend analysis was superior to all other models, so all data were analyzed with PROC MIXED with the incorporation of the selected trend analysis. Interactions were analyzed with the LSMEANS SLICE option where every two-factor combination is analyzed separately with its own separate error. Differences between treatment least square means were compared using the Diff option at P < 0.05.

RESULTS AND DISCUSSION

There were no ratoon × residue removal method or ratoon × residue removal time interactions, but there was a residue removal method × time interaction in all measured parameters for the combined first, second, and third ratoons. Theoretical recoverable sugar was increased at predormancy by burning (115 kg Mg⁻¹) and mechanical removal (113 kg Mg⁻¹) compared with the control treatment (113 kg Mg⁻¹) (Table 1). At complete dormancy, burning increased TRS by 2 kg Mg⁻¹ relative to mechanical removal and the control. Burning residue at predormancy and complete dormancy produced higher TRS than all other burn treatments, while burning at intermediate dormancy and postdormancy produced TRS similar to the control. Mechanical removal at predormancy produced higher TRS than all other mechanical removal treatments and the control. Previous research indicated no effects on TRS due to residue management; residue retention affected sugar yield by reducing cane tonnage (Viator et al., 2005a, 2005b). The current study, though, encompassed first, second, and third ratoons on both clay and silt loam soils, and thus better represented typical Louisiana conditions compared with previous studies. Viator et al. (2005a) used only first ratoon and used different varieties from the current study, and the findings of Viator et al. (2005b) were based on 1 yr of preliminary data.

Cane and sugar yield were increased at predormancy by burning (58.1 Mg ha⁻¹ and 6800 kg ha⁻¹) compared with mechanical removal (55.7 Mg ha⁻¹ and 6500 kg ha⁻¹) and the control (54.8 Mg ha⁻¹ and 6190 kg ha⁻¹) (Table 1). Moreover, at complete dormancy burning increased cane yield by 2.1 Mg ha⁻¹ compared with the control and sugar yield by 270 and 420 kg ha⁻¹ relative to mechanical removal and the control, respectively. Hernandez et al. (2003) also reported higher yields with burning than full retention with mechanical removal showing an intermediate response. Mechanical removal may have lowered yields compared with burning because leachates from the residue repositioned into the wheel furrow have been reported to severely suppress cane growth and yield (Lorenzi et al., 1989). On the other hand, in the wet tropics of Australia, mechanical removal was a successful strategy for minimizing this impact

| Table 1. Effects of residue removal timing and method† on theoretical recoverable sugar (TRS), cane yield, and sugar yield (means of first-, second-, and third-ratoon sugarcane grown on both clay and silt loam soils in Louisiana in 2003–2004 and 2004–2005). |
|-----------------|-----------------|-----------------|-----------------|
| Growth stage    | TRS              | Cane yield       | Sugar yield     |
| Predormancy     | Burning          | Mechanical       | Control         | Burning          | Mechanical       | Control         |
|                 | kg Mg⁻¹          | kg Mg⁻¹          | kg ha⁻¹         |                 | kg Mg⁻¹          | kg ha⁻¹         |
| Predormancy     | 115Ag           | 115Aa           | 113b            | 58.1Aa          | 55.7Ab          | 54.8b           |
| Complete dormancy| 115Aa          | 113Bb           | 113b            | 56.9Aa          | 55.8Aab         | 54.8b           |
| Intermediate dormancy | 112Ba       | 113Bb           | 113a            | 54.2Ba          | 52.2Ba          | 54.8a           |
| Postdormancy    | 112Ba           | 113Ba           | 113a            | 51.4Cb          | 53.0Bab         | 54.8a           |
| Control         | 113B            | 113B            | 54.8B           | 54.8AB          | 6190B           | 6190BC          |

†Residue removal methods consisted of partial removal (mechanical removal from the row top to the wheel furrow), complete removal (burning), and no removal (control).

‡Predormancy was defined as the period of fall regrowth between harvest and the first killing frost. Complete, intermediate, and postdormancy were defined as the period of postwinter kill of fall shoots, primary spring shoot emergence, and secondary spring shoot emergence, respectively.

§Means within a column followed by the same uppercase letter or in a row followed by the same lowercase letter are not statistically different using the F probability values and the PROC MIXED diff option at α = 0.05.
of trash retention on cane yield (Kingston et al., 2002), but one must note that this research was conducted where there is a much larger period for crop compensation relative to the current study and that of Hernandez et al. (2003). In other grass crops, such as perennial ryegrass (Lolium perenne L.) and tall fescue (Festuca arundinacea Schreb.), mechanical removal has been reported to be as effective as field burning (Young et al., 1999). Burning at postdormancy decreased cane yields by 3.4 Mg ha$^{-1}$ compared with the control and sugar yield by 290 and 440 kg ha$^{-1}$ relative to mechanical removal and the control, respectively. Burning at postdormancy kills all emerged shoots and has the potential to damage the stubble buds just below the soil surface. Residue burning and mechanical removal at predormancy and complete dormancy increased cane and sugar yield relative to burning or mechanical removal at intermediate dormancy and postdormancy.

Yield results were somewhat reflected in stalk population and height. Stalk population and height were increased at predormancy by burning (119,000 stalks ha$^{-1}$ and 175 cm) and mechanical removal (118,000 stalks ha$^{-1}$ and 175 cm) compared with the control (112,000 stalks ha$^{-1}$ and 171 cm) (Table 2). Kingston et al. (2002) reported smaller stalks with residue retention compared with field burning and that residue retention suppressed bud development and was associated with rotting of stubble from the previous crop. At complete dormancy, mechanical removal was the only removal method that increased stalk population by 4000 stalks ha$^{-1}$ relative to the control, with stalk height being similar across removal methods. At intermediate dormancy and postdormancy, stalk population and height did not differ between removal methods. Within the burn treatments, burning at predormancy produced higher stalk populations and heights than all other treatments, while burning at complete dormancy rather than at postdormancy increased stalk height by 4 cm. Similarly, within the mechanical removal treatments, removal at predormancy and complete dormancy resulted in higher stalk populations than all other treatments. Height was highest when mechanical removal was done during predormancy relative to all other mechanical removal timings, while mechanical removal at complete dormancy increased stalk height by 3 and 4 cm relative to mechanical removal at intermediate dormancy and postdormancy, respectively.

Effects of method and timing of postharvest residue removal were consistent across sugarcane ratoons of various ages. However, if one compares the percent yield loss of the control relative to the average yields of burning at predormancy and complete dormancy and mechanical removal at predormancy (the three treatments that increased yields compared with the control), losses were 6% greater in first and second ratoons relative to third ratoons. These results differ from previous research that indicated older ratoons are more sensitive to postharvest residue retention relative to younger ratoons (Viator et al., 2005b), but these treatment applications were made during intermediate dormancy, which could explain the difference in results compared with the current study. We hypothesized that the extended decomposition period (October–March) for residue in the third-ratoon experiment would lead to more autotoxic leachates and N immobilization than younger ratoons with shorter decomposition periods. However, residue data indicate that decomposition (30–33%) was similar across all ratoons (data not shown). Similar decomposition rates may explain why ratoons responded similarly to different removal methods and timings. Purvis (1990) reported that the inhibitory effects of retained stubble on wheat (Triticum aestivum L.) growth and yield were based on the degree of decomposition that the stubble had undergone before the sowing of the subsequent crop. These wheat residues were phytotoxic only before rain-leaching or decomposition, and decomposed crop stubbles actually stimulated wheat growth. Sturgis (1932) demonstrated that if sugarcane residue were allowed to partially decompose before planting to corn (Zea mays L.), subsequent corn yields were not affected.

In this study, there was no soil type × residue management interaction, indicating that residue management practices were consistent across the two contrasting soil types. Wood (1991) reported that waterlogging and N losses have been encountered under the residue on clay soils in a heavy rainfall climate. One reason for the lack of a soil interaction in the present study may have been that during the period that this experiment was


<table>
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<tr>
<th>Growth stage$^5$</th>
<th>Burnign</th>
<th>Mechanical</th>
<th>Control</th>
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<tbody>
<tr>
<td>Predormancy</td>
<td>119Aa</td>
<td>118Aa</td>
<td>112b</td>
</tr>
<tr>
<td>Dormancy</td>
<td>114Bab</td>
<td>116Aa</td>
<td>112b</td>
</tr>
<tr>
<td>Intermediate dormancy</td>
<td>114Ba</td>
<td>112Ba</td>
<td>112a</td>
</tr>
<tr>
<td>Postdormancy</td>
<td>115Ba</td>
<td>113Ba</td>
<td>112a</td>
</tr>
<tr>
<td>Control</td>
<td>112B</td>
<td>112B</td>
<td>112B</td>
</tr>
</tbody>
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<table>
<thead>
<tr>
<th>Population (1000 stalks ha$^{-1}$)</th>
<th>Burning</th>
<th>Mechanical</th>
<th>Control</th>
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<tbody>
<tr>
<td>Predormancy</td>
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<td>175Aa</td>
<td>171b</td>
</tr>
<tr>
<td>Dormancy</td>
<td>173Ba</td>
<td>173Ba</td>
<td>172a</td>
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<tr>
<td>Intermediate dormancy</td>
<td>171BCa</td>
<td>170Ca</td>
<td>172a</td>
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<tr>
<td>Postdormancy</td>
<td>169Ca</td>
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<tr>
<td>Control</td>
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$^5$Residue removal methods consisted of partial removal (mechanical removal from the row top to the wheel furrow), complete removal (burning), and no removal (control).

$^6$Predormancy was defined as the period of fall regrowth between harvest and the first killing frost. Complete, intermediate, and postdormancy were defined as the period of postwinter kill of fall shoots, primary spring shoot emergence, and secondary spring shoot emergence, respectively.

$^6$Means within a column followed by the same uppercase letter or in a row followed by the same lowercase letter are not statistically different using the F probability values and the PROC MIXED diff option at $\alpha = 0.05$. 

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conducted, rainfall during the first 5 mo of the growth period was 20% below the average of 30-yr historical data (NOAA, 2007). These clay soils, therefore, were not under the normal saturated or near-saturated conditions as they were in the study reported by Wood (1991). Rainfall distribution has been shown to interact with residue’s effects on yields (McIntyre et al., 1996). If one compares the percent yield loss of the control relative to the average yields of burning at predormancy and complete dormancy and mechanical removal at predormancy (the three treatments that increased yields compared with the control), losses were 8% greater on clay soils relative to silt loam soils.

Economic analysis of the marketable product of sugar reflected an increase in gross returns by $260, $180, and $130 ha\(^{-1}\) for burning at predormancy, complete dormancy, and mechanical removal at predormancy, respectively. On the other hand, burning at postdormancy actually decreased yields relative to the control and decreased gross returns by $200 ha\(^{-1}\).

CONCLUSIONS

Results suggest that the residue generated during the green-cane harvesting of sugarcane in Louisiana should be removed from harvested fields as soon after harvest as possible to ensure optimum yields of subsequent ratoon crops. Moreover, removal after complete dormancy results in lower yields than the control (no residue removal).

Acknowledgments

The authors would like to thank the American Sugarcane League and the Terrebonne-Barataria National Estuary Program for financial support to conduct this research.

References


