Dynamics of sugar cane harvest residue decomposition

Patricia A. Digonzelli*, J. Fernández de Ullivarr*, Mercedes Medina*, Laura Tortora*, Eduardo R. Romero* and Hugo Rojas Quinteros**

ABSTRACT

After green cane harvesting, between 6 and 30 tons of dry matter per hectare of trash remains in the field. The aim of this paper was to evaluate the dynamics of sugarcane residue decomposition, and to study nutrient release from harvest residue. The trial was conducted in Tucumán-Argentina. The soil was a typical Haplustol. Sugarcane varieties LCP 85-384 and RA 87-3 were used in the trial, which lasted from 2008 to 2012. Every 25-35 days we evaluated: 1) quantity of residue (fresh weight and dry weight), and 2) C/N ratio in the residue. Besides, at the beginning and end of each cycle we evaluated P and K contents in the residue. In the four crop cycles considered (ratoon 1 to ratoon 4), the amount of residue left on the ground, expressed as tons of dry matter per hectare, was high. In LCP 85-384, initial trash amount ranged from 11.6 t/ha (ratoon 3) to 15.2 t/ha (ratoon 2), whereas decomposition percentages varied between 43% and 59% in a period of 260 to 323 days. In RA-87-3 initial trash amount ranged from 12.5 t/ha (ratoon 4) to 18.1 t/ha (ratoon 1), with decomposition percentages between 36% and 60% for a period of 194 to 323 days. In general, fresh residue C/N ratios were high (over 60). Initial C/N ratio varied among the following values: 79.2 (2008/2009), 77.4 (2009/2010) and 68.8 (2010/2011), and 93.5 (2008/2009), 102.9 (2009/2010) and 60.5 (2010/2011) for LCP 85-384 and RA 87-3, respectively. Final C/N ratio ranged from 30.8 (2010/2011) to 31.9 (2008/2009) and 39.3 (2009/2010) for LCP 85-384, and from 29.9 (2010/2011) to 33.9 (2008/2009) and 43.4 (2009/2010) for RA 87-3. This represented a reduction in at least 50% in all situations studied. Trash initial C concentration, expressed as percentage of dry matter, amounted to values between 42% and 45.5%, and between 38.8% and 47.5% in LCP 85-384 and RA 87-3, respectively. Residue initial N concentration varied between 0.53% and 0.71% and between 0.43% and 0.66% in LCP 85-384 and RA 87-3, respectively. As expected, N contents were more variable than C contents. Trash final C and N concentrations ranged from 30.4% to 33.2% and from 0.84% to 1.00% in LCP 85-384, whereas these values varied from 27.8% to 34.5% and from 0.82% to 1.1% in RA 87-3. Residue initial P concentrations reached 0.05% and 0.07% in LCP 85-384, and 0.06% and 0.1% in RA 87-3. Final P concentration ranged from 0.06% to 0.08% in both varieties. Residue initial K concentrations were between 0.64% and 0.75% for LCP 85-384, and between 0.56% and 0.67% for RA 87-3, respectively. Final K concentration varied from 0.09% to 0.19% and from 0.11% and 0.19% for LCP 85-384 and RA 87-3, respectively. K release values were high, whereas P ones were generally low.

Key words: sustainability, trash blanketing, residue decomposition.

RESUMEN

Dinámica de la descomposición del residuo de cosecha de la caña de azúcar

En este trabajo se estudió la dinámica de descomposición y la liberación de nutrientes del residuo de cosecha de la caña de azúcar. El ensayo se realizó en Tucumán-Argentina entre 2008 y 2012. Los cultivares empleados fueron LCP 85-384 y RA 87-3. Cada 25-35 días se determinó: 1) peso fresco y seco del residuo y b) relación C/N del residuo. Al inicio y fin de ciclo se evaluó el contenido de P y K del residuo. En el ciclo de evaluación (rañado 1 al rañado 4), la cantidad de residuo que quedó en el campo, expresado en toneladas de residuo por hectárea, fue alta. En LCP 85-384, la cantidad inicial de residuo varió entre 11.6 t/ha (rañado 3) y 15.2 t/ha (rañado 2), mientras que la descomposición varió entre 43% y 59% en un periodo de 260 a 323 días. En RA 87-3, la cantidad inicial de residuo varió entre 12.5 t/ha (rañado 4) y 18.1 t/ha (rañado 1), con descomposiciones entre 36% y 60% para un periodo de 194 a 323 días. En general, los valores de relación C/N del residuo fueron altos (más de 60). En general, los valores de relación C/N del residuo fueron altos (más de 60). La relación C/N inicial del residuo varió entre 79.2 (2008/2009), 77.4 (2009/2010) y 68.8 (2010/2011) para LCP 85-384, y 93.5 (2008/2009), 102.9 (2009/2010) y 60.5 (2010/2011) para RA 87-3, respectivamente. La relación C/N final varió entre 30.8 (2010/2011) y 31.9 (2008/2009) para LCP 85-384 y 39.3 (2009/2010) para RA 87-3. Esto representó una reducción en al menos 50% en todas las situaciones estudiadas. La concentración inicial de C, expresada como porcentaje de materia seca, varió entre 42% y 45.5%, y entre 38.8% y 47.5% para LCP 85-384 y RA 87-3, respectivamente. La concentración inicial de N varió entre 0.53% y 0.71% y entre 0.43% y 0.66% para LCP 85-384 y RA 87-3, respectivamente. Como se esperaba, los valores de N fueron más variables que los de C. La concentración final de C y N varió entre 30.4% y 33.2% para LCP 85-384, y entre 0.84% y 1.00% para RA 87-3. La concentración final de P varió entre 0.05% y 0.07% para LCP 85-384, y entre 0.06% y 0.1% para RA 87-3. La concentración final de K varió entre 0.64% y 0.75% para LCP 85-384, y entre 0.56% y 0.67% para RA 87-3, respectivamente. La liberación de K fue alta, mientras que la de P fue generalmente baja.

Palabras clave: sostenibilidad, caña verde, descomposición del residuo agrícola de cosecha.
INTRODUCTION

The need to implement more sustainable production systems led to adopting green cane harvesting. When sugar cane is harvested without burning, a significant residue amount remains in the field (7-30 t dry matter/ha) (Thorburn et al., 2001; Robertson and Thorburn, 2007; Romero et al. 2009 and Digonzelli et al., 2011). This residue can be kept over the soil as mulch, which can be incorporated in the most superficial layers of the soil profile or removed from the field by baling it.

Preserving crop residue as a blanket in the field has important consequences, which include the following: organic matter content and soil structural stability are increased, as well as nutrient cycling levels and soil moisture conservation; water infiltration rates are improved and erosion and weed populations are diminished, in contrast to what happens with populations of beneficial microorganisms, which grow (Wood, 1991; Prove et al., 1995, Graham et al., 1999; Braunack and Ainslie, 2001; Graham et al., 2002; Thorburn et al., 2004; Kingston et al., 2005; Souza et al., 2005; Meier et al., 2006; Núñez and Engels, 2007; Romero et al., 2007 and Sanzano et al., 2009).

This work is part of a study that compared two sugarcane management systems: 1) maintaining residue cover on the ground and 2) eliminating residue. The purpose of this study was to analyze crop residue decomposition dynamics under green sugar cane management and nutrient release from this residue in two sugarcane varieties, throughout the 2008/2011 period.

MATERIALS AND METHODS

The trial was conducted on a farm in Leales department, Tucumán, Argentina (27º14'18" and 65º12'57" W), between years 2008 and 2012. Soil was a silt loam typical Haplustol, artificially drained.

Cultivars used were LCP 85-384 (cultivated in 76.65% of the sugarcane area in Tucumán) and RA 87-3 (planted in 5.64% of this area) (Ostengo et al., 2012).

During the 2008/2009, 2009/2010, 2010/2011 and 2011/2012 growing seasons, amount of residue (fresh and dry weight) was evaluated every 25 to 35 days. Residue C/N ratio was also determined with that periodicity, but only during the 2008/2009, 2009/2010 and 2010/2011 seasons. Organic carbon was determined by using the Walkley and Black method, while overall N was estimated with The Kjeldahl method. Results for 2011/2012 are still being processed.

At the beginning and end of each crop cycle, residue P and K contents were determined by means of the colorimetric method and photometry, respectively.

The experimental design was a completely randomized block with four replications. Each experimental plot consisted of five 10 m long rows.

For statistical analysis, an ANOVA with fixed effects was used, and comparisons of means were performed by using the LSD Fisher test with a 5% probability.

RESULTS AND DISCUSSION

Residue amount

Tables 1 and 2 show initial and final sugar cane crop residue amounts under green cane management, as well as residue decomposition rate for the two varieties in each cycle considered.

Tables 1 and 2 show that the initial amount of residue left on the ground was high in every year considered. RA 87-3 left a significantly higher amount of residue than LCP 85-384 (15.43 t/ha vs. 13.11 t/ha), considering the overall average of the four cycles evaluated.

When analyzing the behavior of both cultivars, initial LCP 85-384 residue amount was higher only when comparing 2009/2010 and 2010/2011 seasons. No significant differences were found between the other analyzed cycles.

On the other hand, initial amount of RA 87-3 residue was significantly lower in 2011/2012 as compared to amounts recorded in 2008/2009 and 2010/2011. During all the cycles analyzed, residue amount decreased significantly from the beginning to the end of the season in both varieties.

According to numerous studies, the amount of residue remaining in the field after sugarcane green residue is important for soil fertility, water infiltration, and erosion control.


<table>
<thead>
<tr>
<th>Sugar cane residue (dry matter, t/ha)</th>
<th>Crop cycle</th>
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<tbody>
<tr>
<td></td>
<td>2008/09</td>
</tr>
<tr>
<td>Initial amount</td>
<td>13.34bc</td>
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<tr>
<td>Final amount</td>
<td>5.47a</td>
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<tr>
<td>Amount decomposed</td>
<td>7.87</td>
</tr>
<tr>
<td>Decomposition percentage</td>
<td>59%</td>
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</tbody>
</table>

Different letters indicate significant differences ($p <= 0.05$).
harvest varies from 6 to 30 tons of dry matter/ha. The amount of residue found in this study was similar to those reported by Núñez and Spaans (2007) and Robertson and Thorburn (2007) for Ecuador and Australia, respectively. In Tucumán, Romero et al. (2009) reported between 7 and 16 tons of dry matter/ha depending on variety and cane production level. The decomposition rates found in this study varied between 35% and 60%. Other international studies reported residue decomposition percentages that ranged between 22% and 98% (Oliveira et al., 2002; Robertson and Thorburn, 2007). In Tucumán, Digonzelli et al. (2011) reported 54% to 64% decomposition rates.

Figure 1 shows LCP 85-384 residue decomposition evolution, evaluated throughout four cycles. The cycles were completed in 285, 260, 301 and 323 days, respectively.

Figure 2 shows RA 87-3 residue decomposition evolution during the four evaluated cycles. However, in the first two cycles evaluated (2008/2009 and 2009/2010), cane of this variety underwent lodging after 195 and 194 days, respectively, so evaluations of residue amount per hectare could not continue up to the end of the cycle. By contrast, assessment could be successfully completed in the 2010/2011 and 2011/12 seasons.

C/N ratio
Tables 3 and 4 show residue C/N ratio immediately after harvesting, and at the end of each season under consideration.

C/N ratio of sugar cane residue accumulated immediately after harvest was high and ranged between 69 and 80 for LCP 85-384, without significant differences among the cycles considered.

For RA 87-3, C/N ratio varied between 103 and 60, and the value obtained in the 2010/2011 cycle (60.48) was significantly lower than those obtained in the 2008/2009

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<td></td>
<td>2008/09</td>
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Different letters indicate significant differences ($p \leq 0.05$).
and 2009/2010 cycles (93.50 and 102.95, respectively). The C/N ratio values observed in all the cases indicated that residue decomposition process was slow.

After each agricultural cycle considered, there was a significant reduction in the C/N ratio due to residue mineralization.

Figures 3 and 4 show the evolution of the C/N ratio in the three cycles considered, for both varieties.

**C and N contents**

Initial residue C concentration levels were similar in both varieties in all the cycles tested, and ranged between 39% and 47% (% dry matter).

By contrast, initial residue N concentration was more variable and its value varied from 0.4% to 0.7%. This behavior was expected, since green cane harvesting residue is composed of varying proportions of green and

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**Figure 2.** Evolution of RA 87-3 residue amount during the four cycles evaluated. Tucumán, Argentina.

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<thead>
<tr>
<th>Residue C/N ratio</th>
<th>Crop cycle</th>
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<tbody>
<tr>
<td></td>
<td>2008/09</td>
</tr>
<tr>
<td>Initial C/N ratio</td>
<td>79.2a</td>
</tr>
<tr>
<td>Final C/N ratio</td>
<td>31.92b</td>
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<tr>
<td>Reduction percentage</td>
<td>59.7%</td>
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</table>

Different letters indicate significant differences (p <= 0.05).

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<th>Crop cycle</th>
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<tr>
<td></td>
<td>2008/09</td>
</tr>
<tr>
<td>Initial C/N ratio</td>
<td>93.50c</td>
</tr>
<tr>
<td>Final C/N ratio</td>
<td>33.92a</td>
</tr>
<tr>
<td>Reduction percentage</td>
<td>63.72%</td>
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</table>

Different letters indicate significant differences (p <= 0.05).
dry leaves, and tops, which in turn have different N contents. In Figures 5 and 6, initial and final C and N contents for the two varieties and three cycles considered in this study are shown.

At the end of each growing season considered in this work, residue C content, expressed as % dry matter, decreased significantly in both varieties, except for RA 87-3 in the 2010/2011 cycle, where C content suffered a fall, but of no statistical significance.

Likewise, residue N content percentage increased significantly at the end of each growing cycle, and this applied to both varieties.
A similar behavior has been reported for residues from other crops, such as maize and sorghum (Morón, 2000 and Ernst et al., 2002), which have high C/N relationships. In the case of sugar cane residues, similar results were reported by Digonzelli et al. (2011).

In residues with high C/N ratios, an N immobilization process is triggered by the action of microorganisms, especially fungi. Thus, residue N concentration increases during its decomposition, due to residue weight loss and N immobilization by soil microorganisms. Furthermore, in residues with high C/N relationships, N is released more slowly than C during the decomposition process, so N concentration increases as the process develops.

In the short term, sugarcane trash is an N source of...
slow availability for the crop. However, in the long term, trash retention improves soil N fertility.

Figures 7 and 8 show residue N content evolution expressed as % dry matter, for the two tested varieties and the three growing cycles considered.

Therefore C/N ratio decrease observed in all the cycles is the result of the decrease in C concentration and the increase in N concentration in this type of residue.

Considering residue amount and C content (% dry matter), Tables 5 and 6 were designed to show initial and final residue C contents (kg/ha), and the contribution of C to the agro-ecosystem caused by the decomposition of LCP 85-384 and RA 87-3 residues, in the three cycles under evaluation.

In Tucumán, Digonzelli et al (2011) found that in the case of LCP 85-384, residue supplied the agroecosystem with 3796 kg to 5730 kg of C/ha in two different growing cycles.

![Figure 7](image1.png)

Figure 7. N concentration (% dry matter) evolution in LCP 85-384 residue throughout the three evaluated crop cycles. Tucumán, Argentina.

![Figure 8](image2.png)

Figure 8. N concentration (% dry matter) evolution in RA 87-3 residue throughout the three evaluated crop cycles. Tucumán, Argentina.
In Australia, Robertson and Thorburn (2007) found that this contribution ranged between 3000 kg and 5000 kg of C/ha, which implies a release of 84% to 98% of the original C contents of the residue.

In Brazil, Oliveira et al. (2002) found contributions of 6260 kg of C/ha at the beginning of the cycle and 3640 kg of C/ha at its close, which equaled to a total contribution of 41.8% of residue original C.

In relation to N, amounts contributed by LCP 85-384 residue were 14.33 kg N/ha, 23.38 kg N/ha and 20.80 kg N/ha, in the 2008/2009, 2009/2010 and 2010/2011 seasons, respectively. Original residue N was released at the following rates: 21.38%, 25.69% and 25.18%, during the three seasons, respectively.

In the case of RA 87-3, lodging occurred in the first two cycles, so evaluations could only be made during a 195-day-period in 2008/2009 and a 194-day-period in 2009/2010. In these two cycles, N was not supplied for the agroecosystem. This could be explained by the correlation between residue decomposition and the days that elapsed since harvest, as reported by Thorburn et al., 2001, Robertson and Thorburn, 2007 and Digonzelli et al., 2011.

By contrast, the 2010/2011 cycle could be evaluated until its end, and in this case there was a 39.39 kg/ha N contribution, which implied the release of 36.2% of the original N contents of the residue. Digonzelli et al. (2011) obtained release values of 13% and 56% of the original N contents of the residue in two different growing cycles.

In Brazil, Oliveira et al. (2002) found initial values of 64 kg of N/ha in the residue and final values of 53 kg of N/ha, which represented a contribution of approximately 19.7% of original residue N contents, amounts similar to those reported in the present work.

### Residue P and K contents

Figure 9 shows initial and final residue P contents, expressed as percentage of dry matter, for the three cycles evaluated. It is observed that residue P content levels were generally similar at the beginning and end of each cycle, except in the 2008/2009 season for LCP 85-384, and in the 2010/2011 season for RA 87-3. There were no significant differences in P contents between the two varieties in all the cycles studied.

In Australia, Spain and Hodgen (1994) found initial and final P values of 0.04 in residues, and Digonzelli et al. (2011) indicated initial and final sugarcane residue values that ranged between 0.05 and 0.06%.

In Tables 7 and 8, initial and final P contents (kg/ha) in LCP 85-384 and RA 87-3 residues, and the contribution of this nutrient to the agroecosystem at the end of each studied cycle are shown.

In the case of RA 87-3, the 2008/2009 and 2009/2010 crop seasons were cut short after 195 and 194 days, respectively, since cane lodging interrupted assessments.

Figure 10 shows initial and final residue K contents, expressed as % dry matter, for the three cycles under evaluation. In the case of both varieties, there was a significant decrease in K content in the residues towards the end of the three analyzed seasons.

Tables 9 and 10 show initial and final K contents (kg/ha) in LCP 85-384 and RA 87-3 residues, and the contribution of this nutrient to the agroecosystem at the end of each season.

High K release levels observed in this study are explained by the fact that this element is present in ionic form in cells and not forming compounds, so it is quickly

### Table 5. Initial and final C contents (kg/ha) in LCP 85-384 residues, and the contribution of this nutrient to the agroecosystem at the end of each crop season. Tucumán, Argentina.

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<tbody>
<tr>
<td>Initial C content (kg/ha)</td>
<td>5287.24</td>
<td>6823.23</td>
<td>5300.49</td>
</tr>
<tr>
<td>Final C content (kg/ha)</td>
<td>1664.76</td>
<td>2662.51</td>
<td>1906.24</td>
</tr>
<tr>
<td>Reduction percentage (%)</td>
<td>68.51</td>
<td>60.98</td>
<td>64.04</td>
</tr>
<tr>
<td>Contribution to the agro-ecosystem (kg/ha)</td>
<td>3622.48</td>
<td>4160.72</td>
<td>3394.26</td>
</tr>
</tbody>
</table>

### Table 6. Initial and final C content (kg/ha) in RA 87-3 residues, and the contribution of this nutrient to the agroecosystem at the end of each crop season. Tucumán, Argentina.

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<tbody>
<tr>
<td>Initial C content (kg/ha)</td>
<td>5842.30</td>
<td>6364.59</td>
<td>6404.43</td>
</tr>
<tr>
<td>Final C content (kg/ha)</td>
<td>2455.87</td>
<td>2767.36</td>
<td>2061.24</td>
</tr>
<tr>
<td>Reduction percentage (%)</td>
<td>57.96</td>
<td>56.52</td>
<td>67.82</td>
</tr>
<tr>
<td>Contribution to the agro-ecosystem (kg/ha)</td>
<td>3386.42</td>
<td>3597.23</td>
<td>4343.18</td>
</tr>
</tbody>
</table>
Sugar cane residue descomposition

released when cell membranes break up.

K release from sugarcane residue constitutes an effective contribution of this nutrient, in an amount that ranges between 74 kg and 80 kg of nutrient/ha.

**CONCLUSIONS**

The amount of residue left in the field after sugarcane green cane harvesting was high, but decreased significantly throughout the growing season, facilitating its management in the field.

Sugarcane residue presented a high C/N ratio, which indicated that the residue was decomposed slowly. C/N ratio decreased significantly along the season, as a result of the reduction in C content (% dry matter) and the increase in N content in the residue, during its decomposition process.

Crop residue decomposition under green cane management contributed between 3400 kg and 4400 kg of C/ha to the agroecosystem, depending on the variety and the season under consideration.

Residue left after sugar cane harvesting also
supplies the agroecosystem with varying N and K amounts, which may bring about beneficial consequences and help meet fertilization needs in the medium term. P can also be provided by this type of residue, though in small quantities.

**CITED REFERENCES**


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