ISSN 0370-5404
TRABAJO YA PUBLICADO

Rev. Ind. y Agríc. de Tucumán
Tomo 92 (1): 39-49; 2015

Dynamics of sugar cane harvest residue decomposition

Patricia A. Digonzelli*, J. Fernández de Ullivarri*, 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. Para LCP 85-384 la cantidad inicial de residuo varió entre 11,6 y 15, 2 t/ha y la tasa de descomposición estuvo entre 43% y 59%. Para RA 87-3 la cantidad inicial de residuo estuvo entre 12,5 y 18,2 t/ha, con porcentajes de descomposición entre 36% y 60%. La relación C/N inicial del residuo fue alta, pero decreció significativamente durante cada ciclo agrícola. Los valores más elevados fueron 79,2, para LCP 85-384 (2008/09) y 102,9 para RA 87-3 (2009/10). La concentración inicial de C del residuo varió entre 42% y 45,5% y entre 38,8% y 47,5% para LCP 85-384 y RA 87-3. La concentración inicial de N estuvo entre 0,53% y 0,71% y 0,43% y 0,66% para LCP 85-384 y RA 87-3. La concentración de C decreció y la de N aumentó durante el transcurso de cada ciclo. El contenido de P del residuo no varió entre inicio y final de ciclo. El contenido inicial de K estuvo entre 0,64% y 0,75% (LCP 85-384) y entre 0,56% y 0,67% (RA 87-3). La liberación de K del residuo fue elevada. La cantidad de residuo que quedó después de la cosecha y la relación C/N del mismo fueron altas, pero ambas decrecieron significativamente durante el ciclo agrícola. La descomposición del residuo aportó cantidades variables de C, N y K, lo cual puede modificar las necesidades de fertilizantes en el mediano plazo.

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

Paper presented at the XXVIII Congress of the International Society of Sugar Cane Technologists, Sao Paulo, Brazil, 24-27 June 2013 and published here with the agreement of the Society.

*Sección Caña de Azúcar, EEAOC. pdigonzelli@eeaoc.org.ar
**Sección Suelos y Nutrición Vegetal, EEAOC.

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

Table 1. Initial and final LCP 85-384 residue amounts, decomposed residue and decomposition percentage in the 2008/2009, 2009/2010, 2010/2011 and 2011/2012 crop cycles. Tucumán, Argentina.

Sugar cane residue (dry matter, t/ha)	Crop cycle			
	2008/09	2009/10	2010/11	2011/12
Initial amount	13.34bc	15.17c	11.64b	12.27bc
Final amount	5.47a	8.03a	6.08a	6.96a
Amount decomposed	7.87	7.14	5.56	5.31
Decomposition percentage	59%	47.1%	47.8%	43.3%

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

Table 2. Initial and final RA 87-3 residue amounts, decomposed residue and decomposition percentage in the 2008/2009, 2009/2010, 2010/2011 and 2011/2012 crop cycles. Tucumán, Argentina.

Sugar cane residue (dry matter, t/ha)	Crop cycle			
	2008/09	2009/10	2010/11	2011/12
Initial amount	18.06f	14.70de	16.49ef	12.47cd
Final amount	7.92ab	9.48bc	6.50ab	5.46a
Amount decomposed	10.14	5.22	9.99	7.01
Decomposition percentage	56.2%	35.5%	60,60%	56.2%

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

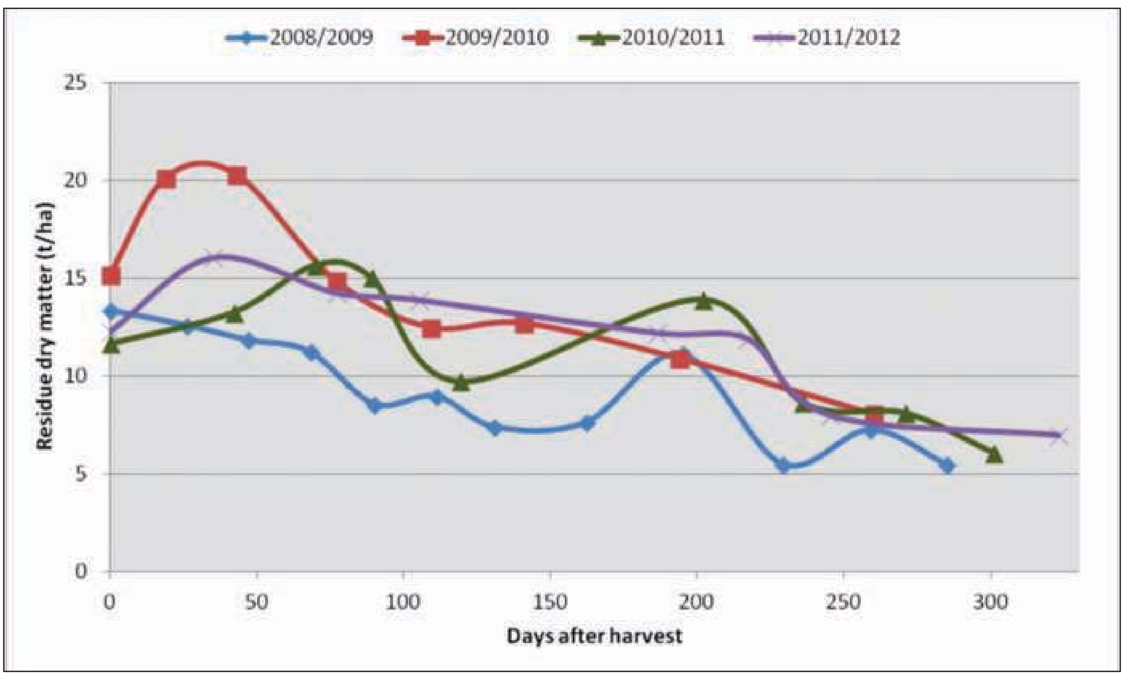

Figure 1. Evolution of LCP 85-384 residue amount during the four evaluated cycles. Tucumán, Argentina.

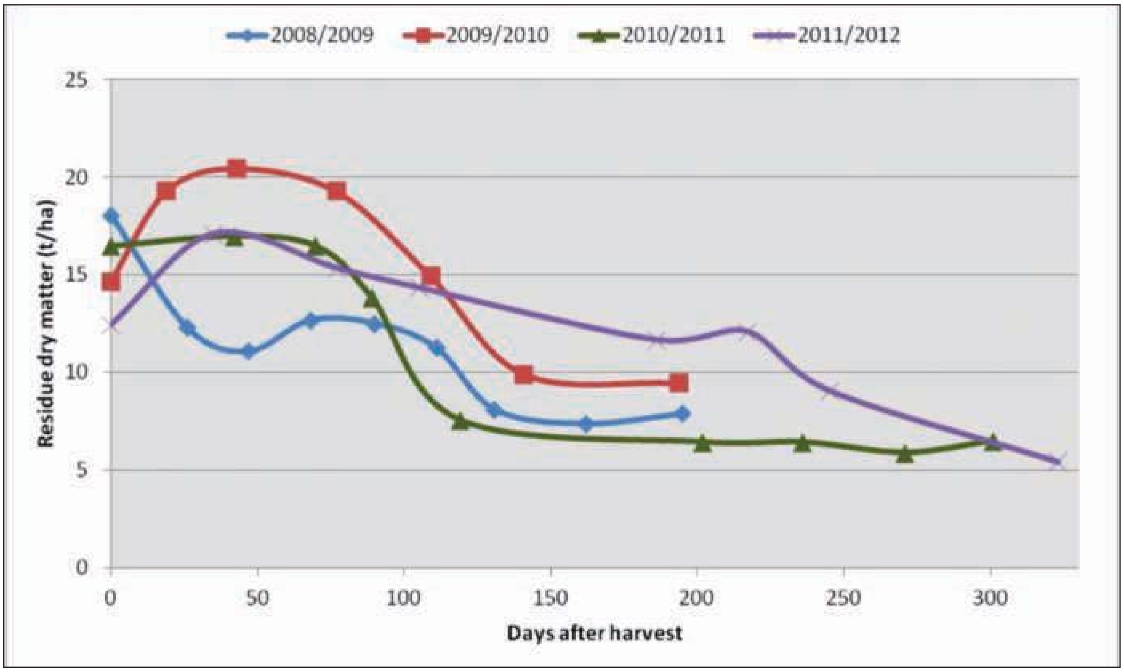

Figure 2. Evolution of RA 87-3 residue amount during the four cycles evaluated. Tucumán, Argentina.

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

Table 3. Initial and final residue C/N ratios and C/N ratio reduction percentages in 2008/2009, 2009/2010 and 2010/2011 crop cycles, for LCP 85-384 variety. Tucumán, Argentina.

Residue C/N ratio	Crop cycle		
	2008/09	2009/10	2010/11
Initial C/N ratio	79.2a	77.40a	68,75a
Final C/N ratio	31.92b	39.28b	30.85b
Reduction percentage	59.7%	49.25%	55.13%

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

Table 4. Initial and final residue C/N ratios and C/N ratio reduction percentages in 2008/2009, 2009/2010 and 2010/2011 crop cycles, for RA 87-3 variety. Tucumán, Argentina.

Residue C/N ratio	Crop cycle		
	2008/09	2009/10	2010/11
Initial C/N ratio	93.50c	102.95c	60.48b
Final C/N ratio	33.92a	43.45ab	29.92a
Reduction percentage	63.72%	57.8%	50.53%

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

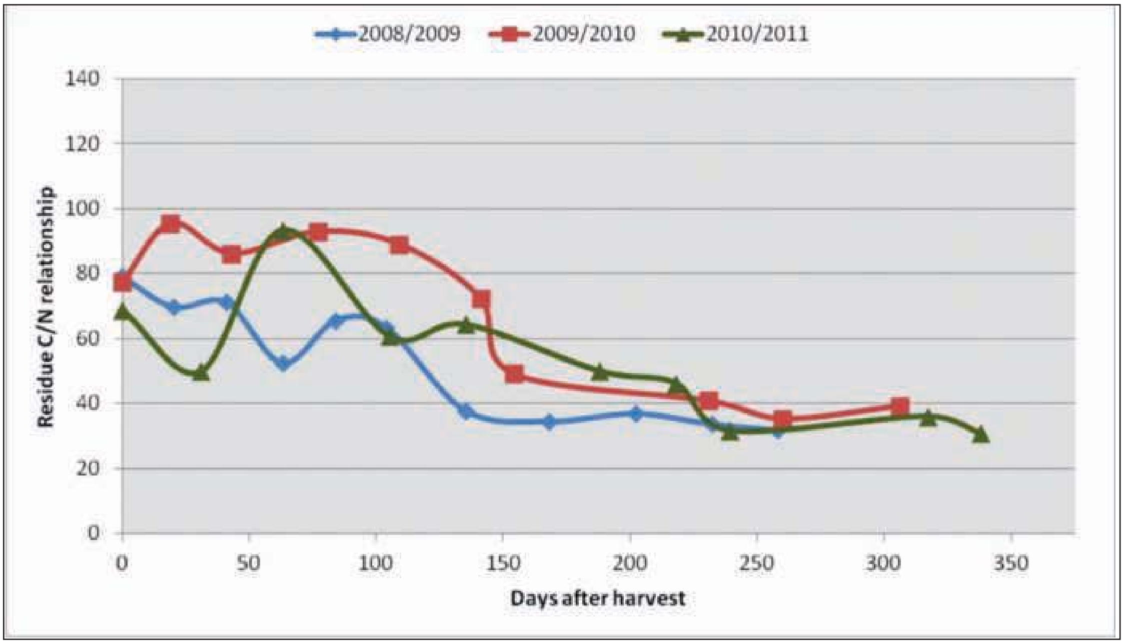

Figure 3. Evolution of LCP 85-384 residue C/N ratio in the 2008/2009, 2009/2010 and 2010/11 cycles. Tucumán, Argentina.

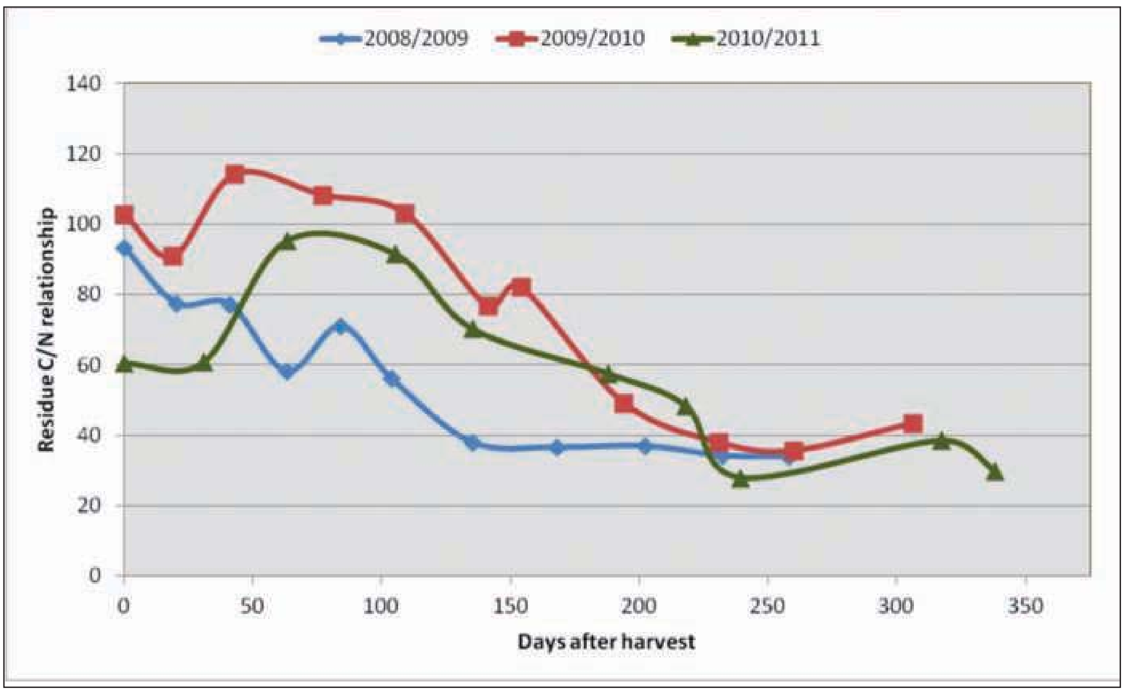

Figure 4. Evolution of RA 87-3 residue C/N ratio in the 2008/2009, 2009/2010 and 2010/2011 cycles. Tucumán, Argentina.

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.

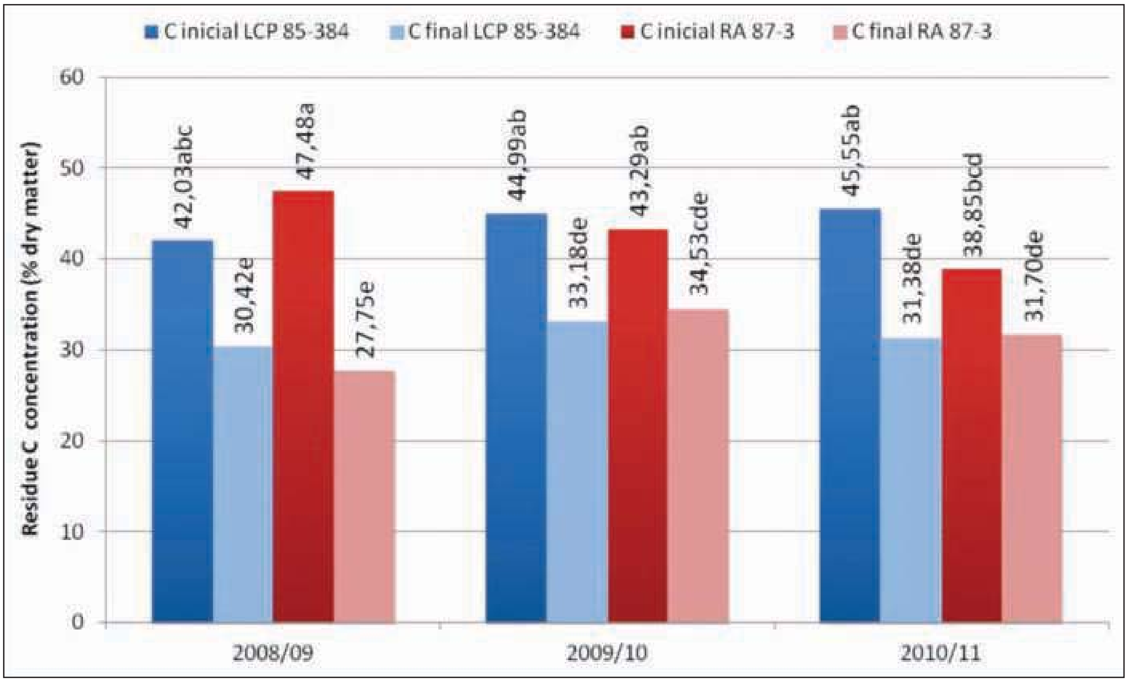

Figure 5. C concentration (% dry matter) in LCP 85-384 and RA 87-3 residue at the beginning and end of each season, in Tucumán, Argentina. Different letters indicate significant differences (*p*<=0.05).

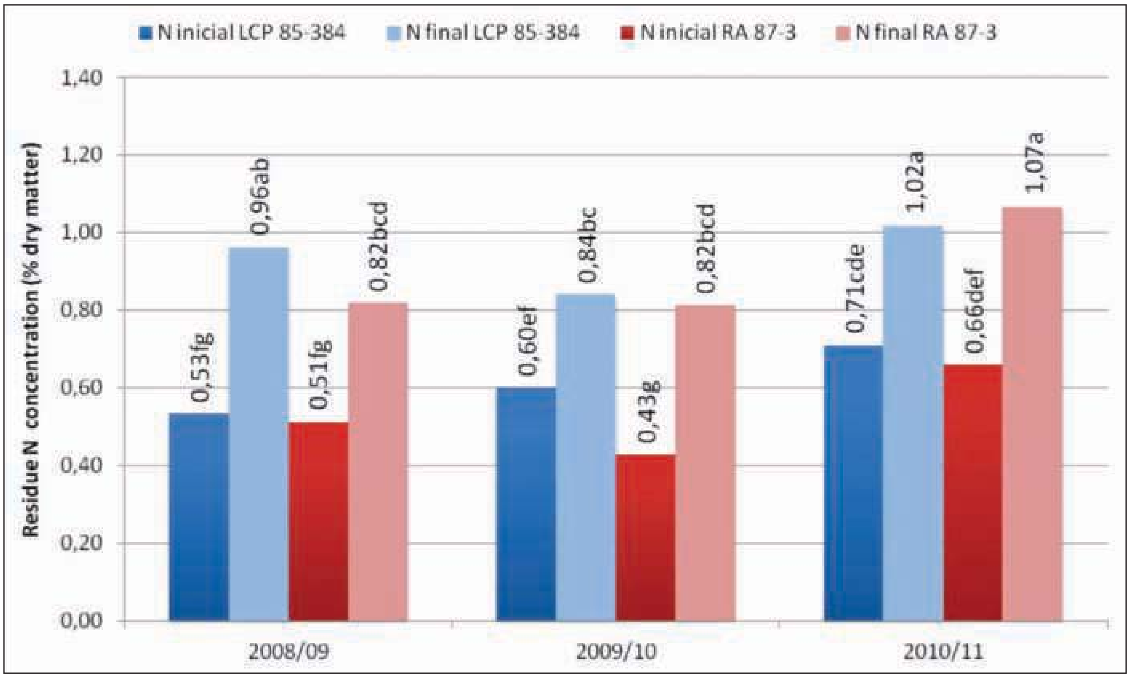

Figure 6. LCP 85-384 and RA 87-3 N concentration (% dry matter) at the beginning and end of each season, in Tucumán, Argentina. Different letters indicate significant differences (*p*<=0.05).

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.

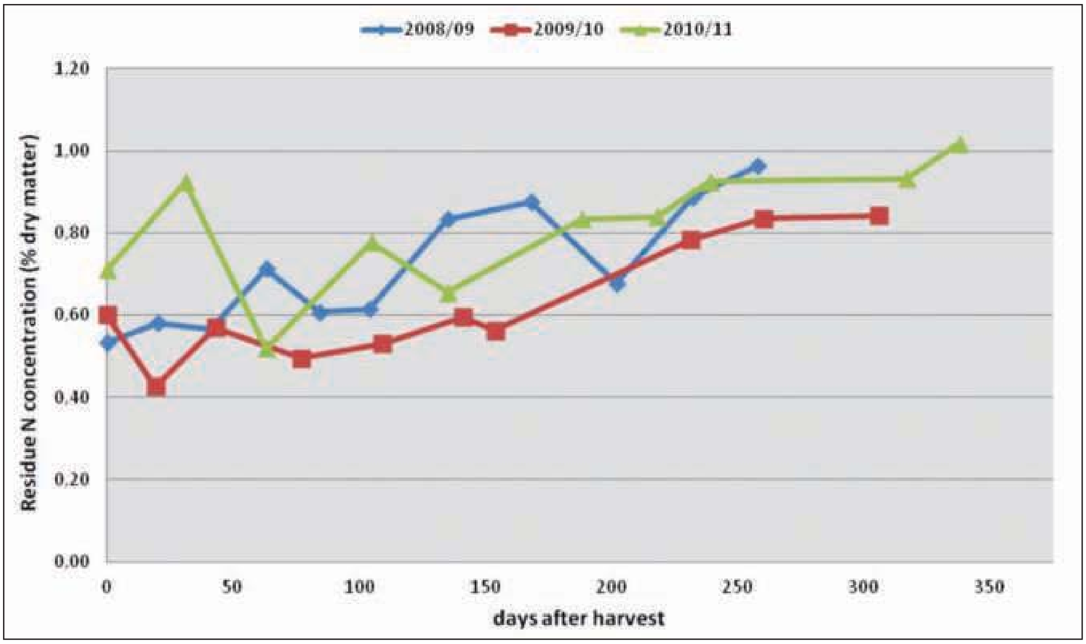

Figure 7. N concentration (% dry matter) evolution in LCP 85-384 residue throughout the three evaluated crop cycles. Tucumán, Argentina.

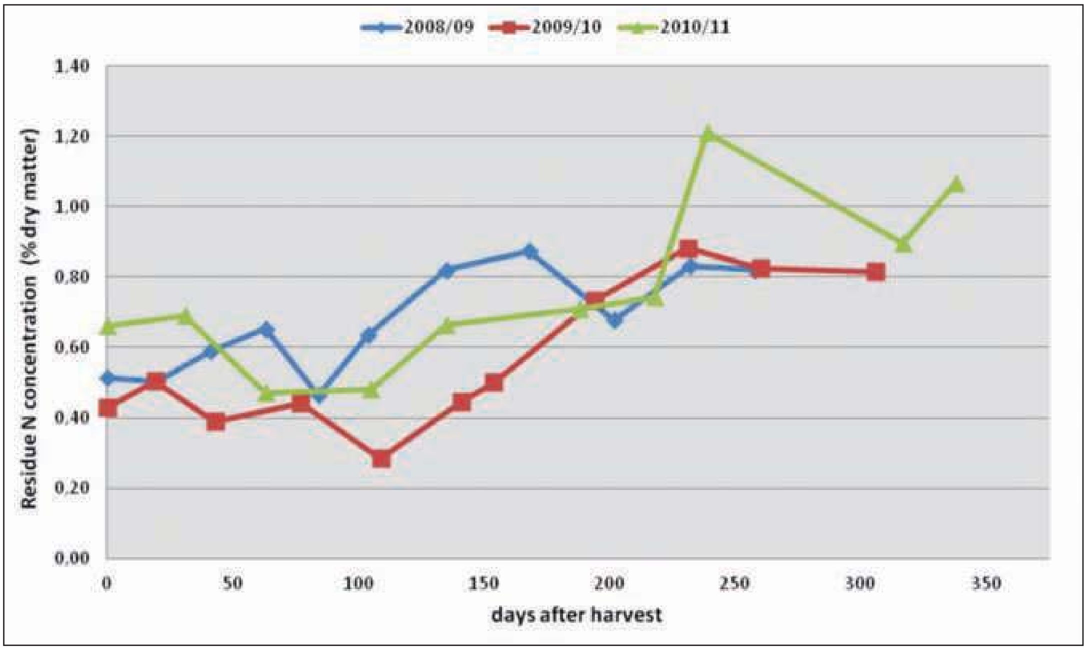

Figure 8. N concentration (% dry matter) evolution in RA 87-3 residue throughout the three evaluated crop cycles. Tucumán, Argentina.

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.

C	2008/2009	2009/2010	2010/2011
Initial C content (kg/ha)	5287.24	6823.23	5300.49
Final C content (kg/ha)	1664.76	2662.51	1906.24
Reduction percentage (%)	68.51	60.98	64.04
Contribution to the agro-ecosystem (kg/ha)	3622.48	4160.72	3394.26

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.

C	2008/2009	2009/2010	2010/2011
Initial C content (kg/ha)	5842.30	6364.59	6404.43
Final C content (kg/ha)	2455.87	2767.36	2061.24
Reduction percentage (%)	57.96	56.52	67.82
Contribution to the agro-ecosystem (kg/ha)	3386.42	3597.23	4343.18

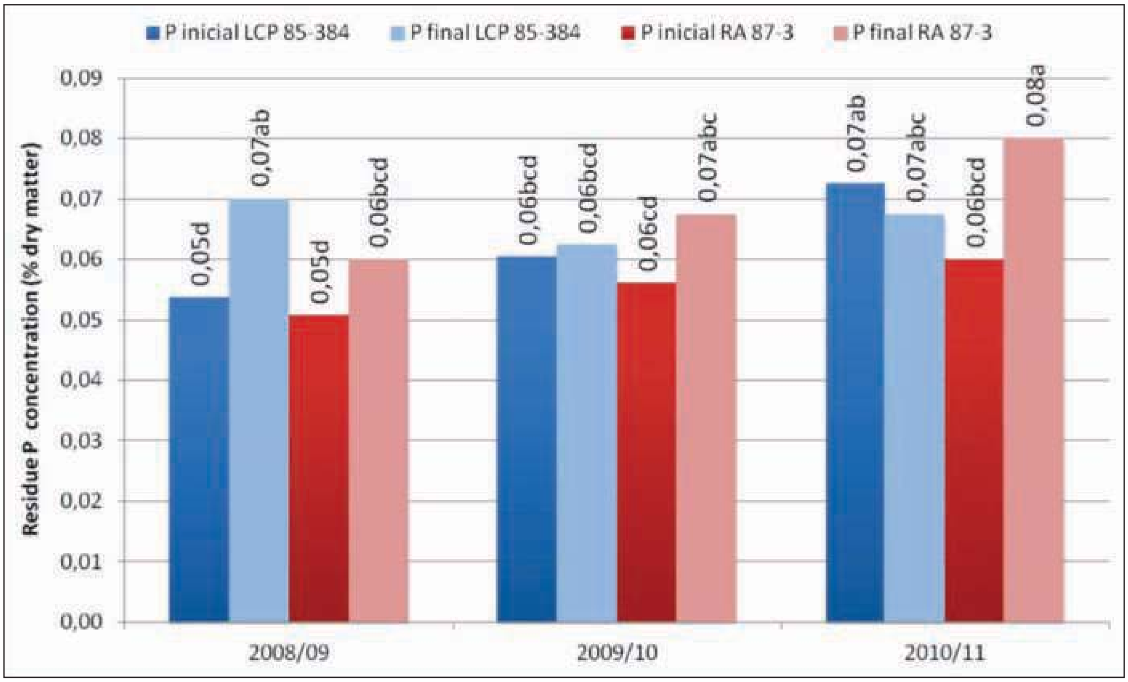

Figure 9. P concentration (% dry matter) in LCP 85-384 and RA 87-3 residues at the beginning and end of each cycle considered, in Tucumán, Argentina. Different letters indicate significant differences (*p*<=0.05).

Table 7. Initial and final P contents (kg/ha) in LCP 85-384 residues, and the contribution of this nutrient to the agroecosystem, at the end of each analyzed crop season. Tucumán, Argentina.

P	2008/2009	2009/2010	2010/2011
Initial P content (kg/ha)	6.76	9.16	8.44
Final P content (kg/ha)	3.83	5.02	4.10
Reduction percentage (%)	43.36	45.26	51.39
Contribution to the agro-ecosystem (kg/ha)	2.93	4.15	4.34

Table 8. Initial and final P contents (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.

P	2008/2009	2009/2010	2010/2011
Initial P content (kg/ha)	6.25	8.25	9.89
Final P content (kg/ha)	4.75	6.40	5.20
Reduction percentage (%)	23.95	22.41	47.41
Contribution to the agro-ecosystem (kg/ha)	1.50	1.85	4.69

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

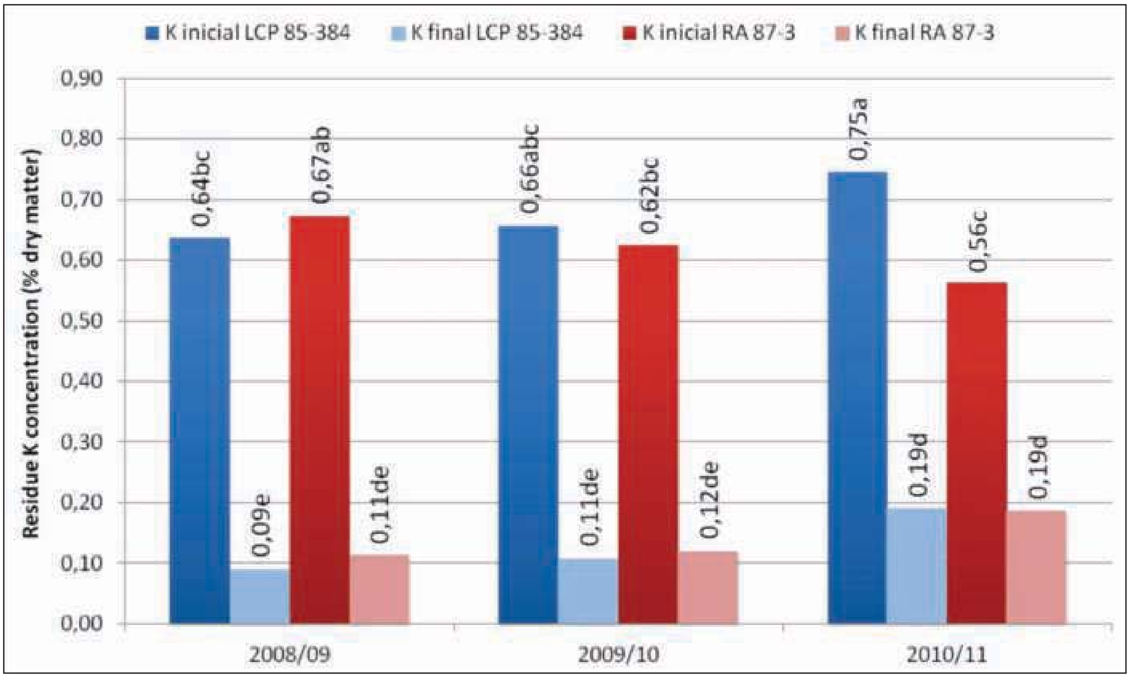

Figure 10. K concentration (% dry matter) in LCP 85-384 and RA 87-3 residues at the beginning and end of each cycle. Different letters indicate significant differences (*p*<=0.05). Tucumán, Argentina.

Table 9. Initial and final K 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.

K	2008/2009	2009/2010	2010/2011
Initial K content (kg/ha)	80.21	99.72	86.69
Final K content (kg/ha)	4.92	8.63	11.54
Reduction percentage (%)	93.86	91.35	86.68
Contribution to the agro-ecosystem (kg/ha)	75.28	91.09	75.15

Table 10. Initial and final K contents (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.

K	2008/2009	2009/2010	2010/2011
Initial K content (kg/ha)	82.76	91.76	92.73
Final K content (kg/ha)	8.91	11.37	12.19
Reduction percentage (%)	89.24	87.61	86.85
Contribution to the agro-ecosystem (kg/ha)	73.85	80.39	80.54

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

Braunack, M. and H. Ainslie. 2001. Trash blankets and soil physical properties: Mackay experience. Proc. Aust. Soc. Sugar Cane Technol. 23: 154-160.

Digonzelli, P. A.; E. R. Romero; L. Alonso; J. Fernández de Ullivarri; H. Rojas Quinteros; J. Scandaliaris and S. Fajre. 2011. Assessing a sustainable sugarcane production system in Tucumán, Argentina. Part 1: Dynamics of sugarcane harvest residue (trash) decomposition. Rev. Ind. y Agric. de Tucumán 88 (1): 01-12.

Ernst, O.; O. Betancur y R. Borges. 2002.

Descomposición de rastrojo de cultivos en siembra sin laboreo: trigo, maíz soja y trigo después de maíz o soja. Agrociencia 6: 20-26.

Graham, M. H.; R. J. Haynes and J. H. Meyer. 1999. Green cane harvesting promotes accumulation of soil organic matter and an improvement in soil health. Proc. S. Afr. Sug. Technol. Ass. 73: 53-57.

Graham, M. H.; R. J. Haynes and J. H. Meyer. 2002. Changes in soil chemistry and aggregate stability induced by fertilizer applications, burning and trash retention on a long-term sugarcane experiment in South Africa. Eur. J. Soil Sci. 53: 589-598.

Kingston, G.; J. L. Donzelli; J. H. Meyer; E. P. Richard; S. Seeruttun; J. Torres and R. Van Antwerpen. 2005. Impact of green cane harvest and production system on the agronomy of sugarcane. In: Proc. ISSCT Congress, 25, Guatemala, 2005, pp. 521-533.

Meier, E.; P. J. Thorburn; K. Wegener and K. Basford. 2006. The availability of nitrogen from sugarcane trash on contrasting soils in the wet tropics of North Queensland. Nutr. Cycl. Agroecosyst. 75: 101 114.

Morón, A. 2000. El rol de los rastrojos en la fertilidad del suelo. Documentos Online. 030. [On line]. Available at www.inia.org.uy/online/ (accessed 2 December 2009). Instituto Nacional de Investigación Agropecuaria Uruguay.

Núñez, O. and E. Spaans. 2007. Evaluation of green-cane harvesting and crop management with trash-blanket. In: Proc. ISSCT Congress, 26, Durban**,** Sudáfrica, pp. 131-142.

Oliveira, M. W.; P. C. O. Trivelin; G. Kingston; M. H. Pereira Barbosa and A. C. Vitti. 2002. Decomposition and release of nutrients from sugarcane trash in two agricultural environments in Brazil. Proc. Aust. Soc. Sugar Cane Technol. 24: 290-296.

Ostengo, S.; M. A. Espinosa; M. B. García; N. Delgado y M. I. Cuenya. 2012. Distribución varietal del cultivo de la caña de azúcar y aplicación de otras tecnologías en la provincia de Tucumán. Relevamiento de la campaña 2010/2011. Gac. Agroindustrial EEAOC (76).

Prove, B. G.; V. J. Doogan and P. N. V. Troung. 1995. Nature and magnitude of soil erosion in sugarcane land on the wet tropical coast of northeastern Queensland. Aust. J. Exp. Agric. 35: 641-649.

Robertson, F. A. and P. Thorburn. 2007. Decomposition of sugarcane residue in different climatic zones. Aust. J. Soil Res. 45: 1-11.

Romero, E. R.; P. A. Digonzelli; L. Alonso; J. Fernández de Ullivarri; G. A. Sanzano; J. Scandaliaris y H. Rojas Quinteros. 2007. La caña verde: un aporte a la sustentabilidad de la producción de caña de azúcar. I: Consideraciones generales. Avance Agroind. 28 (4): 11-15.

Romero, E. R.; J. Scandaliaris; P. A. Digonzelli; L. G. Alonso; M. F. Leggio; J. A. Giardina; S. D. Casen; M. J. Tonatto and J. Fernández de Ullivarri. 2009. Effect of variety and cane yield on sugarcane potential trash. Rev. Ind. y Agríc. de Tucumán 86 (1): 9-13.

Sanzano, G. A.; F. A. Sosa; C. F. Hernández; M. Morandini; H. Rojas Quinteros; J. I. Romero y P. A. Digonzelli. 2009. Evaluación de la erosión hídrica en caña de azúcar con y sin cobertura de maloja. Avance Agroind. 30 (3): 16-18.

Souza, Z. M.; R. Mello Prado; A. C. Paixao e L. G. Cesarin. 2005. Sistemas de colheita e manejo da palhada de cana-de açucar. Pesq. Agropec. Bras. 40 (3): 271-278.

Spain, A. V. and M. J. Hodgen. 1994. Changes in the composition of sugarcane harvest residues during decomposition as a surface mulch. Biol. Fertil. Soils 17: 225-231.

Thorburn, P. J.; H. L. Horan and J. S. Biggs. 2004. Nitrogen management following crop residue retention in sugarcane production. [On line]. Available at www. regional. org. au/au/asssi/supersoil2004/s9/oral/ index.htm (accessed 8 January 2010).

Thorburn, P. J.; E. A. Meier and M. E. Probert. 2005. Modelling nitrogen dynamics in sugarcane systems: Recent advances and applications. Field Crops Res. 92: 337-351.

Wood, A. W. 1991. Management of crop residues following green harvesting of sugarcane in north Queensland. Soil Tillage Res. 20: 69-85.