TRASH MANAGEMENT AFTER GREEN CANE HARVESTING AND ITS EFFECT ON PRODUCTIVITY AND SOIL RESPIRATION

By

F. MUÑOZ-ARBOLEDA[1] and R. QUINTERO-DURAN

Centro de Investigación de la caña de azúcar de Colombia (Cenicaña)[1]
fmunoz@cenicana.org

**KEYWORDS: Crop Residues, Sustainability,
Soil Organic Matter, Carbon Dioxide Emission.**

Abstract

A LONG-TERM trash management experiment is in progress at Cenicañas´ experiment station to evaluate the effect of continual retention of cane residues on the soil surface after green cane harvesting. The soil is a Mollisol with medium organic matter content (3.6%), high content of P (42 ppm) and K (0.46 cmol/kg) at the beginning of the study. Three trash loads of residues produced by the crop were evaluated: zero, single and double load of fresh residues were retained or removed from the soil surface of each treatment. To evaluate the nutrient supply from each load of residues, six fertiliser doses of N (0–200), P (0–75) and K (0–90) kg/ha were applied. During the plant crop, all treatments yielded close to 150 t/ha. After the eighth crop cycle, the plots without trash retention and without fertiliser application yielded 80 t/ha. The presence of residues or the application of fertilisers increased cane yield by 30 t/ha, while the combination of residues and the application of fertilisers maximised the yield up to 160 t/ha. In general, the cane yield of the trash loaded treatments tended to increase as the dosage of NPK was higher. As an indicator of soil microbial activity and crop metabolism, CO_2 fluxes from the soil surface were measured just before harvest of the seventh ratoon and two more times at 75 and 93 days in the eighth ratoon crop. CO_2 gas emissions from plots with single and double load of residues were three fold (303 mg/m^2/h) of the plots without trash retention (115 mg/m^2/h). The following two CO_2 samplings detected lower emission rates but the pattern was similar to the sampling before harvest. From the results obtained up to now, it is concluded that higher fertiliser doses are not enough to compensate for the negative effect of residue removal from cane fields.

Introduction

The long-term maintenance of soil chemical, physical and biological fertility in soils devoted to sugarcane production depends largely on the management of the crop residues. Leaving the sugar cane residues after green cane harvesting on the soil surface, a large proportion of the nutrients removed in the biomass during the crop cycle will return to the soil. Sugarcane is a crop with high soil nutrient extraction. In the aerial biomass (leaves, leaf sheaths and stems) of the cane variety CC 85-92 under typical production conditions prevailing in Valle del Cauca, the total nutrient extraction observed was 136, 31 and 245 kg/ha of N, P and K respectively per 100 tonnes of cane stalks (CENICAÑA, 2009). From the total extraction of major elements in the aerial biomass, 57, 9 and 103 kg/ha of N, P and K stay in the field in crop residues (leaves and leaf sheaths). From a nutritional point of view, it is important to highlight the importance of the nutrient return to the soil. Nutrients in the crop residues represent 42% of N and K and 29% of P present in the total aerial biomass (leaves, leaf sheaths, and stems) to produce 100 tonnes of cane stalks in this area. Among the benefits achieved by a proper waste management are: reduction of erosion by wind and water, increased soil organic matter (SOM), increased retention of water available to plants and increase in beneficial organisms (Andrews, 2006). Despite the benefits of keeping crop residues in the field, the effects vary between sites so, in some production systems with high incorporation of crop residues in the temperate zone, an increase in diseases and low seed germination has been reported (Linden *et al.*, 2000). A trash blanket is a positive factor in well-drained soils because better soil moisture conservation allows high water use efficiency by the crop. However, the advantage of a trash blanket can turn into a problem in areas with poorly drained soils where the trash cover can increase problems derived from waterlogging (Wood, 1991).

Increased microbial biomass is a good indicator of SOM dynamics because it responds rapidly to changes in C supply and differences can be detected as they can be measured by the total organic matter content (Gregorich *et al.*, 1997). One way to assess the soil microbial activity and root system respiration is to measure CO_2 emission from the ground which is a good indicator of the agro-ecosystem metabolism (Ryan and Law, 2005). It is estimated that nearly half of soil respiration is produced by metabolic activity to maintain and develop roots and associated mycorrhizae (Hanson *et al*., 2000; Hogberg *et al*., 2001). Most of the remainder is associated with the respiration of heterotrophic microbial communities that use organic matter as an energy substrate (Trumbore, 2000; Giardina *et al*., 2004). Therefore, CO_2 emission is a good index to indirectly measure soil microbial activity and crop physiology.

Faced with the imminent stopping of the sugarcane burning practice before harvesting in Valle del Cauca, the need to know the long-term impact of sugarcane residues from green cane harvesting on the physical, chemical and biological soil fertility is crucial. In 2000, Cenicaña set up an experiment to be continued for an indefinite period, under three different management schemes of crop residues. At present, this experiment is starting its tenth cropping cycle, and this paper provides a summary of cane productivity from the plant to the seventh ratoon crop harvested and a preliminary view of SOM content.

Material and methods

The experiment was established in lot 19 of the Experimental Station San Antonio (EESA) of Cenicaña. The soil is classified as Cantarina (Pachic Vertic Haplustoll), fine textural family (IGAC-CENICAÑA, 2006) 6H1 agroecological zone (CENICAÑA, 2006) with pH near neutrality, medium content of SOM (3.63%) and high P content (42 ppm) and exchangeable K (0.46 cmol/kg). The sugarcane variety planted was CC 85-92. The lot was divided into three equal parts and in each of them we established three management schemes of crop residues. All the trash was removed (TR) from one of the thirds and placed in another third to accumulate into a double load (DL) of residues arranged following a pattern of two inter-row spaces with residues and two without residues.

The last third was left with the single load (SL) of residues arranged following a pattern of two inter-rows with residues and one inter-row without residues. Each third assigned to a trash management scheme was divided in three equal areas to be used as replications. Each replication was sub-divided into six plots consisting of 10 rows of 12 metres in length, with 1.5 m between rows. In each of the plots, one of six doses of N, P and K as fertilisation treatments was applied. Three treatments consisted of three levels of N-P-K (low, medium, and high), two with the medium level of N and without P or K, and one treatment with no application of fertilisers.

The fertilisation treatments were randomised according to a complete block design within each area of residue management. Soil tillage during ratoon crops was limited to cultivation between rows to control weeds and to incorporate the fertiliser applied. Statistical analysis was done separately for each area representing a scheme of crop residues management. An analysis of variance using the mixed procedure (SAS, 2008) was performed in order to detect differences in productivity parameters under the six fertilisation treatments applied into each one of the three areas with different trash management schemes.

Fertilisation treatments were applied 45 days after planting or harvest with the exception of P and K which were applied to the bottom of the row before plant cane sowing. Population density and stem height were evaluated at 3, 4.5 and 6 months after planting. At the same time, leaf tissue samples were taken to evaluate foliar content of major and minor elements. Crop cycle length was about 13 months. Height of millable stalks was measured prior to harvest and a sample of millable stalks was taken to the laboratory for juice analysis. At the beginning of the experiment and after each harvest, four soil samples 0–20 cm depth were taken and bulked to represent each plot. Soil samples were analysed for pH, SOM, P, Ca, Mg, and Na. At plant cane harvest, soil texture was determined from the soil sampling.

This paper reports on cane yield (TCH), sucrose % cane (SPC) determined by the direct analysis of cane method (DAC) and soil organic matter (SOM) determined by the dichromate methodology (Walkley and Black, 1934), during eight crop cycles. Emission of carbon dioxide (CO_2) from samples taken two days before the harvest of the eighth cycle, and two more at 75th and 93rd days of the ninth cycle was also recorded. Gas samples were taken in plots fertilised with 150-50-60 kg/ha of NPK inside of each one of the trash management schemes. In each of the sampled plots, 2 PVC chambers were installed (one between rows and one in-row), and a sequence of four samples of gases at intervals of 0, 10, 20 and 30 minutes were taken. Gas samples were analysed with a CO_2 gas analyser with NaOH and silica gel trap.

Results and discussion

In areas with single (SL) and double trash (DL) loads, average TCH over the eight crop cycles resulted in lower cane production under no fertilisation treatments (Table 1). Although, in the area with a double trash load, the difference in cane production among treatments with varying fertilisation was not significant, it followed a similar pattern to cane production under single trash load where differences were significant at 6% level (Table 1). The negative effect of crop residues removal (TR) on fertiliser efficiency is evident by the no response of TCH to the increase of NPK dose and the highly significant difference among plots with fertiliser application and plots without fertiliser application (Table 1).

Under the single trash load scheme, there were no differences in TCH between plots applied with the lowest dose of NPK, plots without K application, and plots without fertiliser application suggesting a suboptimal NPK dose as limiting to cane production. Sucrose content was reduced significantly with no application of fertilisers under single and double trash loads, while no difference between fertilised and non-fertilised plots was visible under the trash removal (TR) treatment (Table 1). The trend to higher PSC observed in plots with trash removal could be attributed to crop stress due to lower use efficiency of fertilisers caused by the lack of the synergistic effect of crop residues left on the soil.

Table 1—Cane yield (TCH), sucrose percent cane (SPC) and soil organic matter (SOM) averaged over eight crop cycles under effect of trash load and NPK doses.

N-P-K Kg/ha	Single trash load (SL)			Double trash load (DL)			Trash removal (TR)		
	TCH	SPC %	SOM %	TCH	SPC %	SOM %	TCH	SPC %	SOM %
100-25-30	142 ac	12.04 a	3.00	142	12.14 ac	3.17	141 a	12.66	3.16
150-50-60	153 a	12.46 a	3.09	147	12.04 b	3.22	145 a	12.49	3.10
200-75-90	154 a	12.30 a	3.11	158	12.11 ac	3.27	139 a	12.46	2.91
150-0-60	150 a	12.38 a	3.29	152	12.32 a	3.35	141 a	12.49	3.27
150-50-0	143 ac	12.43 a	3.07	146	12.01c	3.36	143 a	12.16	3.30
0-0-0	131 bc	11.59 b	3.19	132	11.75 d	3.20	96 b	12.30	2.98
Sig. level	0.06	0.08	ns	ns	0.03	ns	<0.0001	ns	ns

Means followed by different letter are statistically different to the indicated level. Mean separation by Least Squares Means procedure.

No difference in soil organic matter (SOM) under different trash management schemes or fertiliser treatments was detected and the expected effect of trash removal on SOM was not evident (Table 1). This could be explained by the soil sampling depth used in this experiment (20 cm) and the relatively short life time (10 years). After 59 years, in the long-term experiment located at Mount Edgecombe, difference in organic carbon (OC) from plots with trash burnt before harvest and plant tops raked off (4.3% OC) and plots with green cane harvest with trash retention (5.1% OC) were evident at a depth as far as 5 cm and almost disappeared at 10 cm (Graham *et al.*, 2002).

Based on the factors tested in this experiment, three scenarios could be defined as follows: plots without addition of crop residues or fertilisers, plots with addition of fertilisers or crop residues, and plots with addition of both fertilisers and crop residues. By plotting the results of the cane yield (TCH) under these three scenarios (Figure 1) it has been possible to describe three different situations through to the eighth ratoon crop. Plots without crop residues and without fertilisers (TR – F) had a descending trend in cane yield from about 140 t/ha at plant cane to 80 t/ha at the seventh ratoon. This clearly descendent pattern could be attributed to deterioration of chemical, physical and biological soil fertility.

Contrasting with this situation, treatments with trash and fertiliser application (SL + F and DL + F) diminished their TCH until the third ratoon crop but, after that, a clear uprising pattern was observed until the eighth ratoon crop when a similar cane yield to the plant cane was reached again. This situation shows how important for the sugarcane system to include crop residues with fertiliser addition in order to achieve a synergetic effect that allows the crop to recover productivity levels as high as those of the plant cane (Figure 1). An intermediate situation in terms of TCH was achieved when crop residues or fertilisers were applied individually (SL – F, DL – F and TR + F), cane yield decreased from 150 – 165 t/ha in plant cane to a relatively steady TCH of approximately 125 t/ha from the third to the eighth ratoon crop (Figure 1). It highlights that it is not possible to compensate the negative effect of trash removal by addition of synthetic fertilisers even when applied at higher rates. Furthermore, it was clearly demonstrated that crop residues have not just an effect on chemical fertility but they can also impact positively on physical and biological soil factors.

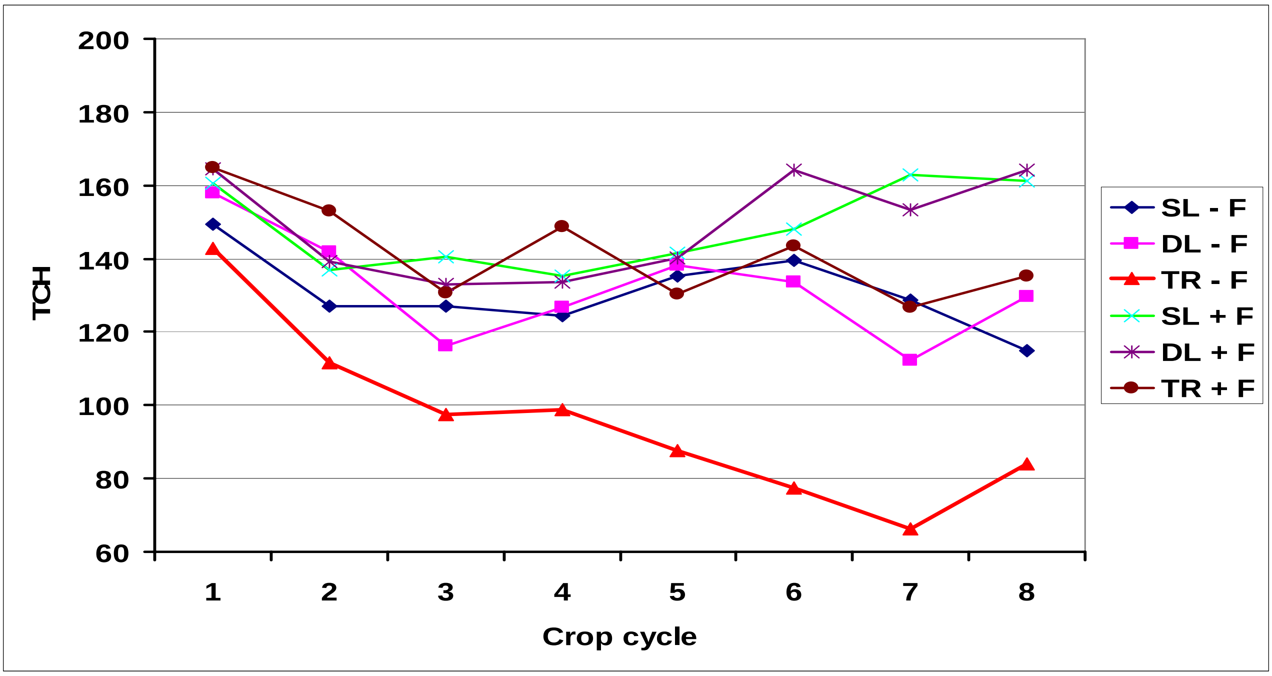

Fig. 1—Cane yield (TCH) under three trash management schemes, single load (SL), double load (DL), and trash removal (TR) combined with application (+F) or not (–F) of fertilisers.

Emission of CO_2 from plots with double and single trash load was systematically higher than that from plots with trash removal suggesting increased microbial activity and crop physiology enhanced by the crop residues left on the field during eight consecutive crops (Figure 2).

This fact is coincident with the higher crop productivity observed in plots with combined application of residues and fertilisers (Figure 1).

The downshift in emission of CO_2 observed 75 days after harvest as compared with the emission rate observed just before harvest could be mainly due to decreased root respiration caused by the interruption of all physiological crop processes after cane cutting (Figure 2).

After cane harvest, a renewed root system starts growing during the succeeding ratoon and this was reflected by the gradual increase of CO_2 emission rate observed between the 1^{st} and 19^{th} of June (Figure 2).

Higher CO_2 emission from plots with combined trash and fertiliser application (Figure 2) was expected because their higher biomass production (Figure 1) and increased C input by trash application as compared with plots where trash removal was done.

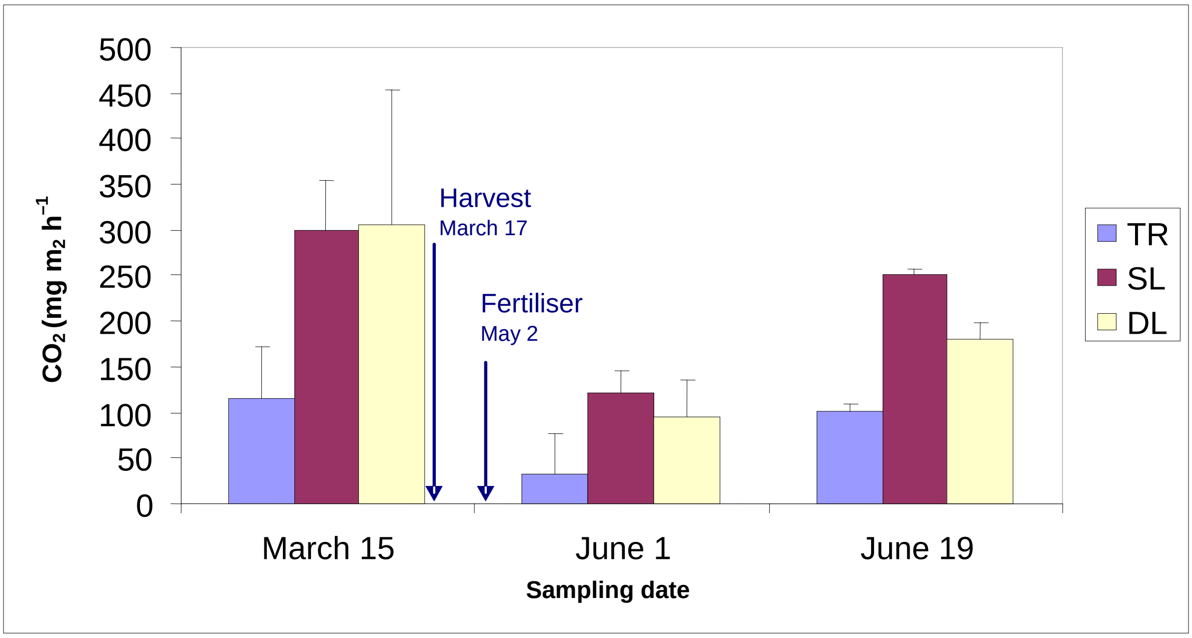

Fig. 2—Carbon dioxide (CO_2) emission from plots fertilised with N-P-K at 150-50-60 kg/ha, amended with single (SL), double (DL) trash load or trash removal (TR) after eight crop cycles of sugarcane.

The beneficial effect of crop residues from sugarcane on soil health and crop productivity is shown by the results of this experiment. Under the environmental conditions of this experimental site, it was observed that productivity and sustainability of the system in terms of TCH, was achieved only with treatments where trash was left on the ground and additional fertiliser was applied.

Until the eighth ratoon crop, individual application of crop residues or fertilisers even at high rates, were not sufficient to match the productivity of plots in which fertilisers and crop residues were applied simultaneously.

In plots with trash removal without fertiliser application, productivity declined significantly. This experimental site will be maintained and monitoring will continue indefinitely in order to quantify the long-term effect of continuous addition of crop residues after green harvesting on sugarcane production and soil health.

REFERENCES

Andrews, S. S. (2006). Crop residue removal for biomass energy production: Effects on soils and recommendations. Soil Quality National Technology Development Team. USDA- Natural Resource Conservation Service. White paper. 15 p.

Centro de Investigación de la Caña de Azúcar de Colombia (CENICAÑA). (2006). Zonificación agroecológica de la zona productora de caña de azúcar. Cenicaña´s Webpage (www.cenicana.org) accessed on June 3rd 2009.

Centro de Investigación de la Caña de Azúcar de Colombia (CENICAÑA). (2009). Cuarto Informe trimestral del 2009. Área Agronomía, sección Nutrición y Fertilización.

Giardina, C.P., Binkley D., Ryan M.G., Fownes J.H. and Senock R.S. (2004). Belowground carbon cycling in a humid tropical forest decreases with fertilisation. Oecologia, 139: 545–550.

Graham, M.A., Haynes, R.J. and Meyer, J.H. (2002). Changes in soil chemistry and aggregate stability induced by fertiliser applications, burning and trash retention on a long-term sugarcane experiment in South Africa. European Journal of Soil Science, 53: 589–598.

Gregorich, E.G., Carter, M.R., Doran J.W., Pankhurst, C.E. and Dwier, L.M. (1997). Biological attributes of soil quality. In: Gregorich, E.G. and Carter, M.R. (eds). Soil quality for crop production and ecosystem health. Elsevier, Amsterdam, pp 81–113.

Hanson P.J., Edwards N.T., Garten C.T. and Andrews J.A. (2000). Separating root and soil Microbial contributions to soil respiration: a review of methods and observations. Biogeochemistry, 48: 115–146.

Hogberg P., Nordgren A., Buchmann N., Taylor A.F.S., Ekblad A., Hogberg M.N., Nyberg G., Ottosson-Lofvenius M. and Read D.J. (2001). Large-scale forest girdling shows that current photosynthesis drives soil respiration. Nature, 411: 789–792.

Instituto Geográfico Agustín Codazzi (IGAC) and Centro de Investigación de la Caña de Azúcar de Colombia (CENICAÑA) (2006). Estudio detallado de suelos y capacidad de uso de las tierras sembradas con caña de azúcar en el valle geográfico del río Cauca. 128 p.

Linden, D.R., Clapp, C.E. and Dowdy, R.H. (2000). Long-term corn grain and stover yields as a function of tillage and residue removal in east central Minnesota. Soil and Tillage Research, 56: 167–174.

Ryan, M.G. and Law, B.E. (2005). Interpreting, measuring and modeling soil respiration. Biogeochemistry, 73: 3–27.

SAS Institute Inc. (2008). Software for statistical analysis system licensed to Centro de Investigación de la Caña de Azúcar de Colombia.

Trumbore, S. (2000) Age of soil organic matter and soil respiration: radiocarbon constraints on belowground C dynamics. Ecology Applied, 10: 399–411.

Walkley, A. and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter, and proposed modification of the chromic acid titration method. Soil Science, 37: 29–38.

Wood, A.W. (1991). Management of crop residues following green harvesting of sugarcane in north Queensland. Soil Tillage Research, 20: 69–85.

GESTION DU PAILLIS APRÈS LA RECOLTE DE CANNE VERTE ET SON EFFET SUR LA PRODUCTIVITÉ ET LA RESPIRATION DU SOL

Par

F. MUÑOZ-ARBOLEDA[1] et R, QUINTERO-DURAN

Centro de Investigación de la caña de azúcar de Colombia (Cenicaña)[1]

fmunoz@cenicana.org

MOTS-CLÉS: Résidus de Récolte, Durabilité,
Matière Organique du Sol, Émission de Dioxide de Carbone.

Abstract

UNE EXPÉRIENCE à long terme concernant la gestion du paillis a été entreprise sur la station expérimentale de Cenicañas´ pour évaluer l'effet de la conservation des résidus de récolte sur la surface du sol après la récolte en vert de la canne. Le sol est un Mollisol comportant un taux moyen de matière organique (3.6%), une teneur élevée en P (42 ppm) et en K (0.46 cmol/kg) au début de l'étude. Trois doses de paillis produit à la récolte ont été évaluées : aucun paillis, deux doses simple et double de résidus frais ont été enlevées ou maintenues à la surface du sol sur chaque traitement. Pour évaluer l'apport nutritif de chaque dose des résidus, six doses d'engrais en kg/ha de N (0-200), de P (0-75) et de K (0-90) ont été appliquées. En canne plantée, tous les traitements ont produit à peu près 150 t/ha. Après le huitième cycle de récolte, les parcelles sans paillis et sans application d'engrais ont produit 80 t/ha. La présence des résidus ou l'application des engrais a augmenté le rendement en canne de 30 t/ha. L'association des résidus et des engrais ont produit des rendements maximum atteignant 160 t/ha. Généralement les rendements des traitements avec paillis étaient supérieurs car la dose effective de NPK était plus élevée. Comme indicateur d'activité de sol et du métabolisme microbien, les flux de CO2 provenant de la surface du sol ont été mesurés juste avant la récolte de la septième repousse et 75 et 93 jours après cette récolte. Avant récolte, les émissions de CO2 des parcelles ayant reçu des doses simple et double de paillis furent trois fois supérieures (303 mg/m2/h) à celles des parcelles sans paillis (115 mg/m2/h). Les deux prélèvements suivants ont révélé des taux inférieurs d'émission de CO2 mais avec des rapports identiques à ceux mesurés avant récolte. Des résultats obtenus jusqu'ici, on peut conclure que les doses plus élevées d'engrais ne sont pas suffisantes pour compenser l'effet négatif de l'enlèvement des résidus.

MANEJO DE LOS RESIDUOS DE COSECHA EN VERDE Y SU EFECTO SOBRE PRODUCTIVIDAD Y RESPIRACIÓN DEL SUELO

Por

F. MUÑOZ-ARBOLEDA[1] y R. QUINTERO-DURAN

Centro de Investigación de la caña de azúcar de Colombia (Cenicaña)[1]

fmunoz@cenicana.org

PALABRAS CLAVE: Residuos de Cosecha, Sostenibilidad,
Materia Orgánica del Suelo, Emisión de Dióxido de Carbono.

Resúmen

UN EXPERIMENTO a largo plazo sobre manejo de residuos está en marcha en la estación experimental de Cenicaña para evaluar el efecto de la retención o remoción continua de los residuos de cosecha en verde de la caña. El suelo es un Mollisol con contenido medio de materia orgánica (3.6%), altos contenidos de P (42 ppm) y K (0.46 cmol/kg) medidos al comienzo del estudio. Tres cantidades de residuos producidos por el cultivo fueron evaluadas: remoción total, carga sencilla y carga doble de residuos frescos fueron aplicados al suelo en cada tratamiento. Durante la plantilla,

todos los tratamientos produjeron alrededor de 150 t/ha de caña. Después de la octava soca, las parcelas sin residuos y sin aplicación de fertilizantes produjeron 80 t/ha. La presencia de residuos o la aplicación de fertilizantes incrementó la producción de caña en 30 t/ha, mientras la combinación de residuos y la aplicación de fertilizantes maximizó la producción hasta 160 t/ha. En general, la producción de caña de los tratamientos con retención de residuos tendió a incrementarse cuando la dosis de NPK fue más alta. Los flujos de CO_2 desde la superficie del suelo fueron medidos justo antes de la cosecha de la séptima soca y dos veces más a los 75 y 93 días de la octava soca. La emisión de CO_2 desde las parcelas con carga sencilla y doble de residuos fue casi el triple (303 $mg/m^2/h$) de la de las parcelas sin residuos (115 $mg/m^2/h$). En los siguientes dos muestreos se detectaron tasas de emisión menores pero el patrón fue similar al del muestreo de antes de la cosecha. De los resultados obtenidos hasta ahora, se concluye que altas dosis de fertilización no son suficientes para compensar el efecto negativo de la remoción de residuos de los campos de caña.