Proc. Aust. Soc. Sugar Cane Technol., Vol. 26, 2004

CANE TRASH AND CALCIUM-BASED SOIL AMENDMENTS: A COMBINATION TOO GOOD TO MISS

By

B.L. SCHROEDER[1] and A.W. WOOD[2]

[1]BSES Limited, [2]CSR Sugar

bschroeder@bses.org.au

KEYWORDS: Sugarcane Trash, Amendments, Nutrients, Millmud.

Abstract

GREEN cane trash retention and acidic soils occur widely in the Australian sugar industry. Although both have received individual attention over the years, little information is available on the interaction between trash and the calcium-based ameliorants routinely applied to sugarcane producing soils. For this reason, the effects of applying amendments to trash were explored in terms of decomposition of the trash and the release and availability of associated nutrients. Pot experiments were conducted in subtropical and moist tropical conditions using various amendments and common soil types. A field trial, aimed at validating the results from the pot experiments, was conducted. The results showed that certain calcium-based amendments, especially lime and millmud, accelerated trash decomposition. Differences in rates of decomposition in simulated subtropical and moist tropical conditions suggested that temperature and water availability were important factors for decomposition. Amendments applied to the surface of the trash layer were found to have the ability to ameliorate conditions in the underlying soil. Although millmud and mill ash applied to trash increased the amount of N, P and K removed by the harvested cane, these elevated levels could either have been the result of the amendments themselves, or due to enhanced decomposition of the trash, or a combination of both of these. The combination of trash retention and the application of calcium-based soil amendments enables the advantages of both practices to be harnessed for sustainable sugarcane production.

Introduction

Green cane harvesting and trash blanketing is widely used in the Australian sugar industry, with trash being recognised as a valuable source of soil organic matter (Moody, 2002) and plant nutrients that are gradually released as the trash breaks down (Wood, 1991; Mitchell and Larsen, 2000; Robertson and Thorburn, 2000). Although acidic soils are commonly found in the sugarcane areas of Australia, with lime routinely used to ameliorate such conditions (Noble *et al.*, 1997; Aitken *et al.*, 1998), and lime and gypsum routinely applied to supply calcium (Kingston and Aitken, 1994), little information is available on the effect of calcium-based amendments applied to a trash blanket. This paucity of knowledge, evidence of slow trash decomposition rates in some circumstances (Kingston *et al.*, 1998), and possible acidification of soils with trash retention (A.D. Noble, pers. comm.) indicated that the combination of these two routine practices should be explored. This paper includes:

- Information from three pot experiments that were aimed at determining the effect of calcium-based amendments on trash decomposition and the amelioration of the underlying soil, some details of which have been previously reported by Wood *et al*., 2001.

- A report on a trial in which the interaction between trash and lime/millmud was evaluated under field conditions.

- A description of investigations aimed at determining whether the application of calcium-based amendments would deliver benefits in terms nutrient availability.

Assessment of trash decomposition and soil amelioration in pot experiments

Method

A series of three separate yet interlinked pot experiments provided information on trash decomposition and soil amelioration associated with the combination of a trash layer and the use of various calcium-based amendments (Wood *et al*., 2001). A summary of the details of these experiments (Experiments 1, 2 and 3) is given below.

Experiment 1

Two acidic topsoils (Hydrosol (pH(water) = 3.85, Exch. Al = 110.6 mg/kg) and Kurosol (pH(water) = 4.95, Exch. Al = 46.5 mg/kg)) were used in an uncropped glasshouse pot experiment (Wood *et al*., 2001). Lime was applied to the surface of the trash or incorporated into the soil (prior to the placement of trash) at rates of 0, 3 and 6 t/ha. The equivalent of 25 t/ha of air-dry trash was used in each case. Soils were kept at field moisture capacity by spraying water onto the surface of the trash. Undecomposed trash, the 0–10mm decomposed trash/soil interlayer, and the 10–50mm soil layer were destructively sampled after four and seven months.

Experiments 2 and 3

Two pot trials were established in glasshouses, one in simulated subtropical conditions and the other in simulated moist tropical conditions (Wood *et al*., 2001). In the simulated subtropical conditions, temperatures in the glasshouse ranged from 10^{o}C to 30^{o}C and the pots were irrigated with 300 mL of water twice weekly. In the simulated moist tropical conditions, glasshouse temperatures ranged from 15^{o}C to 40^{o}C and the pots were irrigated with 500 mL of water twice weekly. While the 'subtropical' experiment included five different soil types, the 'moist tropical' experiment included four soils, of which two were from the 'subtropical' experiment for cross-referencing purposes (Table 1). With the exception of the treatment without trash, amendments were spread on the surface of a trash layer (Table 2). Residual trash was determined after seven months by combining the un-decomposed trash layer with the material remaining after the soil/trash interlayer was washed with de-ionised water.

Results and discussion

The four-month sampling in Experiment 1 indicated that lime, applied at both 3 and 6 t/ha, had a significant effect on trash decomposition (Wood *et al*., 2001). However, the extent of

decomposition was also dependent on the method of lime application and soil type (Table 3). It is thought that the enhanced decomposition due to spreading lime on the surface of the trash layer was possibly due to increased solubility of organic matter and improved microbial activity with increased pH within the decomposing trash blanket. After seven months, the observed differences in residual trash were no longer significant. In terms of the ameliorative effect, lime applied to the trash blanket increased soil pH in the surface soil (0–10 mm) and decreased the exchangeable Al in the 10–50 mm soil layer (Figure 1).

Table 1—Soils used in Experiments 2 and 3.

Experiment	Soil	Local soil identifier	pH (water)	Org C (%)	ECEC (cmol(+)/kg)
2	Hydrosol	Garrett	4.5		16.42
2, 3	Kurosol	McCord	4.7	1.0	3.29
2	Podosol	Cook	5.2	3.3	4.63
2	Vertosol	Barratta	7.0	1.4	19.16
2, 3	Kandosol	Red loam	5.5	1.3	3.32
3	Tenosol	River Bank	5.0	1.0	4.07
3	Dermosol	River Overflow	5.3	1.6	9.99

Table 2—List of amendments included in Experiments 2 and 3 (after Wood *et al*., 2001).

Treatment	Amendment and equivalent rate[1]
1	Lime (calcium carbonate) at 3.0 t/ha
2	Gypsum (calcium sulphate) at 4.10 t/ha
3	Calcium hydroxide at 2.22 t/ha
4	Lime (1.5 t/ha) + gypsum (2.05 t/ha)
5	Mill mud at 30 t dry mud/ha[1]
6	Potassium hydroxide at 1.7 t/ha
7	Magnesium oxide at 1.2 t/ha
8	Urea at 160 kg N/ha
9	Lime at 3.0 t/ha, No trash
10	No amendment, Trash only (40 t/ha)
11[2]	No trash, no amendment

[1]Rates of amendments, other than that of millmud, were calculated to give Ca supply capacities and/or acid neutralising capabilities similar to 3 t/ha of calcium carbonate.
[2] Subtropical conditions only.

Table 3—Amounts of residual trash after four months in Experiment 1.

Soil	Residual trash (t/ha)	Lime applied (t/ha)	Residual trash (t/ha)	Application	Residual trash (t/ha)
Hydrosol	20.45	0	20.57	Spread on trash	19.70
Kurosol	19.61	3	19.83	Incorporated in soil	20.36
		6	19.70		
Significance	**		**		**
LSD (p<0.05)	0.23		0.28		0.23
LSD (p<0.01)	0.31		0.38		0.31

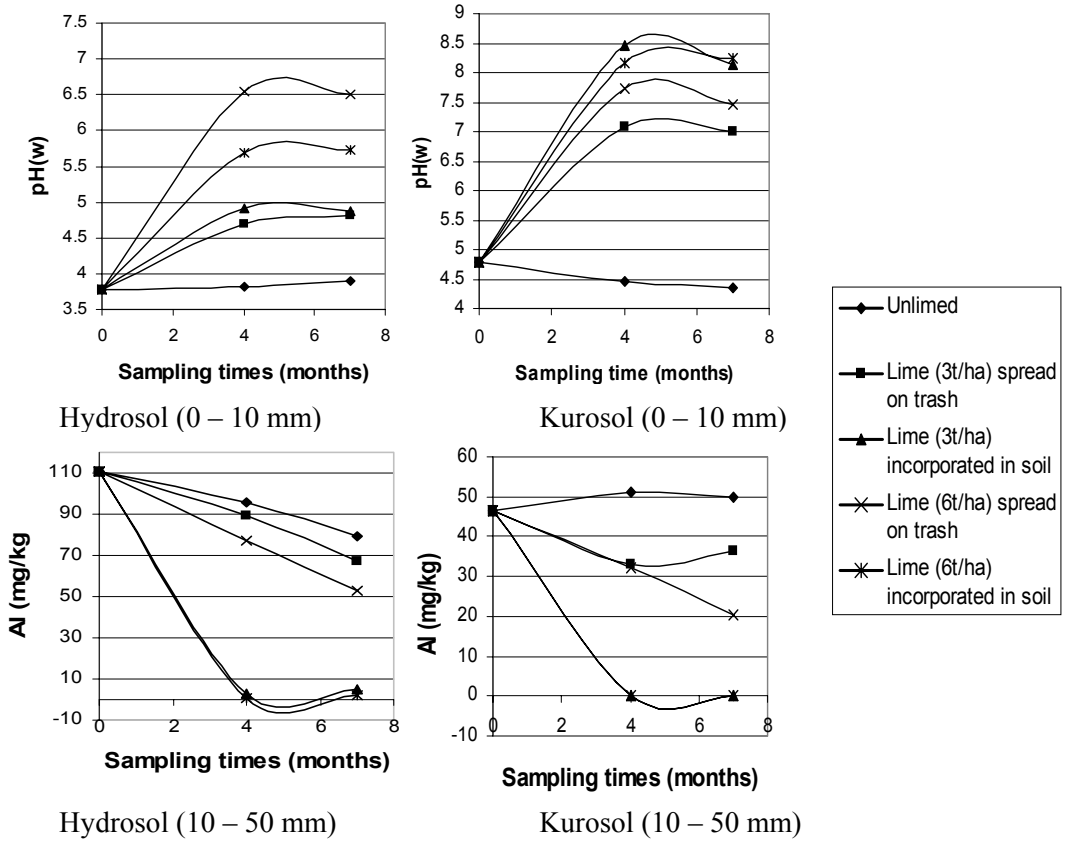
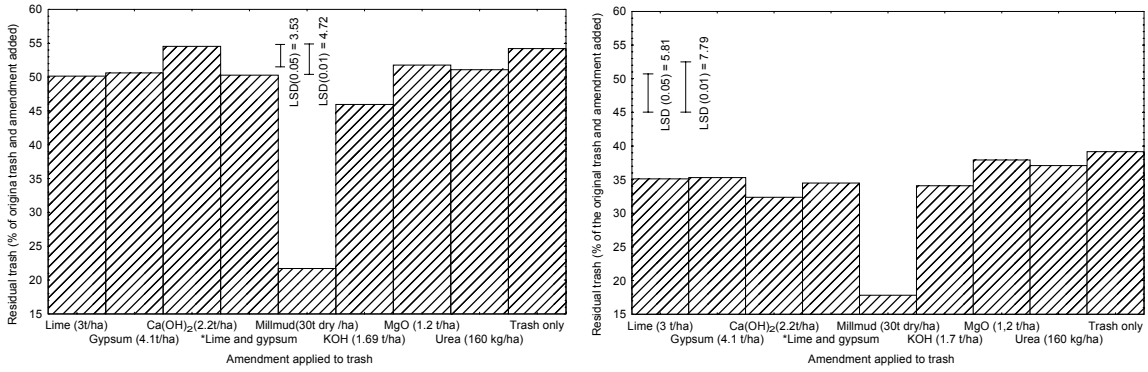


Fig. 1—pH of the 0–10 mm soil depth interval, and exch. Al in the 10–50 mm soil depth interval (Wood *et al*., 2001), as influenced by time and lime application in Experiment 1.

In Experiments 2 and 3, trash decomposition in the 'subtropical' and 'moist tropical' experiments (Experiments 2 and 3 respectively) was affected to some extent by soil type (data not shown here), but the major effects were due to the amendments applied (Figure 2). Residual trash (mass of remaining trash expressed as a percentage of the original mass of trash and amendment applied) in Experiment 2 indicated that lime, a combination of lime and gypsum, millmud, and KOH resulted in residual trash levels significantly lower ($p = 0.05$) than that of unamended trash (Figure 2(a)).



(a) Simulated subtropical environment

(b) Simulated moist tropical environments

Fig. 2—Residual trash as influenced by the type of amendment applied to the trash blanket in Experiments 2 and 3.

However, millmud resulted in residual trash levels markedly lower (about 30 percentage units) than any of the other treatments. In Experiment 3, the application of millmud again resulted in the most marked decomposition of the trash layer (Figure 2(b)). Gypsum and MgO did not contribute to increased trash decomposition.

When the residual trash data relating to the soils common to the two experiments (Kurosol and Kandosol) were pooled, it was found that similar trends to the applied amendments occurred (Figure 3). Although the amount of residual trash on the Kandosol was significantly lower than that on the Kurosol (probably due to better aeration), the most marked difference in residual trash was due to environmental effects, with the mean amount of residual trash in the moist tropical environment significantly lower ($p<0.01$) than the mean amount of trash remaining in the simulated subtropical environment. As millmud was the only amendment that did not result in a significant difference in residual trash between the subtropical and moist tropical conditions, it appears to be effective in enhancing trash decomposition across the two environments.

A rationalised set of treatments (lime applied to trash, millmud applied to trash, surface applied lime (no trash), trash (no amendment), and no trash or amendment (Experiment 3 only)) was considered when assessing the ameliorative effect of applying amendment to the trash blanket. Wood *et al*. (2001) reported that in the subtropical environment (Figure 4(a)):

- Soil type, treatment and depth below the trash layer had a significant interactive effect on soil pH.
- While surface applied lime increased soil pH across the five soil types, the presence of a trash blanket (in the absence of any amendments) had variable effects on soil pH.
- Surface applied trash appeared to increase the pH of the Kurosol, Humic Podosol and Kandosol, but in the Hydrosol this effect was less marked, probably due to a higher buffering capacity.
- In the Vertosol, the presence of trash resulted in a decrease in soil pH.
- Lime applied to the surface of the trash layer resulted in soil pH values similar to or less than that of the surface applied lime in the absence of trash in all the soils except the Kurosol. Lime applied to the trash blanket on the Kurosol resulted in higher soil pH values in the sub-surface layer than when lime was applied in the absence of trash.

In the moist tropical environment, pH trends were similar to those noted in Experiment 2 in the acid soils (Figure 4(b)). However, a higher buffering capacity of the Dermosol probably contributed to a smaller increase in soil pH than in the other soils. Lime application to trash on the Kurosol again resulted in higher pH values in the sub-surface layers (10–20 and 20–50 mm) than when lime was applied in the absence of trash. This may have important implications for certain acid soils where amelioration of sub-surface layers may be enhanced by this interaction of lime and trash, and possibly due to more soluble organo-calcium complexes.

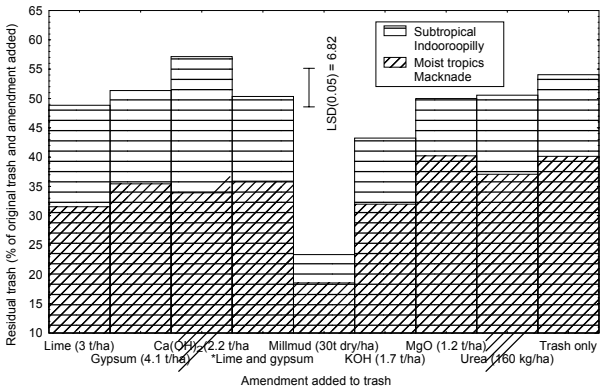
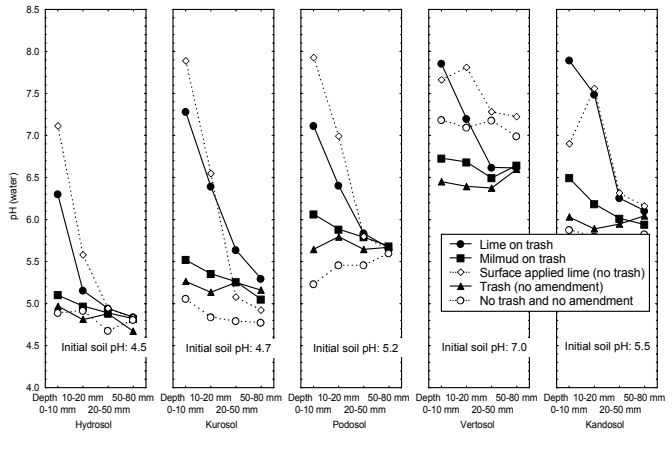
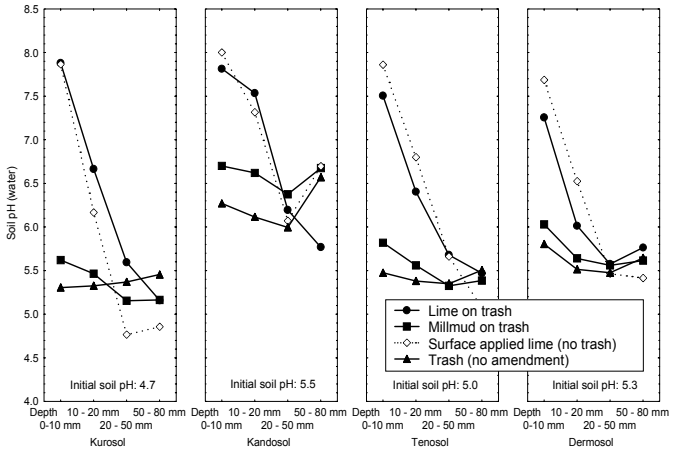


Fig. 3—Residual trash as influenced by environment (subtropical vs moist tropical) and amendment applied.



(a)



(b)

Fig. 4—Interactive effect of soil type, treatment and depth on soil pH in
(a) Simulated subtropical environment (Wood *et al*., 2001): LSD(0.01) = 0.46;
(b) Simulated moist tropical environment: LSD(0.05) = 0.77; LSD(0.01) = 0.84.

Assessment of trash decomposition and soil amelioration in a field trial (Experiment 4)

Method

A trial was established to evaluate the interaction between trash and lime/millmud under field conditions (Table 4). Soil samples were collected from beneath the green cane trash blanket at the site prior to the layout of the trial. The amount of trash originally present was determined. Quadrats were established in each plot to enable measurement of trash decomposition. Treatments (Table 4) were applied on the surface of the trash. Residual trash and soils samples were collected from each quadrat immediately prior to harvest of the next crop.

Table 4—Details of Experiment 4 at Macknade.

Selected mean pre-treatment topsoil values (0–200 mm)		Treatment applied
		Lime (2.5 t/ha)
pH(water)	5.73	Lime (5 t/ha)
Org C (%)	0.7	Millmud (60 dry t/ha)
Exch. Ca (cmol(+) kg^{-1})	7.55	Millmud/mill ash (60 dry t/ha)
ECEC (cmol(+) kg^{-1})	9.28	Control (unamended trash)

Results and discussion

In relation to trash decomposition, all but the lime (applied at 2.5 t/ha) resulted in significantly less trash than the control (trash with no amendment added) after a twelve month period (Figure 5). Millmud (60 dry t/ha)), millmud/ash combination (60 dry t/ha) and lime (5 t/ha) were equally effective in their ability to decompose trash.

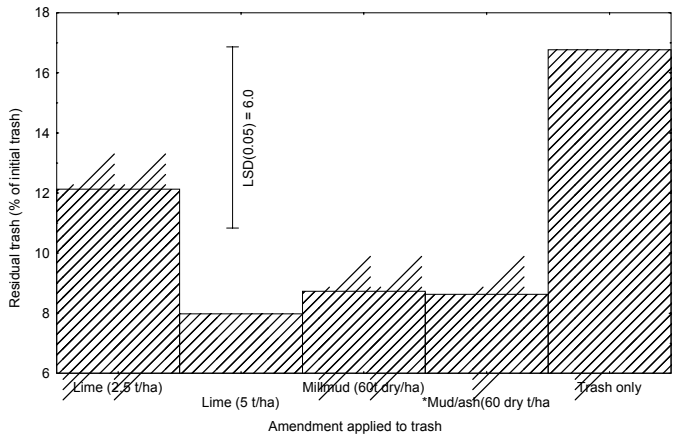


Fig. 5—Residual trash (% of initial trash present) associated with each of the amendments applied to the surface of the trash blanket in the field trail at Macknade (Experiment 4).

Although the initial soil pH and exch. Ca values of the soil indicated that amelioration of acidic conditions was not required (Table 4), soil pH values were increased by the application of the amendments to the trash blanket (Figure 6). As expected, the lime applications resulted in the largest increase in soil pH. Although the millmud/mill ash mixture resulted in a moderate change in

soil pH, not change in soil pH occurred when millmud only was applied (Figure 6). This effect was probably due to the increased buffer capacity of the soil due to increases in organic C. The unamended soil has a relatively low buffer capacity due to low clay and organic C contents (Table 4). In general millmud/mill ash mixtures are generally lower in organic C than plain millmud, and have added abilities to increase soil pH values due to the nature of the ash material.

The absence of a change in soil pH when millmud was applied to trash has important implications for certain soils, particularly where enhanced trash decomposition is desirable without further elevation of soil pH above 5.5.

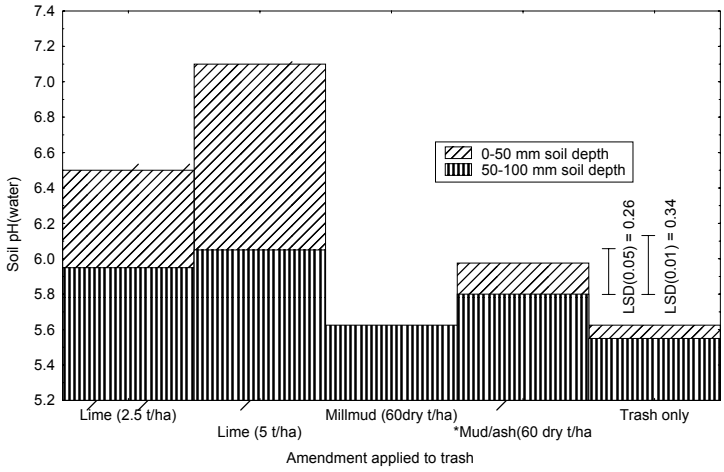


Fig. 6—pH of the soil below the trash blanket as influenced by the application of various amendments.

Nutrient availability

Method

Two separate but linked pot experiments (Experiments 5 and 6) were used to determine whether the application of calcium-based to trash would deliver benefits in terms of nutrient availability to sugarcane.

While Experiment 5 was conducted at Macknade and included soils found in the Herbert River district, Experiment 6 was conducted in Bundaberg using three local soils and one soil from the Herbert region (Tables 5 and 6).

Three previously germinated single-eyed setts of sugarcane were planted in the pots filled with appropriate soils. An equivalent of 15 t/ha of trash was applied to each pot. The amendments (Table 5) were spread on the surface of the trash layer in each pot. The pots were placed on exterior seedling benches and watered regularly with automatic overhead water sprinkling systems.

The above ground parts of the sugarcane plants were harvested at six months of age, weighed, shredded, dried and re-weighed. The dried biomass was dispatched to a laboratory for chemical analysis.

Table 5—Details of pot experiments conducted at Macknade and Bundaberg.

Pot experiment	5	6
Soils	River sand (Rudosol)	Woongarra (Ferrosol)
	Red loam (Kandosol)	River sand (Rudosol)
	River overflow (Dermosol)	Oakwood (Kandosol)
	Fine black sand (Hydrosol)	Kepnock (Yellow Dermosol)
Variety	Q158	Q155
Amendments	Trash only, millmud (80 wet t/ha), mill ash (80 wet t/ha), lime (5 t/ha)	

Table 6—Selected chemical properties associated with the soils used in the pot experiments at Macknade (Experiment 5) and Bundaberg (Experiment 6).

Exp. No.	Soil type	pH (water)	Org C (%)	BSES P (mg/kg)	Nitric K	Exch K	Exch Ca	ECEC
					(cmol(+)/kg)			
5	River sand	5.1	0.4	137	1.46	0.13	1.27	2.47
	Red loam	5.6	0.9	38	1.79	0.19	3.04	3.82
	River overflow	5.3	1.6	102	3.25	0.32	6.98	7.69
	Fine black sand	5.5	2.6	61	1.08	0.10	3.27	4.08
6	Woongarra	6.3	1.1	65	0.73	0.25	4.21	8.69
	River sand	5.2	0.4	176	1.68	0.13	1.29	2.51
	Oakwood	5.8	1.2	10	0.66	0.38	3.56	6.50
	Kepnock	5.4	0.8	39	0.42	0.30	3.86	5.46

Results and discussion

The mean dry matter yield values associated with the amendments applied to the trash in Experiment 5 (Figure 7) indicated that the largest response occurred due to the application of millmud (80 wet t/ha), but that the application of mill ash (80 wet t/ha) and lime (5 t/ha) also resulted in significantly higher yields than the trash only treatment. Although, both the mill mud and mill ash could have directly and indirectly improved the moisture status of the soil, this would not have been the case when lime was added. In terms of the soil test values (Table 6) responses to applied nutrients other than N and K were unlikely (Wood *et al.*, 2003), despite the large amounts of nutrients present in the millmud and mill ash. The responses to the amendments applied to the trash layer were therefore attributed, at least in part, to the enhanced decomposition of the trash and presumably the release of N from the subsequent increase in organic carbon.

Millmud and mill ash treatments resulted in significantly higher amounts of N, P and K removed by the harvested biomass (Figure 8). These elevated values could either have been the result of the nutrients within the amendments themselves, or due to enhanced decomposition of the trash, or a combination of both of these effects.

In Experiment 6, the mean dry matter yield values associated with the amendments applied to the trash in Experiment 6 (Figure 9) indicated that, as in the case of the Macknade experiment, the largest response was due to the application of millmud (80 wet t/ha). Although the application of mill ash (80 wet t/ha) also resulted in a significant increase ($p<0.05$) in dry matter production compared to the unamended trash treatment, lime (5 t/ha) applied to the trash blanket did not result in significantly different yields. This was surprising as lime applied to trash had increased decomposition of the trash layer in all previous experiments and had resulted in increased yields in Experiment 5.

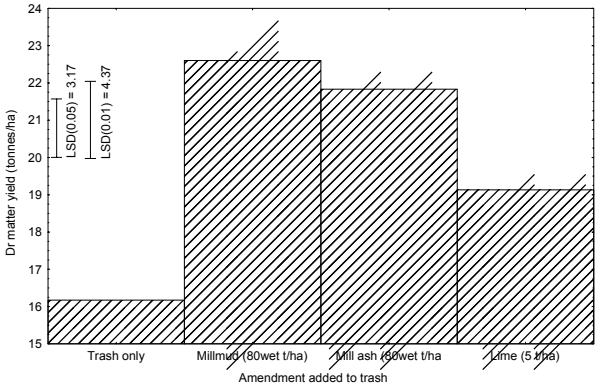


Fig. 7—Mean dry matter yield values associated with each of the amendments applied to the trash in Experiment 5.

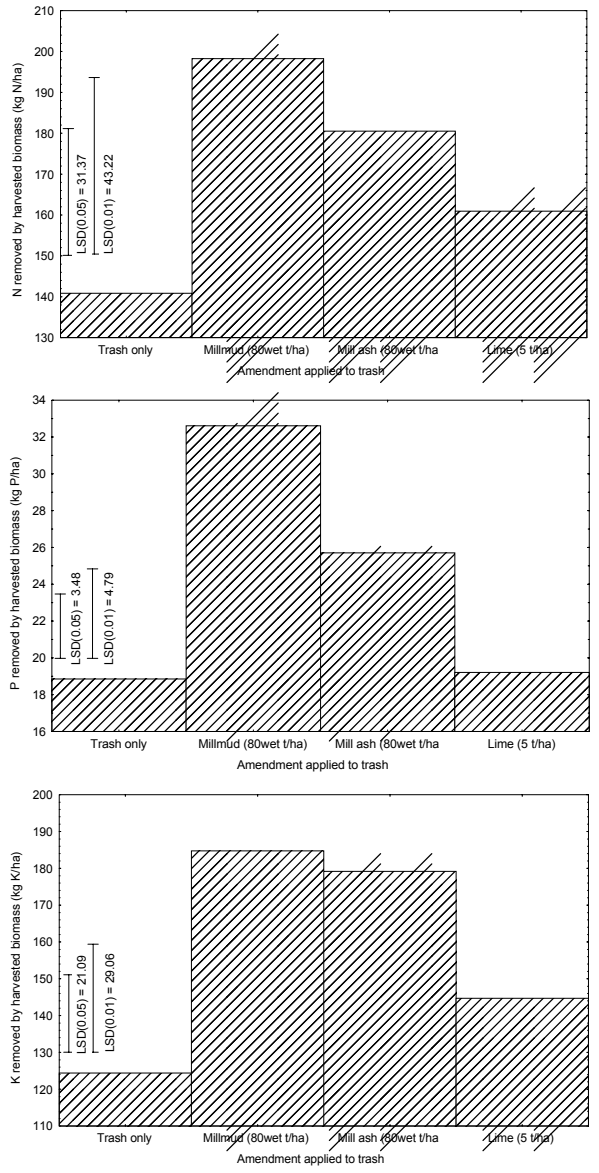


Fig. 8—N, P and K removal plotted against amendments applied to the trash in Experiment 5.

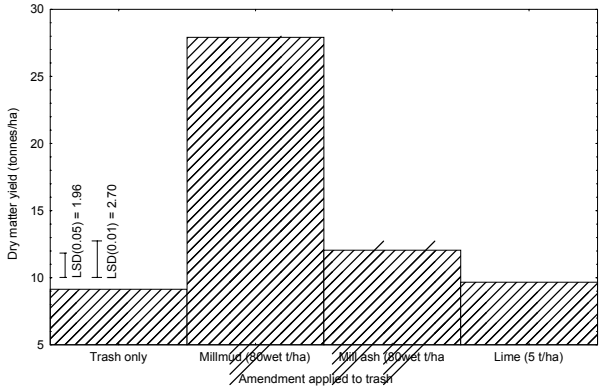


Fig. 9—Mean dry matter yield values associated with the amendments applied to the trash in Experiment 6

Unlike the Macknade experiment (Experiment 5), soil type and amendment applied to the trash resulted in a significant interactive effect ($p<0.01$) on dry matter yield (Figure 10). In particular, millmud applied to the trash layer on the Rudosol (River sand) and the Dermosol (Kepnock) resulted in significantly lower dry matter yields than those achieved on the Ferrosol (Woongarra) and Kandosol (Oakwood).

However, the yields obtained on the Rudosol and Dermosol were not substantially different to the mean dry matter yield value (22.5 t/ha) associated with the millmud application to trash in Experiment 5.

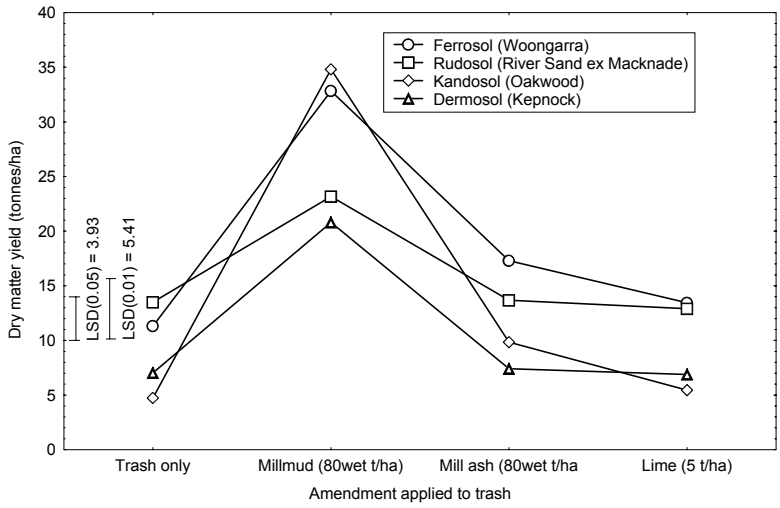


Fig. 10—Interactive effect of soil type and amendment applied to the trash on dry matter yield in Experiment 6

Nitrogen, P and K removal by the harvested biomass (Figure 11) reflected the trends that occurred in dry matter yields (Figure 9).

The differences noted between the two trials are best explained by the differences in the amount of water that moved through the pots. As both experiments were conducted on external seedling benches, the Macknade experiment would have benefited from both the irrigation water and the relatively high rainfall in the moist tropical conditions.

A total of 596 mm of rainfall was recorded at Macknade over the duration of the experiment. At Bundaberg, only 203 mm of rainfall was recorded during the trial period and hence much of the water was from the automatic irrigation system.

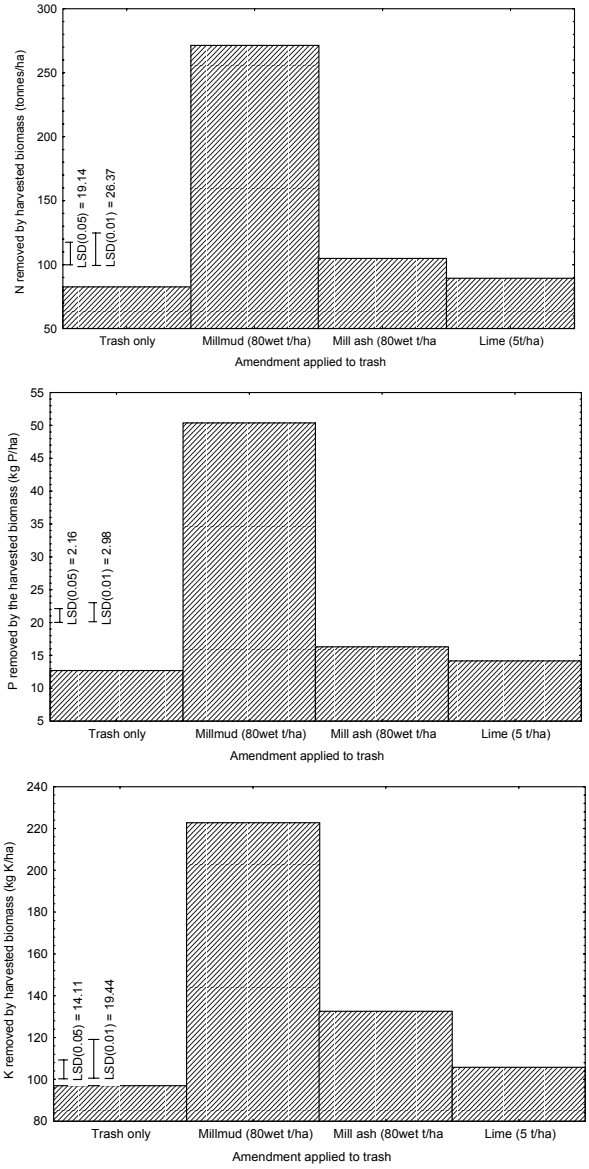


Fig. 11—N, P and K removed by the harvested biomass plotted against amendments applied to the trash in Experiment 6

Conclusions

Calcium-based amendments such as lime, millmud and mill ash have been shown to have the potential to accelerate the decomposition of sugarcane trash. Importantly this decomposition appears to be most effective when the amendments are applied to the surface of the trash layer. When comparing the effectiveness of the amendments in assisting decomposition, millmud repeatedly outperformed the other amendments.

Whereas other amendments such as $Ca(OH)_2$ and KOH did have the ability to enhance the decomposition process, they are not considered suitable for widespread use in the industry due to their corrosive nature.

Importantly, the enhanced trash decomposition that occurred due to lime and millmud applied to trash in pots under semi-controlled conditions was also found to be applicable in the field.

The differences in the rates of decomposition in the simulated subtropical and moist tropical conditions suggest that environmental conditions involving temperature and the amount of water (rain and/or irrigation) are important factors within this trash/ameliorant system.

Lime applied to the surface of the trash layer did have the ability to ameliorate acid soil conditions. In some soils lime applied to the trash blanket resulted in higher pH values in the sub-surface soil layers than when lime was applied in the absence of trash.

This apparent synergistic effect has important implications for certain soils especially when minimum tillage is practiced. Importantly, millmud applications to the surface of the trash layer also resulted in some amelioration of the subsurface layers in terms of reduced soil acidity.

Although millmud and mill ash applications to trash resulted in significantly higher amounts of N, P and K removed by the harvested biomass, these elevated values could either have been the result of the nutrients within the amendments themselves, or due to enhanced decomposition of the trash, or a combination of both of these effects.

The effect on nutrient uptake by sugarcane when lime was applied to trash was less apparent. Environmental effects (water, temperature and soil properties) are considered important factors in relation to the overall nutrient availability in these amended trash systems

Acknowledgements

SRDC, CRC Sugar, BSES Limited and CSR Sugar contributed financially to the work reported in this paper. The authors would like to acknowledge the initial contribution made by Dr Robert Aitken to the project. Jason Hillyard, Tim Shapter and Lee Aitken (BSES), Sandra Coco, Lenelle Martin, Naomi Mackee (CSR Sugar), and Pat Victor and Bruce Compton (QDNR&M) are thanked for their valuable technical assistance.

REFERENCES

Aitken, R.L., Moody, P.W. and Dickson, T. (1998). Field amelioration of acidic soils in south east Queensland. 1. effect of amendments on soil properties. Aust. J. Agric. Res., 49: 627–637.

Kingston, G. and Aitken, R.L. (1994). Final Report on SRDC Project BS98S Factors affecting the residual value of lime. BSES Publication SRDC Final Report SD97002.

Kingston, G., Davis, R.J., Chapman, F.L. and Nielsen, P.J. (1998). Progress with green cane systems research in cool wet environments. Proc. Aust. Soc. Sugar Cane Technol., 20: 552.

Mitchell, R.D.J. and Larsen, P. (2000). A simple method for estimating the return of nutrients in sugarcane trash. Proc. Aust. Soc. Sugar Cane Technol., 22: 212–216.

Moody, P.W. (2002). Maintenance of soil organic matter. In: Bruce, R.C. ed. Managing Soils, Nutrients and the Environment for Sustainable Sugar Production, 99–101. CRC Sugar, Townsville.

Noble, A.D., Bramley, R.G.V., Wood, A.W. and Hurney, A.P. (1997). Sugarcane and soil acidity—Why should we be worried? Proc. Aust. Soc. Sugar Cane Technol., 19: 187–199.

Robertson, F.A. and Thorburn, P.J. (2000). Trash management: consequences for soil carbon and nitrogen. Proc. Aust. Soc. Sugar Cane Technol., 22: 225–229.

Wood, A.W. (1991). Management of crop residues following green harvesting of sugar cane in north Queensland. Proc. Aust. Soc. Sugar Cane Technol., 25: 14.

Wood, A.W., Schroeder, B.L. and Aitken, R.L. (2001). The effect of various calcium amendments applied to sugarcane trash. Proc. 10th Aust. Agron. Conf., Tasmania, (CD-ROM), 4 p.

Wood, A.W., Schroeder, B.L. and Stewart, R.L. (2003). The development of site-specific nutrient management guidelines for sustainable sugarcane production. Proc. Aust. Soc. Sugar Cane Technol., 25: (CD-ROM), 12 p.