# SRA Grower Group Innovation Project

# Final Report

# GGP1102

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| SRA project number: | GGP1102 |
| SRA project title: | Assessing the impact of biochar in the Herbert cane industry. |
| Group name: | The Biochar Grower Group of Lannercost |
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## Executive Summary:

Biochar is the charred by-product of biomass pyrolysis, the heating of plant-derived material in the absence of oxygen in order to capture combustible gases. It is generally accepted that biochar is a highly stable form of carbon and as such has the potential to form an effective C sink, therefore sequestering atmospheric CO2.

The objective of this report was to report on the findings of a SRDC/SRA funded Grower Group project that was undertaken in the Herbert cane growing region between 2012 and 2014 to assess the impact of biochar and compost in a sugarcane farming system. The trial was conducted on a low cation exchange capacity soil in the Lannercost farming area west of Ingham.

A large number of studies (on numerous crops) have been conducted where biochar application has shown significant agronomic benefits, with a minor number of studies showing no significant effects on crop productivity and some studies reporting adverse effects (Sohi et. al., 2009). These results clearly suggests that crop productivity is variable due to a multiple number of reasons which are not fully understood. The mitigation potential of biochar with regard to other greenhouse gases, such as $N_2O$ and $CH_4$, through its application to soil is less well established and requires further research (Sohi et. al., 2009). In this particular trial there were no significant difference in levels of greenhouse gases measured for the various treatments accessed.

In the trial conducted for this project, there was no significant cane productivity (being measured as cane and sugar yield) or economic advantage from applying biochar. The only way biochar may become viable is if a carbon market is established. The economic value of sequestered carbon is still being researched and debated in scientific and political arenas, so while this is occurring it will be challenging for biochar to be economically viable based upon the results from this trial. If biochar is to be considered as a part of a carbon sequestration program, a whole of carbon life cycle analysis will be required to better understand the carbon pathways and potential loss mechanisms.

In this trial the use of biochar in a sugarcane farming system is uneconomical based upon the results obtained. The only way that biochar may be economically viable in a sugarcane farming systems is through a government or community carbon credit program whereby a grower may be paid for the amount of carbon sequestered.

Composts can be a useful source of nutrients, however the nutrient content of parent materials will need to be considered. This trial has shown that sugarcane can be produced using compost as a nutrient source. If composts are to provide the nutrients for cane growth, an assessment of total nutrients present and their availability and speed of release will be required. Because the nutrients are in organic forms in compost, the availability of nutrients may be variable.

Composts should only be applied when they are “stabilised” and are not being acted upon by microbial activity. In this trial it is suspected that the composting process was still active when the product was applied and the compost was not yet “stabilised”. Germination and establishment of the plant cane were negatively impacted upon, with the crop showing nitrogen deficiencies in early stages of growth due to the compost not releasing sufficient nitrogen for crop growth. Composts could be a useful source of nutrients to grow a crop, however the economics associated with purchase and application will need to be considered.

## Background:

Sugarcane belongs to the family Poaceae, comprising several species of perennial tall grasses of the genus *Saccharum*. The crop is cultivated in around 90 countries, primarily for sugar, but also for bioethanol and electricity production.

In Australia in 2010-2011, 308,000 ha were planted to sugarcane, producing 25 million tonnes of cane for crushing at an average yield of 82 t/ha (ABS, 2012). The highest average annual district yield applicable in north Queensland is 100 t/ha with a yield potential of 120 t/ha (Schroeder et al., 2010). Australia is the third largest producer of raw sugar, producing 4-4.5 million tonnes of raw sugar annually. The industry is valued at $1.7-2.0 billion annually, with 80% of production for export. Sugarcane production therefore represents a very significant and extensive industry in Australia.

In general terms, sugarcane is a wet tropical crop that benefits from a well-drained, well-aerated, porous soil with pH between 5 and 8.5. Compacted soils affect root penetration, water and nutrient uptake and the crop is moderately sensitive to soil salinity. Sugarcane has a shallow root system and yield is heavily dependent on nutrient supply and availability. In north Queensland, nutrient requirements are usually in the range 100-180 kg N/ha, 20-40kg P/ha and ~70kg K/ha (Wood, 1985). In addition, calcium, magnesium and sulphur are often required, depending on soil type and cropping history. The trace nutrients, copper, zinc, iron, manganese, boron, molybdenum, chloride and silicon may also be required in small quantities.

Garside et al. (2005) concluded that a long-term decline in sugarcane yield in Australia has resulted from the intensive cultivation of sugarcane as a monoculture, resulting in declining soil health. This is manifest as lower soil pH, microbial populations, soil organic carbon, water infiltration capacity and essential nutrients as well as higher bulk density, exchangeable aluminium and pathogens. Sugar yield per plant is predicted to increase in the future, as a result of higher atmospheric $CO_2$ levels, however the available simulations do not account for changing distribution of rainfall as a result of climate change (Singels et al., 2013), which may negatively impact on rain-fed crops.

In addition to problems associated with declining yields and soil resilience, significant issues for the sugarcane industry in Australia relate to the heavy dependence of the industry on chemical fertilizers. Fertilizer use has resulted in nutrient runoff to the Great Barrier Reef (Armour et al., 2013; Brodie and Mitchell, 2005; Thorburn and Wilkinson, 2013) along with the potential for significantly increased greenhouse gas fluxes - particularly $N_2O$ - to the atmosphere (Allen et al., 2010; Denmead et al., 2010; Thorburn et al., 2010). Any fertilizer losses also decrease crop profitability (Armour et al., 2013).

There have been significant efforts to adapt farm management practices to reduce environmental impacts on soil degradation, nutrient runoff and GHG emissions, including strategies associated with residue management (Wood, 1991; Robertson and Thorburn, 2007; Page et al., 2013) and fertilizer optimization (Thorburn et al., 2011; Webster et al., 2012), with variable success. Whereas optimized fertilizer applications can reduce requirements it is unclear, for example, whether there is a significant benefit to soil carbon and nitrogen associated with the use of trash blankets (Robertson and Thorburn, 2007; Page et al., 2013).

Considerable quantities of bagasse (the ligno-cellulosic stalk remaining after sugar extraction) is produced by the industry worldwide. As a result there has been considerable research that has demonstrated the feasibility of generating biochar from bagasse feedstock (e.g. Zandersons et al., 1999; Katyal et al., 2003; Parihar et al., 2007; Inyang et al., 2010). These studies have determined that the characteristics of bagasse biochar and its sorption characteristics are strongly dependent on pyrolysis temperature.

There has been comparatively little research on the use of biochar on soils cropped to sugarcane. Chan et al. (2010) found that bagasse biochar increased soil water holding capacity, cane yield and cane sugar content while decreasing nitrate losses through infiltration in a field trial in Japan. Yang et al. (2014) used a pot trial approach to demonstrate that cassava stem biochar improved sugarcane seedling root properties at seedling stage, and also raised soil pH and significantly increased available nutrients. Kameyama et al. (2012) found that bagasse biochar produced at 800˚C could increase the residence time of nitrate in the root zone thus providing greater opportunities for crop uptake. Eykelbosh et al. (2014) reported dramatic decreases in CO2 flux from filtercake-biochar amended sugarcane soils in comparison with filtercake amended soils in Brazil, as well as improved water retention and nutrient availability. Eykelbosh et al. (2015) found that the same biochar application to Brazilian sugarcane soil reduced leaching of dissolved organic carbon but did not have a significant effect on nitrate leaching.

Quirk et al. (2012) reported results from a pot trial suggesting that bagasse/trash biochar reduced $N_2O$ fluxes from alluvial soils in the Burdekin region in Queensland. They also reported preliminary results from a field trial using green waste and paper mill residue biochar on sugarcane in northern NSW, with no effect of biochar discernible on either yield or leaf nutrients in the first year.

There has been some recognition of the potential for composts to be utilized in the sugarcane industry in order to halt or reverse soil fertility decline (e.g. Kumari et al. 2014). There is also some research into the use of compost amendments in combination with conventional fertilizers or ameliorants such as gypsum on soils cropped to sugarcane. These have generally demonstrated variable improvements in soil properties (carbon and nutrient content, water holding capacity) and also in leaf nutrients and cane yield (Viator et al., 2002; Tan et al., 2012).

Of particular relevance in tropical Queensland have been the field trials of Calcino et al. (2009). This study investigated the effects of using Bedminster compost, incorporated into the soil at a high rate of application (150t/ha) prior to planting, in combination with NPK fertilizers at a reduced rate and assessed against a control that had the usual rate of NPK fertilizer applied. The average increase in cane yield over all three years was 24%, with an 18% increase in sugar yield, both decreasing successively from year 1 to 3. Most soil nutrients as well as carbon and pH in the compost-amended plots remained significantly above the control plots over the three years of the trial, with the differences decreasing over time.

In summary, both biochar and compost appear to provide a variable degree of improvement to soil characteristics in terms of promotion of higher pH, lower bulk density, higher water holding capacity and improved nutrient retention. The evidence across all studies is currently equivocal in terms of yield improvement, nitrate leaching losses and the impact on $N_2O$ fluxes, likely because these are dependent also on interactions with soil type and climate. There is no research on the combined use of compost and biochar on sugarcane crops.

Compost addition has a long history in agriculture, returning carbon and nutrients to the soil thereby improving soil structure and fertility (eg Calcino et al., 2009). Biochar is charcoal produced from waste organic matter produced by controlled pyrolysis, and has demonstrated utility as a sustainable tool for carbon sequestration, soil amelioration, energy generation, greenhouse gas and fertilizer runoff reduction as well as waste management (Lehmann and Rondon, 2006; Lehmann et al., 2006). In the context of North Queensland in particular, both compost and biochar have considerable unexplored potential to reduce nutrient runoff from agriculture (particularly sugarcane farming) to the Great Barrier Reef through replacement of conventional fertilizers and the ability of biochar to minimize nutrient losses through sorption (Lehmann and Joseph, 2009).

Both compost and biochar can provide significant benefits to soil fertility and resilience. Compost addition alone provides little benefit in terms of long-term carbon sequestration or greenhouse gas flux reduction from agricultural soils. Biochar addition alone provides little available carbon to the soil carbon cycle, but does provide long-term carbon sequestration, microbial habitat and improved soil fertility. Preliminary evidence also suggests that biochar may reduce $N_2O$ flux from the soil with the magnitude likely to be dependent on soil type, climate and biochar type (Lehmann and Joseph, 2009; Singh et al., 2010). There has been comparatively little research into the use of compost-biochar mixes but research to date suggests that biochar addition during composting leads to higher nitrogen retention in the compost, heavy metal stabilization and significant volume reductions as a result of higher carbon mineralization rates (Hua et al., 2009; Dias et al., 2010). A combined biochar-compost product therefore potentially represents a high value product derived from organic waste streams, capable of providing multiple benefits in terms of improved soil fertility and reduction in carbon pollution.

The Biochar Grower Group of Lannercost consists of the following members: Geoff Morley (project leader), John Morley, Carl Accornero, Michael and Glen Cristaudo, Enzo and Joe Crisafulli, David Morselli, Tony Crisafulli, Mark Poggio and Michael Waring. Their farms are located in the wet areas of Lannercost and Lannercost Extension in the Herbert region. This area is low lying and effective drainage is difficult. The soils are acidic with a low CEC, and are subject to significant potential nitrogen losses by denitrification and leaching and are generally low in available nutrients.

## Objectives:

- To assess the impact of compost and biochar amendment on low CEC soils that are subject to significant potential nitrogen losses and are generally low in available nutrients.
- To investigate the opportunity for carbon sequestration associated with biochar and the opportunities that may arise if a "carbon trading" program is introduced into agriculture.
- To investigate the opportunity to produce biochar from locally sourced materials.

## Methodology:

A small plot replicated trial was conducted in the Lannercost area to assess the benefits of compost and biochar in a cane farming system. The trial design was a randomised complete block with 3 replicates. However the control treatment (treatment 1) had only one replicate. Plot size was 6 rows x 251 m row length x 1.65 m row spacing giving a plot size of 0.248 ha.

The trial had the following treatments:

1) Control with no biochar, compost or fertiliser applied. This treatment was included in the trial to provide baseline readings for the greenhouse gas monitoring
2) Compost at 30.3t/ha
3) Biochar at 10t/ha + supplementary fertiliser application (58 kg N/ha, 29.8 kg P/ha, 90 kg K/ha and 17.5 kg S/ha)
4) Compost at 30.2t/ha + biochar at 10t/ha
5) Conventional fertiliser application (123.6 kg N/ha, 29.8 kg P/ha, 90 kg K/ha and 17.5 kg S/ha)

(Note: No other compost or biochar treatments were included in the project because of the cost of transport and the purchase cost of the biochar.

The following assessments were undertaken as part of the trial:

*Soil carbon and soil fertility*

Samples were collected at the beginning of the experiment, at the mid-point of the experiment and immediately after harvesting at each site.

The soils were assessed for:

(i) Total organic carbon and nitrogen content by elemental analyser (Costech).

(ii) Cation exchange capacity and cation composition,

(iii) Available N, P, K and micronutrients.

(iv) Soil texture.

(v) Biochar content will be determined by hydrogen pyrolysis for biochar amended plots.

*Crop monitoring and performance*

The following measurements were taken from the cane treatments:

• Germination and establishment counts of tillers at 6-8 weeks after planting.

• A random 8-stalk sample for CCS determination at harvest.

• Leaf samples taken for nutrient analysis when the crop is 6-8 months of age.

• Stalk height, weight and leaf counts at 6, 9, 12 months after planting.

• Crop yield at harvest using SRA weighing equipment.

*Greenhouse gas fluxes*

Immediately following planting, 10cm diameter PVC soil collars were randomly located in each treatment for determination of soil $CO_2$ flux. Six collars (triplicate within row and triplicate between row) were inserted 2cm into the soil to measure total soil respiration (heterotrophic and autotrophic) and a further six collars were inserted 30cm into the soil adjacent to the surface collars to measure heterotrophic respiration only. Respiration from all collars were measured using a Licor 8100 soil respiration system on a quarterly basis (more frequently during the first three months), ensuring that measurements are made at a range of soil moisture contents during the year.

Static chambers 20cm in diameter were used to measure $CH_4$ and $N_2O$ fluxes. These measurements were made by extracting sequential gas samples from the chamber over a period of 20 minutes. The gas samples were then analysed in the laboratory by gas chromatography (Shimadzu). The increase in each species over the 20-minute collection period was used to calculate flux. Measurements were made at key periods (following application of fertiliser, during particularly wet periods) as well as at least monthly intervals throughout the crop cycle. A JCU PhD student, Amy Beavan, conducted some of the Greenhouse gas monitoring as a part of her studies.

Both the plant and first ratoon crops were assessed as part of the project. The trial was harvested annually using SRA equipment (weigh bin and harvester).

Biochar was provided by Renewable Carbon Resources Australia for the project and was made from Gidgee trees (*Acacia cambagei*) and the compost was provided by the SITA composting plant in Cairns.

## Results and Outputs:

This project has brought together the Grower Group, Herbert Cane Productivity Services Limited (HCPSL), James Cook University (JCU), SITA Organics and Renewable Carbon Resources Australia. The grower group is appreciative of the effort, co-operation and support from the various supporting agencies/ groups.

HCPSL staff have assisted the group to establish the trial and have provided ongoing monitoring of the site. HCPSL were also responsible for the reporting and extension activities associated with the project.

Professor Michael Bird and Dr. Paul Nelson (JCU, Cairns campus) each have two decades of research experience in greenhouse gas flux determination, tropical agronomy, soil carbon cycling, carbon sequestration and biochar manufacture/characterization. Professor Bird oversees the biogeochemistry laboratory at JCU-Cairns while Dr. Nelson oversees the tropical soil science laboratory at JCU in Cairns. Both Michael and Paul have overseen the greenhouse gas sampling undertaken on site.

PhD student Amy Beavan from JCU-Cairns has used the site as a part of her studies. Amy will be assessing the potential benefits of composting with biochar with a particular focus on changes and reductions to green-house gas emissions (carbon dioxide, methane and nitrous oxide) using a INNOVA 1412 field photo-acoustic spectrometer. Amy has produced compost from various local feed-stocks, with and without the inclusion of biochar as a feedstock on a small scale at the university. The opportunity to participate in the grower group project provided her with an invaluable opportunity to scale up her investigations and it is anticipated that the findings will be useful in determining the carbon offsetting potential of the management practice.

Chris Walsh from SITA Organics has assisted the project with field and compost monitoring activities.

Renewable Carbon Resources Australia assisted the project by providing the biochar at short notice and at a subsidised price to enable an assessment of the product in a cane farming system.

### Trial establishment

Prior to the trial establishment soil tests were taken from the block and a nutrient management plan was developed in accordance with 6 Easy Steps Guidelines for the conventional treatments.

The biochar was purchased from Renewable Carbon Resources Australia based at Charleville, Queensland and transported to the Lannercost site in 1 tonne easy lift bags (Figure 1). The biochar was made from timber sourced from the Charleville area and treated through a pyrolysis process.

Figure 1. Biochar in 1 tonne easy lift bags at the Lannercost site

The biochar was applied to the site on 11th September 2012 through the use of a Marshall Spreader unit. It was applied to the row area where the cane was to be planted (Figure 2).

Figure 2. Biochar applied to the cane row area

The compost was sourced from SITA Organics based in Cairns. The compost is made from municipal waste that has been processed at the SITA waste plant in Cairns (Figures 3, 4 and 5). The product was transported in 2 truck and dog trailers to the Lannercost site on the 11th and 12th of September 2012 (Figure 6).

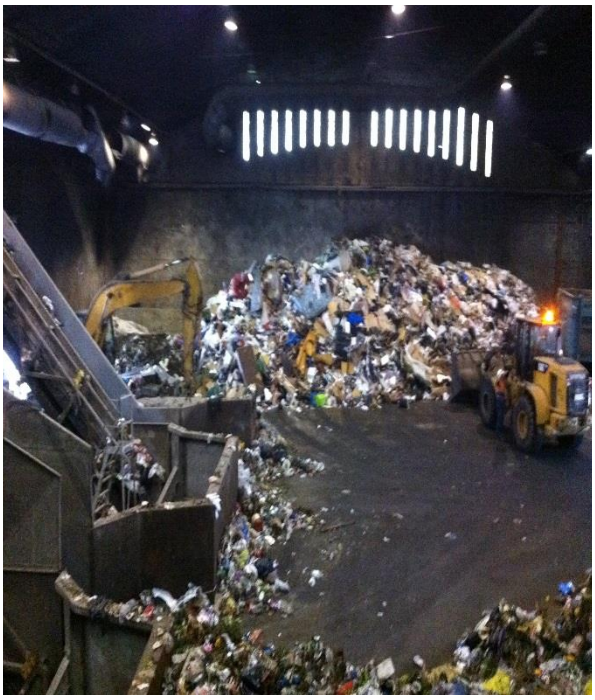

Figure 3. Waste receival at the Cairns SITA site

Figure 4. Bio-digester, SITA Cairns.

Figure 5. A wind row of compost indoors at SITA

Figure 6. Compost being unloaded at the Lannercost site

Chris Walsh (SITA Organics) undertook monitoring of moisture, nutrient and heavy metal levels during the compost production phase. A test of the compost was undertaken prior to field placement (Figure 7). Chris also took soil samples from the field to gain a baseline in relation to heavy metals and pesticides as part of the project.

SITA Organics

## Product Label and Hazard Information

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Product name:** | CROP-ARRT™ REJUVENATE delivered to Geoff Morley, 12th Sept, 2012 | | | | | | | |
| **Source feedstock:** | Mixed organic wastes from households and businesses, Biosolids and Grease Trap | | | | | | | |
| **Content of elements:** | **Element** | **mg / kg** | **% w / w** | **Form** | **Element** | **mg / kg** | **Element** | **mg / kg** |
| | Nitrogen (total) | 11000 | | | Arsenic | 3.8 | DDT / DDD / DDE | <0.01 |
| | Zinc | 900 | | | Cadmium | 2.5 | Aldrin | 0.11 |
| | Potassium | 5200 | | | Chromium | 29 | Dieldrin | 0.03 |
| | Copper | 200 | | | Lead | 390 | Chlordane | <0.01 |
| | Calcium | 33000 | | | Mercury | 0.25 | Heptachlor | <0.01 |
| | Carbon | | 34 | | Nickel | 39 | HCB | <0.01 |
| | Phosphorus | 2600 | | | Selenium | < 1 | Lindane | <0.01 |
| | Sodium | 5700 | | | | | BHC | <0.02+ |
| | | | | | | | PCBs | <0.2 |
| **Classification:** | Raw Mulch ☐ Pasteurized product ☑ Composted product ☑ Mature compost ☐ | | | | | | | |
| **Fineness:** | __8mm screen___(900kg/m$^3$)______________ | | | | | | | |
| **Quantity:** | | | | | **Max rate of application:** | | | |
| _______~ 60 tonne_______ tonnes | | | | | ___________50_ tonnes / ha. | | | |

Figure 7. SITA Organics report on compost provided for the trial.

In the compost + biochar treatments the biochar and compost were applied separately (Figures 8 and 9).

Figure 8. Compost application at the site.

Figure 9. Compost + biochar treated plots. Note the differences in the colour of both products, compost being brown and biochar being grey/black.

On 13th September 2012, the compost and biochar were incorporated into the soil using a zonal ripper and rotary hoe. To ensure soil tilth consistency between all treatments, a zonal ripper and rotary hoeing operation was also undertaken.

The trial was planted on the 15th and 16th September using a double disc single row stick planter on a row spacing of 1.64m (Figure 10). The variety planted was MQ239.

Figure 10. Planting the trial

A field inspection occurred on the 7th October 2012. Tiller counts could not be undertaken at this time because the cane had not fully emerged in all treatments, however general germination observations were taken. It was noted that germination was noticeably slower in the control treatment (treatment 1), compost (treatment 2) and compost + biochar (treatment 4) compared with other treatments. Germination was good in the conventional fertiliser (treatment 5) and biochar + fertiliser (treatment 3) treatments.

A subsequent field inspection occurred on the 24th October 2012 to assess germination and establishment of the trial. Results are presented in table 1. The differences noticed on the 7th October were still present on the 24th October, with the compost (treatment 2) and compost + biochar (treatment 4) and control (treatment 1) treatments still being slower to emerge and establish compared with the conventional fertiliser (treatment 5) and biochar + fertiliser (treatment 3) treatments .

Figure 11 highlights the differences in germination between the biochar + fertiliser treatment (3) on right and compost treatment (2). Note the difference in tiller height and density of stand.

Figure 11. Comparing the germination between biochar + fertiliser treatment (3) on right and compost treatment (2) on the left. Photo taken 24th October 2012.

Table 1. Germination counts (number of tillers) undertaken on the 24th October 2012.

| Treatment name | Treatment | Rep 1 | Rep 2 | Rep 3 | Av. 5m | Av. 1m |
|---|---|---|---|---|---|---|
| Control | 1 | 8 | | | 8 | 1.6 |
| Compost | 2 | 9.5 | 9.5 | 10.5 | 9.82 | 1.96 |
| Biochar + Fertiliser | 3 | 16.25 | 14.75 | 11.5 | 14.16 | 2.83 |
| Compost + Biochar | 4 | 16.25 | 11 | 9.5 | 12.25 | 2.45 |
| Fertiliser | 5 | 13.75 | 16 | 16 | 15.25 | 3.05 |

On 29th September the block was sprayed with Gramoxone @ 1.25L/ha, Flame @ 300mls/ha and Atradex @ 2.2kg/ha to control weeds.

### Results

Biomass sampling was conducted on 9th April 2013 and on 3rd September 2013, just before mechanical harvest. Results are given in Figure 12.

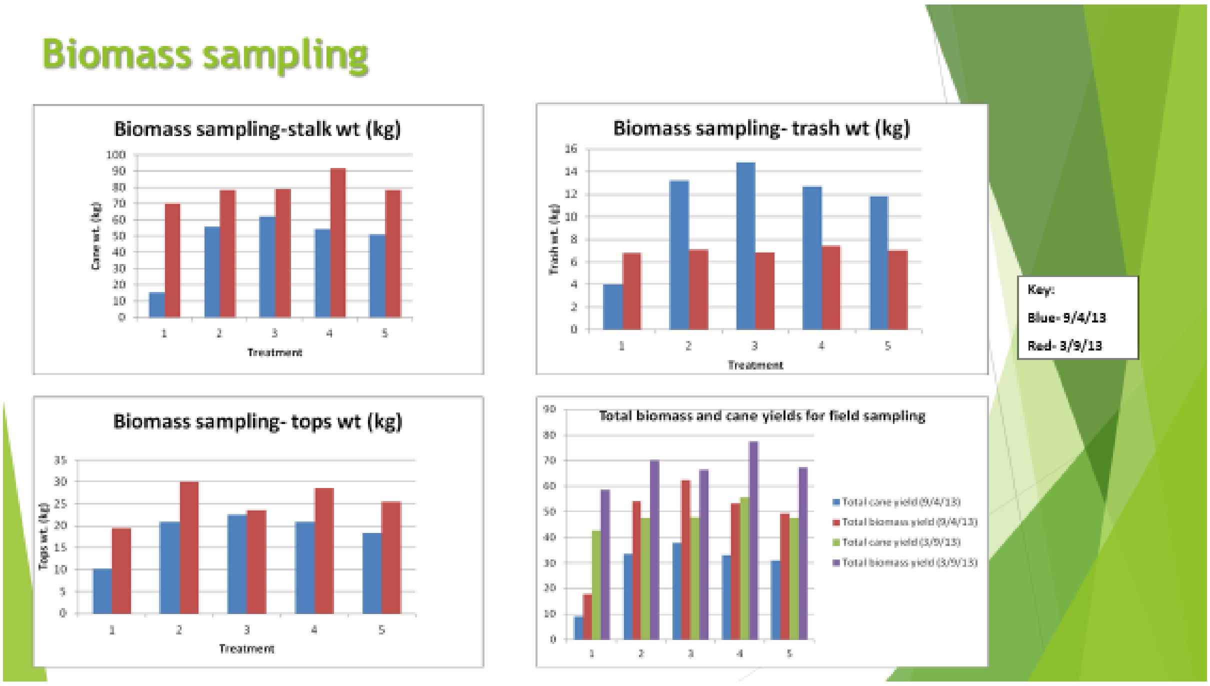


Figure 12. Results of biomass sampling on 9 April and 3 September 2013

On 10th September 2013 the plant cane was harvested mechanically. Cane yield, CCS and sugar yield data at harvest are given in Table 2.

For the first ratoon crop, tiller counts made on 7th November and 18th December 2013, and on 12th March 2014 are given in Table 3. The first ratoon crop was harvested on 15th October 2014. Harvest yield and CCS results are given in Table 4. Leaf samples were taken from each replicate of every treatment in the first ratoon crop. Results in Table 5 are means for the 3 replicates except for the control treatment where only replicate 1 was sampled.

Table 2. Plant cane yield data at harvest (10th September 2013)

| Treatment | tonnes cane/ha | CCS | tonnes sugar/ha |
|---|---|---|---|
| 1 | 35.24 C | 13.70 A | 4.83 C |
| 2 | 45.13 B | 13.82 A | 6.23 B |
| 3 | 57.44 A | 14.07 A | 8.08 A |
| 4 | 46.22 B | 13.70 A | 6.33 B |
| 5 | 48.40 B | 14.00 A | 6.76 B |

Significant differences occur when treatment means are followed by different letters

| | |
|---|---|
| Treatment 1 | Nothing applied ( this is only in rep 1) |
| Treatment 2 | Compost ( 30.2 T/ha) |
| Treatment 3 | Biochar (10T/ha) + supplementary fertiliser |
| Treatment 4 | Compost (30.2 T/ha + Biochar 10 T/ha) |
| Treatment 5 | Conventional fertiliser as per the soil test |

Table 3. Tiller counts first ratoon crop

| Treatment | Stalks/m 07/11/13 | Stalks/m 18/12/13 | Stalks/m 12/03/14 |
|---|---|---|---|
| 1 | 13.67 | 14.92 | 8.50 |
| 2 | 12.05 | 19.89 | 11.48 |
| 3 | 13.33 | 19.05 | 12.98 |
| 4 | 13.40 | 19.95 | 11.90 |
| 5 | 14.40 | 21.00 | 12.63 |

Table 4. First ratoon cane yield data at harvest (15th October 2014)

| Treatment | tonnes cane/ha | CCS | tonnes sugar/ha |
|---|---|---|---|
| 1 | 40.13 C | 15.02 A | 5.99 C |
| 2 | 64.24 B | 15.16 A | 9.75 B |
| 3 | 78.13 A | 15.64 A | 12.21 A |
| 4 | 65.55 B | 15.41 A | 10.12 B |
| 5 | 69.01 B | 15.10 A | 10.57B |

Significant differences occur when treatment means are followed by different letters

Table 5. First ratoon leaf analysis data (sampled 4th April 2014)

| Treatment | N % | P % | K % | S % | Ca % | Mg % | Na % | Fe ppm | Mn ppm | Cu ppm | Zn ppm | B ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.38 | 0.16 | 1.16 | 0.13 | 0.22 | 0.21 | 0.1 | 44 | 130 | 4.3 | 18 | 4.4 |
| 2 | 1.62 | 0.17 | 1.26 | 0.14 | 0.27 | 0.21 | 0.1 | 63 | 150 | 4.8 | 20 | 4.8 |
| 3 | 1.74 | 0.18 | 1.23 | 0.15 | 0.34 | 0.25 | 0.1 | 59 | 180 | 5.2 | 19 | 4.7 |
| 4 | 1.60 | 0.17 | 1.23 | 0.15 | 0.28 | 0.23 | 0.1 | 52 | 150 | 5.0 | 20 | 4.9 |
| 5 | 1.68 | 0.18 | 1.22 | 0.16 | 0.28 | 0.25 | 0.1 | 64 | 190 | 5.1 | 20 | 4.9 |

Amy Beavan (JCU- Cairns) commenced the first set of greenhouse gas measurements on the 24th September, 2012, one week following planting. Measurements were taken from each of the treatments within each of the replicates, mid-way down the third row of the treatment. A closed chamber was incorporated into the soil system. Soil collars (made from PVC pipe off-cuts) were set in the soil a day after planting and allowed to 'settle' in the soil for a week (Figure 13). These open collars were then closed off prior to analysis using a lid with attached tubing connecting the inlet and outlet pumps of the gas monitor. This allowed emitted gas to accumulate inside the chamber for thirty minutes. Soil temperature and moisture was measured adjacent to each collar to allow for consideration of temporal differences. Figure 14 shows Amy Beavan collecting gas samples and recording data.

Figure 13. Soil collars located across the trial site

Figure 14. Amy Beavan undertaking gas sampling at the trial site

Three sampling arrangements were used:

- For the September 2012 and November 2012 sets, gas emissions were measured across all four treatments and the control, one from each of the thirteen replicates.
- For the March 2013 set, gas emissions were measured across all four treatments and the control more intensively, with three measurements taken from each replicate.
- For the December 2012 and January 2013 sets, gases were measured from treatments 3 and 5 only, with three measurements taken from each replicate.

An example of the emission results is given in Figure 15.

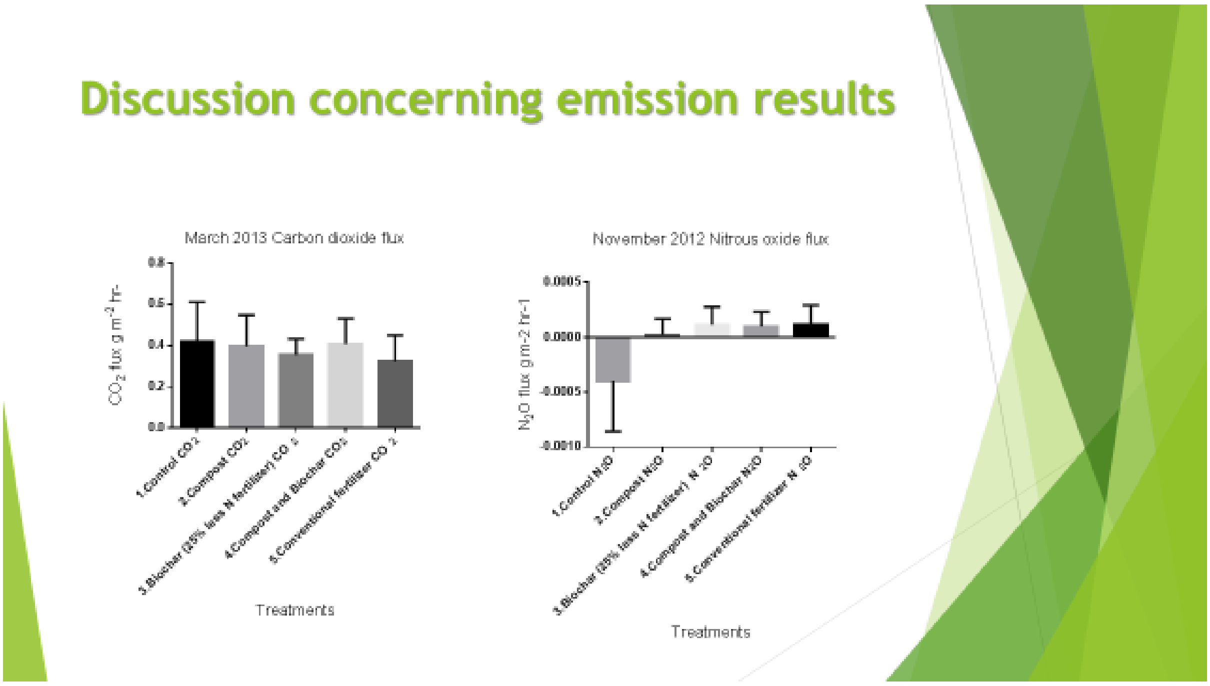


Figure 15. Carbon Dioxide flux in March 2013 and Nitrous Oxide in November 2012

Soil tests were taken on the 4th of September, 2013 prior to compost and biochar applications and planting, on the 9th of October, 2013 post planting and following the harvest of the plant crop in 2014. There was no significant difference found between treatments for soil pH (water), EC (dS/m), organic carbon (OC), phosphorus (BSES) and (Colwell), Potassium (Nitric K) and (Am. Acetate), sulfate, calcium, magnesium, sodium (Am.acetate), sodium % cations, aluminium, CEC, copper (DTPA), Manganese (DTPA), zinc (BSES-HCl) and silicon (CaCl2). Heavy metal levels in soil were not measured, however it is recommended in future trial work.

## Discussion and Conclusions

It is interesting that early germination and establishment were more rapid in the two treatments with fertiliser (treatments 2 and 5). This difference was maintained in the germination count conducted 5 weeks after planting (Table 1). The most likely explanation is differences between treatments in the availability of nitrogen. Mineral nitrogen in the soil before the experiment was conducted must have been low, hence the slow germination in treatment 1. This is supported by the leaf analysis results (Table 5) which showed that the nitrogen content in the crop in the control treatment was lower than the other treatments. The differences in other nutrient levels was much less.

The compost too must have contained little mineral nitrogen when it was applied to the trial. The compost analysis (Figure 7) only provides a total nitrogen figure and most of this nitrogen was probably in the organic form.

The results of the first biomass sampling showed that plant cane in the control treatment was very slow to accumulate cane. The cane yield at 7 months after planting was <10t/ha. This was less than a third of the cane yield in the other 4 treatments. The cane yield at harvest in this treatment was significantly lower than the other four treatments. The treatment with Biochar and supplementary fertiliser had the highest cane and sugar yield and this was significantly higher than the other 4 treatments. There was no significant difference between the yields in treatments 2, 4 and 5.

In the first ratoon crop average yields were higher but again the cane and sugar yields in the control treatment were significantly lower than the other 4 treatments. The treatment with Biochar and supplementary fertiliser had the highest cane and sugar yields and these were significantly different from the other 4 treatments.

There was no significant difference in crop performance between the compost only treatment and the compost plus biochar, so clearly the combination of the two did not have any beneficial effects in this particular trial. However there was a significant difference between the fertiliser only treatment and the biomass plus supplementary fertiliser. Furthermore there was less nitrogen fertiliser in the biochar plus fertiliser treatment (58 kg N/ha vs 123.6 kg N/ha), whilst the other nutrients (P,K and S) were the same. The combination of biochar plus fertiliser is certainly worth further investigation particularly if it can be successfully used with reduced levels of nitrogen fertiliser.

The data collected on greenhouse gas emissions showed no significant differences between treatments for carbon dioxide and nitrous oxide.

## Outcomes:

The project did not deliver the outcomes it initially proposed, however there has been some critical learnings from the project.

(i) The project did not show that there was a reduction in GHG emissions from a tropical sugarcane production system through decreases in nitrogen applications associated with biochar, compost or biochar/ compost combinations. The project did generate useful data to better understand what impact the use biochar and compost has in a cane production system.

(ii) The project generated considerable discussion between Grower Group members and members of the Herbert Sustainable Farming Systems Group meeting in relation to healthier soils and ways to implement change within a sugarcane farming system to improve soil health. The economics associated with changes within the farming systems were also discussed.

(iii) The trial highlighted that nutrient management and nutrient availability is complex, especially when dealing with nutrients in organic forms as found in the compost. Stabilised composts will prevent nitrogen tie down as was noticed in the plant crop. A better understanding of nutrient cycles is essential to minimise nutrient losses within a farming system.

(iv) The trial found no significant difference between the conventionally fertilised treatments, biochar and compost treatments for greenhouse gas emissions, cane and sugar yield. However the biochar plus reduced nitrogen fertiliser treatment did have significantly higher productivity than the other treatments in both plant and first ratoon crops and is therefore worth further investigation.

(v) The trial found that it is uneconomic to apply biochar in a cane production system because of the initial up front cost associated with the purchasing or production of biochar.

During the duration of the project a local company (Select Carbon) commenced the production of biochar from renewable timber sources in North Queensland, but ceased production in late 2014. There are a number of companies like Renewable Carbon Resources Australia that still remain in production throughout Australia. These companies usually target the high value crops and horticultural industries.

The production costs must decrease significantly or a government incentive program be in place for biochar to be a viable option for the sugarcane industry (as sugarcane is regarded as a low value commodity crop).

### Communication and Adoption of Outputs:

The following communication activities were conducted:

- Project activities have been posted on the HCPSL website (www.hcpsl.com)
- Project progress was reported in the Herbert Sugar Industry Report for 2012 and 2013.
- A presentation on the project was given at the Hinchinbrook NRM forum in November 2012. Thirty five industry and community representatives attended the forum.
- Through a partnership between Education Queensland, James Cook University Cairns Campus, Terrain NRM and HCPSL an Earth Smarties project was established. Approximately 140 children from 7 primary schools in the Herbert and Burdekin area participated in the project.
- A poster paper was prepared for the JCU- TESS (Centre for Tropical Environmental and Sustainability Science) postgraduate student conference at the JCU- Cairns Campus, held during the first week of November 2012. The poster paper is attached in Appendix 1.

## Intellectual Property and Confidentiality:

Renewable Carbon Resources Australia wishes that the pyrolysis production techniques and processes remain confidential to their business.

## Capacity Building:

The Grower Group members were involved with the planning of this project and participated at every stage. They were involved with the establishment and conduct of a replicated trial and soon realised from the data as to why replication is such an important component of conducting a research trial. The Grower group members were involved with the calibration and application of equipment used to apply the compost and biochar. The Grower group has held many discussions on the best ways to manage soil carbon levels: through the use of biochar, fallow legume management, cane trash retention, reduced tillage and improved farming practices. They are keen to continue their discussions and explore all avenues to improve their soil health and farm productivity.

### Environmental and Social Impacts:

Biochar represents a highly stable form of carbon and as such it has the potential to form an effective carbon sink by sequestering atmospheric $CO_2$. While biochar surpasses other biological forms of carbon with respect to its stability, estimates of the turnover time of biochar in soil are of the order of tens of thousands of years to hundreds of thousands of years. The potential of biochar for mitigating other greenhouse gases such as $N_2O$ and $CH_4$ is less well established and requires further research. Other environmental benefits of biochar application include its ability to absorb nutrients and herbicide residues and it may have application in reducing contaminated run-off from cane fields and thus improve water quality.

Biochar should be monitored and assessed for concentrations of toxic combustion products such as polycyclic aromatic hydrocarbons especially during the pyrolysis process. The feedstock and any potential contaminants should be considered before pyrolysis is undertaken and before applications of biochar are undertaken. Given the stability of biochar, safe rates of applications need to be determined for individual soil types to avoid possible detrimental effects due to over application (eg. yield reduction) and accumulation of contaminants in the soil.

Composts will also require monitoring of environmental contaminants (like heavy metals and biological populations) to ensure that there are no negative environmental and human health issues. The biggest challenge municipal composts (like that of the SITA compost) will experience is the presence of glass and heavy metals (like lead and cadmium); these issues will need to be addressed.

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## Recommendations:

This trial was undertaken in only one location throughout the sugarcane industry. Sohi et.al (2009) indicated that a large number of studies (on numerous crops) have been conducted where biochar application has shown significant agronomic benefits with a minor number of studies showing no significant effects of biochar application on crop productivity and some studies reporting adverse effects. Further research is warranted to investigate the agronomic benefits on other soil types and gain a better understanding of the reasoning why biochar applications perform differently under different situations. Further research is also required to better understand nutrient release patterns associated with the use of organic nutrient sources like composts.

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