Integrating Organic Matter into Banana Plantation in North Queensland: The Effects on Soil Properties

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Abstract

The major banana production areas in Australia are particularly sensitive environments due to their close proximity to areas of World Heritage rainforest and the Great Barrier Reef catchment. Management of soil quality, nutrients and pesticides are vital to maintaining the integrity of these sensitive areas. Studies on cropping systems have suggested that integrating organic matter into ground cover management would improve the quality of soil under banana cultivation. In this study an alternative management practice for bananas, which addresses the management of organic matter and fertiliser application, was assessed and compared to the conventional practice currently employed in the banana industry. Several chemical, physical and biological soil parameters where measured including: pH; electrical conductivity; water stable aggregates; bulk density; water filled pore space; porosity; water content; fluorescein diacetate hydrolyis (FDA) and β-glucosidase activity. The alternative management practice did not have a significant impact of the production and growth of bananas but overall improved the quality of the soil. Although some differences were observed, the chemical and physical soil characteristics did not differ dramatically between the two management systems. The addition of organic matter resulted in the soil under alternative practice having higher FDA and β-glucosidase levels, indicating higher microbial activity. The integration of organic matter into the management of bananas was found to have positive benefits on soil properties under bananas, however, methods of maintaining organic matter in the soil need to be further researched.

INTRODUCTION

The wet tropics region in North Queensland, Australia is considered a sensitive area for agricultural production because it is nestled within areas of World Heritage rainforest and lies adjacent to the Great Barrier Reef. Methods of reducing run-off, nutrient leaching and carbon sequestration in the banana industry have not been widely researched. It is important that alternative management practices that aim to enhance soil quality do not impact on the viability of the banana cropping system. In

a study which identified the effect of *Arachis pintoi* groundcover on performance of bananas in northern New South Wales, the presence of groundcover reduced total fruit production over the whole trial by 16% and marketable fruit by 19% (Johns, 1994). The application of organic matter supplies the soil with a source of organic carbon, which supplies the energy input for soil biota (Magdoff and Weil, 2004). The conventional method of growing bananas is based on bare soil around banana plants and monthly applications of urea. The purpose of this project is to develop an alternative management practice, based on the integration of organic matter and nutrient management which would reduce the decline of physical, chemical and biological soil parameters in banana cropping systems and sustain production. Improving farming practices in this manner would allow more sustainable farming in this sensitive growing area.

MATERIALS & METHODS

Trial Design

The field trial was located at the Centre for Wet Tropics Agriculture research station at South Johnstone, Queensland, Australia (17.61˚S, 146.00˚E, 18mASL). The trial was established on the 25th of November 2009 on a Dermosol, Innisfail soil series (32% clay, 28% silt and 40% sand). The trial consisted of a single row of Cavendish banana plants divided into 5 replicates of 'conventional practice' (CP) banana farming and 'alternative practice' (AP) banana farming. In each individual plot there was one guard plant at either end and four datum plants between the guards. Irrigation was installed in the row and one micro irrigation sprinkler was placed between every second plant.

Treatments

In the AP plots, Japanese millet (*Echinochloa esculenta*) seed was sown on the soil surface alongside young banana plants as a companion crop, and then subsequently eradicated after six weeks with a single application of Fusilade® 212EC (70L/ha) selective herbicide treatments to become mulch. The crop residues were placed on top of the soil in the AP plots and removed in the CP plots. In the CP plots all the weeds were eradicated four times with Basta® at 400L/ha (09/12/2009, 20/02/2010, 03/05/2010, 20/06/2010, and 25/08/2010) throughout the field trial period.

Fertiliser

Target values of 250kg/ha, nitrogen, 500kg/ha potassium, 20kg/ha phosphorous, 120kg/ha calcium and 20kg/ha sulphur were used to develop a fertiliser program for the field trial with the aid of Bananaman, (a program developed by DPIF, S. Lindsay pers. commun.). Urea ($(NH_2)_3CO$) and potassium chloride (KCl) were applied at monthly intervals to the CP treatment. The AP treatment received fortnightly applications of potassium nitrate (KNO_3). At the beginning of the trial, prior to planting, Nitrophoska® Blue TE was added to both treatments. Magnesium sulphate was also added to all the plants in both treatments on the 10/06/2010. The fertilisers were applied as solid salts, cast evenly on the soil surface.

Soil Samples

Three 10cm soil cores were taken every four weeks from each plot. Soil was homogenised, air dried and sieved (<2mm) before analysis was undertaken. Soil pH and EC were determined at monthly intervals using a pH/EC multi probe (Hanna HI

92129, Mauritius) in a 1 (soil): 5 (deionised water) dilutions. Labile carbon was also determined at monthly intervals by the amount of C oxidised by 33mM $KMnO_4$ (Blair *et al*. 1995), using the method described by Moody and Cong (2008). Bulk densities were taken approximately every eight weeks. Soil water content, soil porosity and water filled pore space (WFPS) were calculated from the bulk density results. Approximately every eight weeks soil aggregate stability was determined using the method developed by Cornell University (Gugino *et al*. 2007). Fluorescein diacetate activity (FDA) was determined using a modified version of the method initially proposed by Schnürer and Rosswall (1982). Soil samples were prepared by placing 5 g in 50 mL centrifuge tubes, rewetted with 2 mL of deionised water and incubated at 26˚C for 7 days. For the FDA analyses, 20 mL of 60 mM phosphate buffer and 200 µL of FDA solution (2000 µg/mL), were shaken for 30 minutes, the reaction was terminated with 20 mL acetone (AR grade). β-Glucosidase was determined using the procedure published by Eivazi and Tabatabai (1987) except the Toluene and modified universal buffer was substituted by 0.1% Tween Solution and McIIvaine buffer, pH 6.0 respectively.

Plant Parameters

Plant growth was determined by measuring the leaf emergence rates and heights every month. Yield was assessed by time to bell emergence and bunching, number of hands per bunch, average number of fingers per bunch and bunch weight (Turner 1972).

Statistics

Statistical analysis was carried out using GenStat (Version 11, VSN International). The chemical, physical and biological soil parameters from the field trial were analysed with one-way analysis of variance (ANOVA) tests. Significance was determined at a 95% confidence level.

RESULTS

Physical

The water stable aggregates did not differ significantly between the two treatments at any of the sampling times. Similarly bulk density and porosity did not differ between treatments throughout the trial period. Water content was significantly higher in the alternative practice treatments in March 2010 (AP = 35%, CP = 33%), May 2010 (AP = 35%, CP = 32%) and November 2010 (AP = 31%, CP = 23%). Water filled pore space measurements did not show any significant trends, however a significant difference occurred in May 2010 after the addition of extra organic matter (AP = 66%, CP = 45%).

Chemical

From November 2009 through to May 2010 there were no significant pH differences between treatments. CP treatments had a significantly lower pH from June 2010 to November 2010 (June: AP = 5.3, CP = 4.9. July: AP = 5.5, CP = 5.2. August: AP = 5.3, CP = 5.0. November: AP = 5.5, CP = 5.3). The EC tended to decline from the initial sampling November 2009 to January 2010 and stabilised from January 2010 to May 2010. During this period the only statistical difference between treatments was observed in March (AP = 26µS/cm, CP = 20µS/cm). There was a large increase in EC in June 2010, with the CP recording a significantly higher EC than the AP (AP = 72µS/cm, CP = 165µS/cm). From July 2010 to August the EC was significantly

higher in the AP treatments (July: AP = 40µS/cm, CP = 70µS/cm; August, AP = 30µS/cm, CP = 58µS/cm). No significant difference in EC was observed in the November 2010 sampling. There was no significant difference in labile carbon detected throughout the entire trial until the final sampling. In November 2010 there was significantly more labile carbon in the AP treatments (Figure 1).

Biological

There was significantly more FDA hydrolysis in the AP treatments in January (Figure 2). The amount of FDA hydrolysis declined in both treatments in April 2010 which coincides with the wettest 14 days prior to sampling (Figure 2). At this sampling time there was significantly more FDA hydrolysis in the alternative practice treatment (Figure 2). The FDA hydrolysis increased in both treatments to levels similar to those prior to the April 2010 sampling in May (Figure 2). This coincides with a dryer sampling period and the application of additional organic matter. No significant differences between treatments were observed until the July 2010, August 2010 and November 2010 samplings when there was significantly grerat FDA hydrolysis in the AP treatments (Figure 2).

β-Glucosidase activity tended to decrease in both treatments as the trial progressed. There was significantly greater β-Glucosidase activity in AP treatments in April 2010 and June 2010 (Figure 3).

Plant Parameters

There were no significant differences observed in any of the measured growth and production measurements taken. The average time to bunch harvest was 332 days and the average weight of a harvested bunch was 24.9kg

DISCUSSION

The AP practice for the management of bananas slowed the decline of the health of the soil. The CP of growing bananas led to a decline in soil health indices, a more acid soil pH and a reduction in the microbial activity. This trial compared two management practices: the effects of the treatments on the soil could not be unequivocally attributed to any individual facet of the practices.

Previous work demonstrated that *Arachis pintoi* as a living groundcover in bananas reduced total fruit production over the whole trial by 16% and marketable fruit by 19% (Johns, 1994).This was contradictory to the results which were obtained in this study. There were no significant differences observed in any of the measured growth and production parameters. Competition was the major attributing aspect which resulted in a decline in productivity in the study conducted in NSW. In this study Japanese millet was only allowed to grow for a short period of time before being eradicated. This would presumably reduce the competition effect. On a larger scale trial there may have been more observable differences between the treatments

The water content of the soils varied significantly different between the two treatments. Crusting of the soil surface was observed in the CP treatment. During a rainfall event this may inhibit water infiltrating into the soil profile, inturn water would run off the soil surface at a higher velocity. This has implications for run-off of sediment, nutrient and pesticides into the Great Barrier Reef catchment. The presence of organic matter on the surface of the soil allowed water to infiltrate. This was reflected by the significantly higher water contents observed at three of the

sampling times. The presence of organic matter has the potential to reduce soil erosion and run-off.

The study was conducted in a consistently wet year which has implications for microbial activity. Waterlogged soils which are deprived of oxygen create an environment unfavourable for microbial activity (Tiedje *et al*, 1984). From the commencement of the trial, FDA hydrolysis tended to rise steadily until February 2010 then gradually decline to its lowest reading in April 2010. This sampling was performed in very wet soils, suggesting that the anaerobic condition of the soil lead to a reduction in microbial activity. The rising trend occurred after this sampling coinciding with re-application of organic matter in May 2010 and the return of additional banana trash as the plants where harvested. This increase in organic matter attributed to there being significantly more microbial activity in the AP treatment in the last three sampling times of the trial.

The increase in microbial activity under the AP treatment was anticipated because the millet and banana trash provided a source of organic carbon which supplies energy input for the soil biota. Accepting a 94% confidence level there was significantly more labile carbon detected in the two months following the addition of extra organic matter. It took a year for labile carbon in the AP treatment to be significantly (95% confidence) greater than the CP treatment. This change corresponds with the time when the plants were being harvested and higher inputs of banana trash were being returned to the soil. This demonstrated that it is difficult to increase and maintain organic carbon in wet tropical climates.

Soil organic matter rapidly decomposes in tropical areas, due to high soil temperatures and non-limiting soil moisture (Feller and Beare, 1997). If more organic matter was applied initially (Japanese millet sown at a higher rate) and/or more organic matter was applied more frequently, changes in labile carbon might have been detected sooner. Further research into application rates, quality and type of organic matter is required to better understand and optimise organic carbon cycling in banana cultivation systems.

Integrating a non-native species into any agricultural system raises queries regarding the plants potential to become an invasive weed. The seed of the Japanese millet that was used in this trial was sterile. If a practice was to be implemented with any species of ground cover, special consideration would need to be taken regarding this issue.

The anticipated changes in physical and biological soil parameters along with growth and production that were not observed may be attributed to by the short-term nature of this study. In commercial production bunches are harvested from several ratoons over several years. In order to see the full effects of the proposed alternative management practice the trial would need to be analysed over several years on a larger scale.

CONCLUSIONS

Integrating organic matter into groundcover management of bananas, reducing herbicide application and fertilising with frequent applications of a NO_3 form of fertiliser reduced the chemical, physical and biological decline of the soil without impacting on the growth and production. Results from the soil under CP had a lower pH, FDA hydrolysis rate and β-Glucosidase activity. The AP treatment had a higher labile carbon level on the final sampling indicating that the addition of organic matter can increase carbon levels in tropical soils. The increase that was observed took a

long period of time to occur. Maintaining and increasing carbon levels in the soil may prove to be difficult in wet tropical regions.

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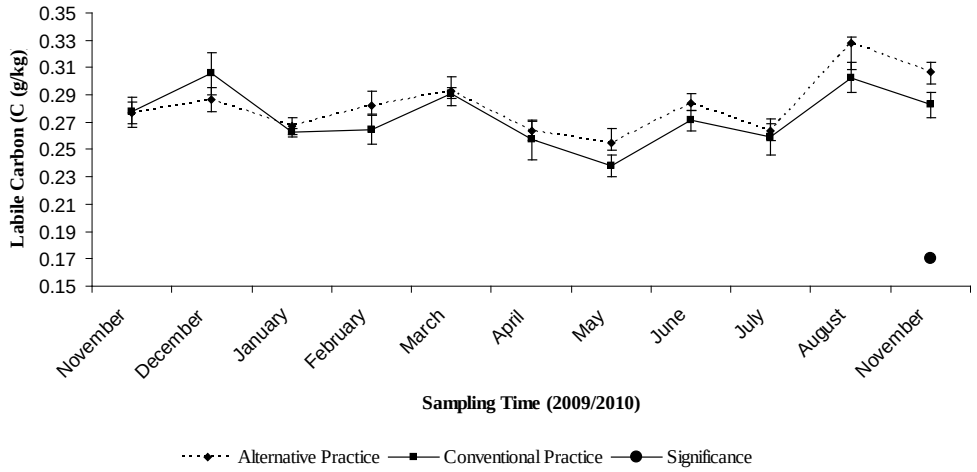

Figure 1: Labile carbon detected in the field trial (10cm deep soil cores) in alternative practice and conventional practice treatments. Points on graph at each sampling represent the mean of five replicates for each treatment. Error bars represent standard error. Significance (95%) indicated by solid circle.

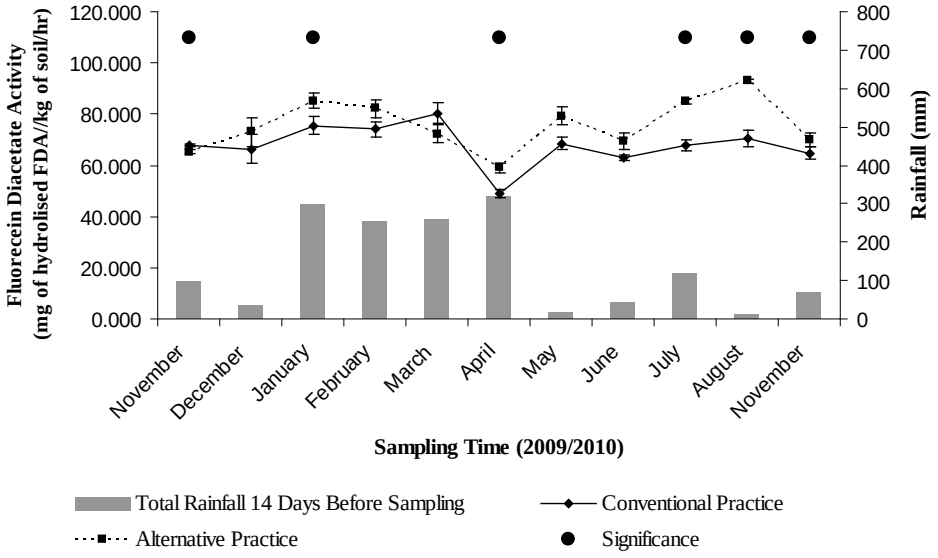

Figure 2: Fluorescein diacetate activity detected in the field trial (10cm deep soil cores) in alternative practice and conventional practice treatments. Total rainfall which fell 2 weeks prior to sampling is recorded in the bar graphs. Points on graph at each sampling represent the mean of five replicates for each treatment. Error bars represent standard error. Significance (95%) indicated by solid circle.

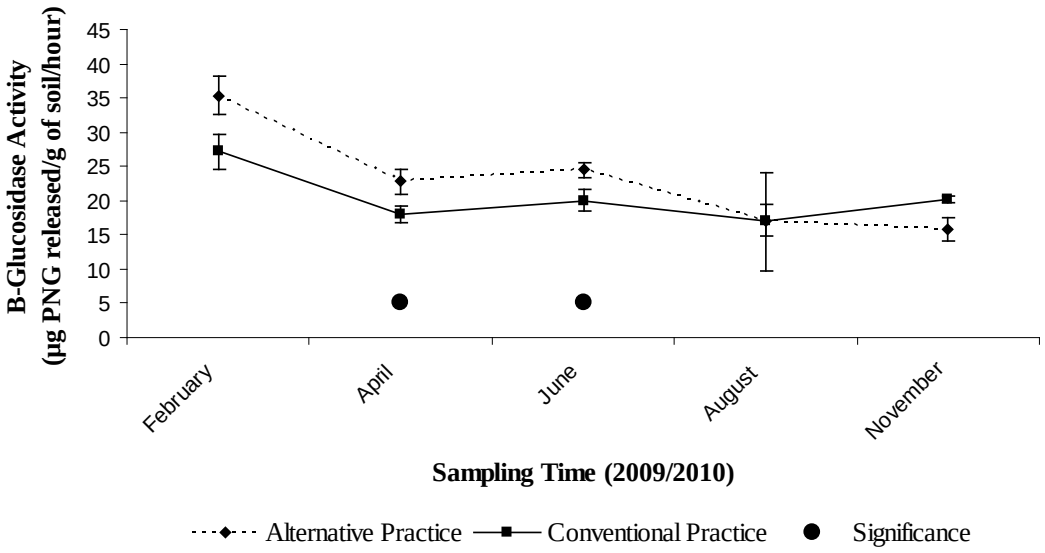

Figure 3: β-Glucosidase activity detected in the field trial (10cm deep soil cores) in alternative practice and conventional practice treatments. Points on graph at each sampling represent the mean of five replicates for each treatment. Error bars represent standard error. Significance (95%) indicated by solid circle.