Final Report: Examining soil and plant health effects by application of compost teas and extracts on dryland broad acre buffel pastures in Central Queensland.

Scott Stevens

Farming and Beyond -

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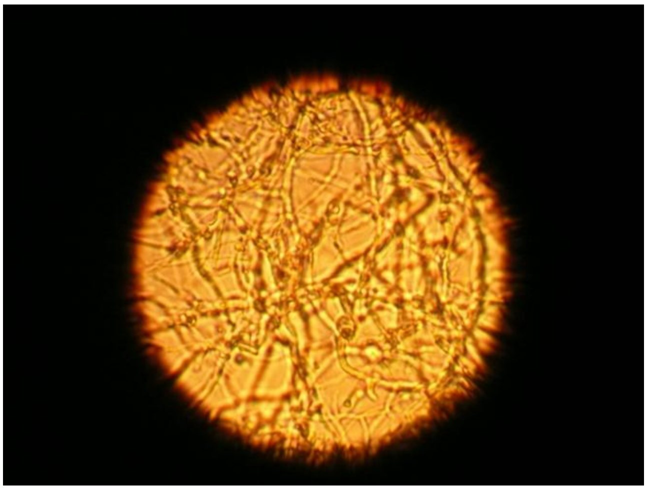

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Description of photos front page (Top left than clockwise)**:** Mr Peter Attard (property owner) soil sampling in dry times (Oct 09); Plant sampling in wet times showing contrasting buffel plant growth and activity to Oct 09 (Apr 11); Aeration effect in 5000 L compost tea brewer produced via side channel air blower through network of pipes; Microscopic view (100x) of branching fungal hyphae in compost tea (Jan 10); Applying compost teas with modified spray rig through boomless jets (Aug 08); Soil samples to 110 cm taken with mechanical sore core with the compost extract treatment (Oct 10).

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1.0 Summary

This report completes an agreement between the Fitzroy Basin Association (FBA) and Farming and Beyond Pty Ltd (F&B) in examining the benefit of compost teas and compost extracts applied as a foliar or soil drench to soil and plant health on broad acre grazing lands within the Fitzroy Basin. The project timeframe of three years commenced in July 2008 and concluded in June 2011.

The study site was located on 'Rainbows End', Moura which is owned and managed by Mr Peter Attard. Mr Attard is a long term advocate of compost teas having devoted significant time and resources examining the effects of biological inoculums on his main property 'Shingle Hut'. 'Rainbows End' was the preferred trial site for the project as no prior applications of either teas or extracts had taken place since the property was purchased in 2004.

The reported benefits of compost teas and extracts to soil and plant health include increases in soluble soil nutrients, soil biology levels, organic carbon, plant nutrient levels and suppression of plant disease (Ingham 2005). The application of compost teas and extracts in this project did not increase soil or plant health. No visual differences were noticeable between treatments or were there any beneficial results from in field or laboratory testing. Increases in soluble calcium, magnesium and iron levels did occur but were observed across all treatments including the control. Soil moisture alone resulted in fluctuations in soil biology levels that could not be attributed to compost teas or extracts.

The compost tea treatment showed a decline within the topsoil (0-10 cm) of organic carbon levels by 26%, slightly higher than the control (17%) and the extract treatment (10%). Low levels of crude protein, calcium, magnesium and minor trace elements of the dominant grass species American Buffel (*Cenchrus ciliaris*) highlighted that plant health was less than desirable when first tested and did not improve in time with compost teas or extracts.

This report concludes that there was no benefit to soil and plant health from the applications of compost teas and extracts. Timing of application to coincide with ideal conditions benefitting the survival and growth of applied biology at the broad scale was rare and often near impossible. If such products are to be included in a soil and plant health program, they should be injected into the ground where conditions are likely to be conducive for biological organisms.

Furthermore, this activity should be undertaken with other soil and plant amendments including deep ripping of compacted layers and establishment of desirable species such as legumes, annual cereals, herbs and grasses in combination with liquid nutrients and biological foods sources. The principal strategy of applying only compost teas and extracts will not provide any benefits unless they form part of a complete soil and plant program.

2.0 Aim

The project's main aim was:

- To monitor the effects of compost tea and extract applications on soil and pasture health in broadacre grazing lands within Central Queensland.

Different terminology exists in defining what is a 'compost tea' and 'compost extract'. Tea or extract can be either aerated or non-aerated however the definitions that this project has adopted are as follows:

- **Compost tea** is a microbial brew where organisms and soluble nutrients are extracted from compost (in water) and with the addition of food sources (molasses, kelp, fish hydrolysate and others), aerated to build numbers of beneficial soil organisms (Ingham 2005).

- **Compost extract** is a microbial brew where organisms and soluble nutrients are extracted from large volumes of compost (in water) via aeration with small quantities of food sources added to aid survival of beneficial soil organisms.

3.0 Property and trial site description

The trial was located at the property, 'Rainbows End', near Moura in Central Queensland. The property was purchased in 2004 and had been partially cleared of native timber species. The existing fencing layout was subdivided into cells between 10 and 20 ha within the first six months. Cell grazing was immediately introduced and continues to be the cattle management system adopted at 'Rainbow's End'.

Soils located within the trial area were described as episodic, self-mulching, grey, vertosol, highly sodic at depth (Appendix 1). Melon holes were spaced randomly across the landscape and contained unique vegetation and aquatic life due to retention of surface water following rainfall.

Figure 1: Typical landscape view of larger vegetation and grass pastures on 'Rainbow's End'. Note areas of grass that appear to be dead in patches are located within melon holes or gilgai's.

Perennial grasses dominate the inter-zonal areas between melonholes with introduced sub-tropical species American Buffel (*Cenchrus ciliaris*), Urochloa (*Urochloa Mosambicensis*) and Callide Rhodes Grass (*Chloris gayana* cv. Callide). The two dominant native perennial grass species were Queensland Bluegrass (*Dichanthium sericeum*) and Forest Bluegrass (*Bothriochloa bladhii*). The overstory vegetation consisted of Dawson Gum or Blackbutt (*Eucalyptus cambageana*) and Brigalow (*Acacia harpophylla*).

Figure 2: Looking down on the ground cover features of American Buffel grass pastures.

4.0 Trial Protocols

A replicated trial was designed under the guidance of a biometrician within the existing cell paddock layout. Individual cell paddocks surrounding a cell centre were assigned either a control, compost tea or compost extract treatment (Figure 3).

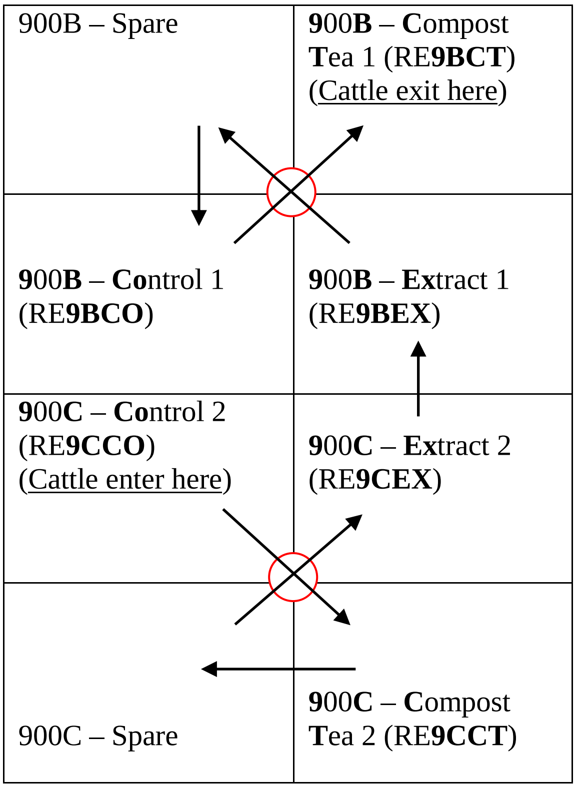

Figure 3: Trial layout with two replications of control, compost tea and compost extract treatments. The arrows indicate cattle movement with the red circles representing a central watering point.

A spare cell beyond the project requirements was used to restrict cattle impact on neighbouring treatments when moving between cells (indicated by arrows in Figure 3). A single watering point was located at each cell centre with electric tape restricting cattle access to the three adjoining cells. Using the cell centre names e.g. 900B, each paddock was assigned a unique code for monitoring and reporting purposes.

4.1 Establishing a Monitoring Pattern

A monitoring pattern was designed and implemented within each paddock and replicated for all treatments where possible. Natural and man-made impediments such as roads, trees, fence lines, seismic line surveys, inherent landscape patterns (melonholes) and paddock access influenced the monitoring pattern within each cell.

Figure 4 represents the final monitoring pattern (not to scale) that was used for all soil and pasture sampling. Four individual monitoring locations (GPS referenced for repeat sampling) within each cell were spaced approximately 30 to 40 m apart. There were no monitoring points selected within melonholes as grass species and soil moisture conditions were in total contrast to the surrounding elevated land surface.

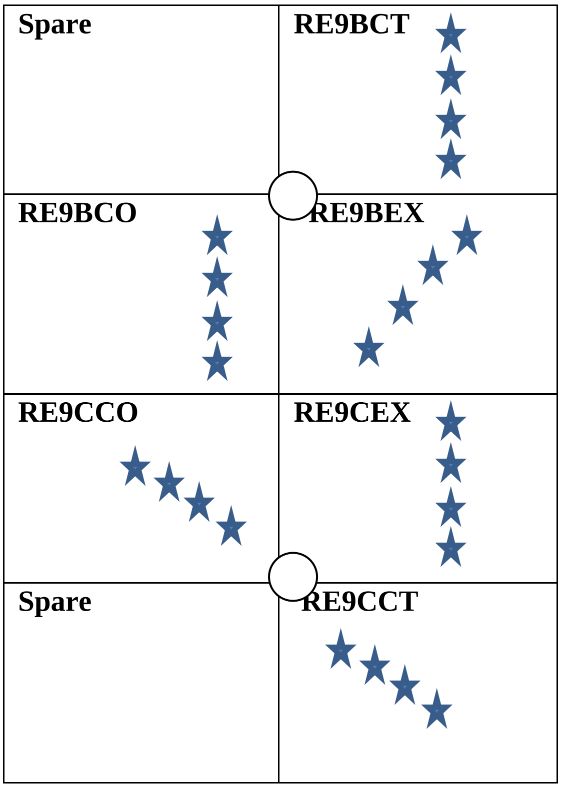

Figure 4: Monitoring pattern layout for each paddock within the replicated trial design.

5.0 Sampling Protocols

Sampling protocols were established for a range of soil and plant health indicators. NATA accredited laboratories were engaged where possible to provide specific analysis of requested indices.

Baseline monitoring conducted prior to the commencement of treatments consisted of:

- Soil nutrients (0-10 cm) including soil carbon,
- Soil biology (0-10 cm),
- Pasture sap analysis of the dominant pasture species (American Buffel).

Monitoring throughout the course of the project including repetition of the baseline monitoring assessment as well as:

- Annual soil nutrients (0-110 cm) including soil carbon,
- Annual bulk density (0-110 cm) including gravimetric soil moisture,
- Compost, Compost Tea and Extract sampling for biology,
- Plant tissue analysis, and
- Plant feed analysis.

5.1 Soil Biology and Nutrient Sampling

Two soil samples were collected at each monitoring point (eight samples in total) and combined into one composite sample per treatment for soil biology analysis. Representative soil samples were taken using a manual coring device adjacent to the basal area of an American Buffel plant to a depth of 10 cm. Soil was placed in plastic zip lock bags, mixed by hand with foreign plant material (i.e. roots, leaves) and additional soil beyond laboratory requirements removed. Samples were placed in cold storage prior to overnight transportation to the respective laboratory.

A similar procedure was adopted for soil nutrient samples extracted with a manual coring device. When soil nutrients were analysed from a soil biology sample, each respective laboratory (located within the same town) removed a sub-sample from the original soil sample.

A mechanical coring device was required to extract a representative soil nutrient sample to a depth of 110 cm. Two random samples were obtained at each monitoring point with the majority of soil cores extracted between individual pasture plants.

A total of eight (8) soil cores were taken at each treatment, combined then sub-sampled at depths of 0-10, 10-20, 20-30, 30-60 and 60-110 cm. The soil was crushed by hand and then placed in labelled brown paper bags. Soils were dried at 40^C for 48 hours then stored at ambient temperature before dispatched to the respective laboratory.

Soil biology was analysed by the Soil Food Institute (SFI) in Lismore, New South Wales. Typical analysis included total bacteria and fungi (biomass and activity), fungal hyphae diameter, soil moisture and protozoas. Soil nutrient analysis consisted of total soil carbon, labile carbon, major cations, available/total major and trace elements. Soil nutrient testing was performed by the Environmental Analysis Laboratory (EAL) in Lismore, New South Wales.

5.2 Pasture Tissue, Sap and Feed Analysis Sampling

Each cell was visually assessed to quantify an average plant height of American buffel (*Cenchrus ciliaris*). Plant biomass was removed using garden shears at the perceived height above ground level that cattle would consume without detrimentally reducing future grass performance.

A minimum of two samples were removed at each monitoring point and combined to give one composite sample per treatment. For each monitoring event, pasture samples were taken in a similar sequence between individual treatments. Samples were handled without protective gloves but extreme care was taken not to contaminate the sample with other foreign matter such as soil and litter. Grass was stored in plastic zip locked bags and remained within cold storage until freighted overnight to the respective laboratory.

Pasture tissue analysis was performed by EAL with pasture sap analysis undertaken by Agvita Analytical Laboratory (Agvita) in Devonport, Tasmania. The Australian Perry Analytical Laboratory (APAL) in Magill, South Australia performed all pasture feed analysis.

5.3 Bulk Density and Gravimetric Soil Moisture

When performing annual soil sampling, one soil core was extracted at each treatment to assess bulk density. This was purely a random sample at one monitoring point although repeat annual samples were extracted at the same location. These samples were sub-sampled at the same depth intervals as the soil nutrient cores. Samples were weighed prior to be being dried at 110^{C} for a minimum of 48 hours. Samples were re-weighed to provide a bulk density and gravimetric soil moisture value.

6.0 Manufacturing Process of Compost, Compost Teas and Extracts

The major source of compost was manufactured on farm using local products where possible and included endemic soil organisms taken under different vegetation communities. Buffel grass was cut, baled and blended with shredded mulch sourced from the local waste transfer station. These two products formed the major carbon source for the compost pile. Composted chook manure, cotton trash and water plants taken from melonholes were added as nitrogen sources. All ingredients were combined with water added where required and sealed with a straw layer reduce evaporation.

The compost pile was turned with a front end loader when the internal temperature reached 65^{C}. Water was added if moisture levels were deemed insufficient. Each pile required a minimum of five to six turns and reached maturity between four and six months.

Compost teas were brewed in a 5000 L central draining fish tank fitted with a side channel air blower for aeration. Rain water was used for all tea brewing as local dam water was of insufficient quality. Mature compost was prepped three days prior to use with fish hydrolysate at 1:2 ratio with water to encourage fungal activity.

Biological food sources including fish hydrolysate, kelp, oat meal and sea minerals were thoroughly mixed via aeration within the brewing tank (Figure 5) prior to the addition of the prepped compost (contained within a stainless steel mesh cylinder). Biology was 'stripped' from the compost by the force of air bubbles rising from purposely drilled holes in PVC tubing on the bottom of the tank. The extracted biology then multiplied in the aerobic environment until all food sources were consumed. Typically the brewing process was completed between 14 and 16 hours depending on water temperature and quantity of food sources.

Figure 5: Aeration effects of 'brewing' compost tea.

Compost extracts were brewed with the same compost base as the teas (but not prepped). Dam water was used in the brewing process due to limited quantities of rain water available for compost teas. Small quantities of food sources were added to assist with the survival of soil biology when extracted from the compost. The pipe configuration located at the bottom of the tank was altered to direct all available air to the compost basket to extract biology and soluble nutrients. Fresh compost was continually added to replace depleted compost until the extract liquid was deemed of sufficient quality. Within two to three hours, the extraction process was completed and applied in field.

6.1 Compost, Compost Tea and Extract Analysis

A sample of compost, compost tea and extract was analysed by SFI as part of the brewing and application process performed in January 2010. The tea and extract sample were acquired when the respective inoculums were applied in field. It was important to assess if the transfer of product from the brewing tank and subsequent application was detrimental to the survival and composition of biology.

The tea and extract sample was analysed independently by SFI and project staff. A full qualitative and quantitative assessment was performed by SFI. Project staff were trained by SFI to perform qualitative assessments only using a standard microscope. Samples were retained for a minimum of three days to assess changes in biological composition and activity levels.

7.0 Application of Tea/Extracts

Applications of compost tea and extracts were performed on the same day where possible. A compost tea was brewed overnight and while it was applied to the field, the compost extract was manufactured. The tea or extract was transferred from the brewing tank to a customised spray rig and applied using a centrifugal pump through several boomless jets. Food sources were applied at the same time to encourage growth and increase survival of biology. The tea/extract was applied along each monitoring pattern of the respective treatments and subsequently in strips approximately 30 m apart.

Figure 6: Compost tea being applied using a customised spray rig. A front tank contains the food and nutrient sources while the rear tank contains the tea/extract. Products remain separated until they converge at the boomless jet.

Ideal field conditions to promote higher rates of survival and colonisation of biology were considered a prerequisite prior to application. A rainfall event of 50 mm or greater over a 24 hour our period was required to provide adequate soil moisture. Pastures had to be actively growing with no sign of moisture stress to increase potential translocation of applied product from the leaf surface to the plant roots. Early morning applications were preferred to reduce exposure of higher daytime temperatures.

An initial application rate of 80 L/ha was performed on the 5th August 2008. With little change in soil biology levels recorded pre and post application, the rate of product applied increased to 150 to 200 L/ha in January and February 2010. This was the first opportunity for a second application post August 2008 due in part to inadequate soil moisture and reduced plant activity.

Date	Compost Tea	Extract
5/8/08	80	80
11/1/10	200	200
8/2/10	150	185
3/3/11	3900	
8/3/11	4000	
9/4/11		2000

Table 1: Application dates and rates applied (L/ha) for compost tea and extract treatments.

Two applications of compost tea occurred in the first week of March 2011. Persistent rainfall and wet field conditions delayed the extract application until early April. The increased volume in January/February 2010 from the initial application in August 2008 was designed as a soil drench rather than a foliar treatment. The final applications in March and April 2011 were increased substantially to address potential losses in biology from anaerobic conditions experienced throughout spring and summer. Prolonged wet weather had maintained soil moisture conditions above field capacity that also hindered plant growth response during this period.

8.0 Cattle Management

Planned cattle grazing patterns was practiced such to minimise impact in aiding movement of applied products between treatments. A cell grazing layout was already adopted that consisted of a central watering point surrounded by four adjoining cells.

Cattle movements between cells were managed using the principals of cell grazing. A record of cattle performance (stock days per hectare) was kept for individual cells and treatments. This form of record keeping was used as it was impractical to weigh cattle due to minimal time spent in each cell and remote access to permanent yard facilities.

9.0 Results

Compost teas and extracts were expected to influence soil nutrient availability and biological levels within the topsoil (0-10 cm) and associated plant health of established pastures. The project had an initial primary focus defining the effect of compost tea and extract treatments on soil biology. Through strategic monitoring and subsequent data analysis it was established that soil moisture was significantly biasing results.

Regular in-field monitoring of soil and plant indices was combined with annual monitoring examining principally the effects of teas and extracts on soil carbon levels. The project employed NATA accredited laboratories where possible to determine the effect of compost teas and extracts on soil biology, soil and plant nutrients including soil carbon, pasture tissue testing and feed analysis.

9.1 Compost Tea and Extract Biology

Compost teas and extracts were analysed by Soil Food Web Institute (SFI) for specific biological organisms until the project team were competent in diagnosing such organisms. Inoculums were not tested for soluble nutrient levels as the amount of compost used in the manufacturing process was deemed insufficient to benefit soil and plant nutrient levels directly. Beneficial biology aided with targeted food sources for survival and growth post application was expected to increase soil and plant nutrient levels.

Major finding: All compost teas analysed by SFI were either within or above desirable levels for all but active bacterial levels (Table 2 and 3). Compost extracts were below desirable levels in active fungi and marginally above the minimum range for total fungi levels. These findings were supported by the project team when analysis of samples was performed independent to SFI.

Minor finding: Fungal biomass levels of compost extracts were very low even though compost (analysed by SFI) used in the manufacturing process recorded levels higher than the desirable range. The ratio of compost to water volume in the manufacturing process diluted the fungal biomass such that the levels recorded were lower than desirable. The relative short brewing period did not permit dormant fungi or spores to reproduce to similar levels in the compost teas.

Overall: The quality of compost and compost teas was deemed to be of sufficient standard to demonstrate beneficial responses in soil and plant health. A highly bacteria inoculum was required to address soil compaction within the entire trial area. Specific food sources and ideal field conditions at application were adopted to improve the survival and growth of applied biology.

Less than desirable levels of active and total fungi within compost extracts were observed. The length of brewing and low levels of targeted food sources potentially limited the development of fungi. Proliferation of fungi biomass in a compost tea or extract is challenging for even the most experienced practitioner. The use of compost extracts should be limited in providing bacterial inoculum and minor amounts of soluble nutrients where required.

	Total Bacteria (µg/mL)		Active Bacteria (µg/mL)	
	Aug-08	Jan-10	Aug-08	Jan-10
Tea	1549	333	18.7	8.5
Extract	5888	755	58.4	8.7
Desirable	150 to 3000		10 to 25	

Table 2: Total and active bacterial biomass (µg/ml) of compost teas and extracts from August 2008 and January 2010.

	Total Fungal (µg/mL)		Active Fungal (µg/mL)	
	Aug-08	Jan-10	Aug-08	Jan-10
Tea	52	68	36.7	53.0
Extract	3.1	5.8	0.5	0.7
Desirable	2 to 20		2 to 10	

Table 3: Total and active fungal biomass (µg/ml) of compost teas and extracts from August 2008 and January 2010.

9.2 Soil Biology

Monitoring for soil biology was conducted from August 2008 until March 2010 (see Appendix 2 for full results). During this period it became apparent that soil moisture was significantly biasing results independent to applications of compost teas or extracts. Soil biology testing was thus terminated in preference to more proven analysis techniques of soil and plant parameters. It must be noted that only three applications of compost teas and extracts occurred between August 2008 and March 2010.

Major Finding: Soil moisture within individual treatments had significantly higher effects on soil biology levels than compost tea or extract applications. Soil moisture had the greatest influence on total fungal biomass (Figure 7) as well as active bacterial and fungal levels (Figure 8).

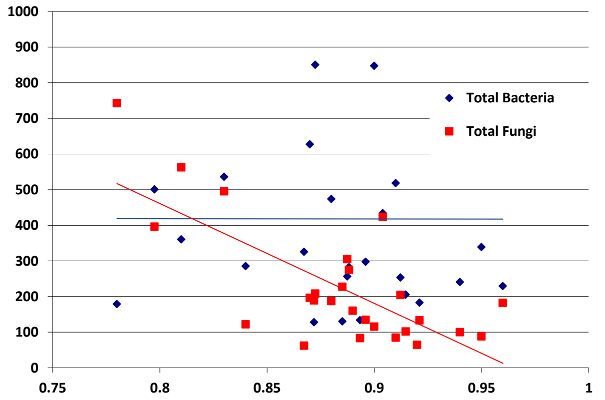

Figure 7: Total bacteria and fungal levels (y-axis) (ug/g) (0-10 cm) compared to soil moisture levels (x-axis). Moisture levels approaching 1 indicate a dry soil.

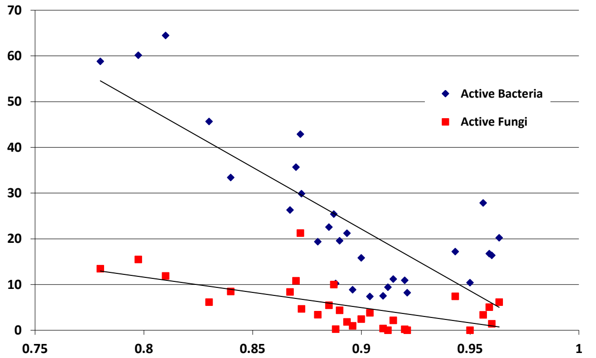

Figure 8: Active bacteria and fungi levels (ug/g) (y-axis) (0-10 cm) compared to soil moisture levels (x-axis). Moisture levels approaching 1 indicate a dry soil.

Between the 16th and 24th March 2010, rainfall totalling 35 mm was recorded. In the compost tea treatment, total fungal biomass increased from 96 to 793 µg/g with the control treatment showing a similar response (93 to 511 µg/g). The extract treatment increased from 263 to 693 µg/g implying that observed changes in fungal biomass was due to higher soil moisture levels. Active bacterial and fungal levels produced a similar response across all treatments.

	Total Fungal (µg/g)		Active Fungal (µg/g)		Active Bacteria (µg/g)	
Treatment	######	24/03/10	16/03/10	24/03/10	16/03/10	24/03/10
Control	93	511	0.44	14.4	7.7	73
Tea	96	793	0.91	13.8	11.20	48.3
Extract	263	693	1.37	13.1	17.9	69.3
Desirable	150 to 300		10 to 25		10 to 25	

Table 4: Total fungi, active fungi and bacterial biomass (µg/g) (0-10 cm) sampled on the 16th and 24th March 2010.

Minor Finding: Levels of total bacteria (Figure 9) decreased for all treatments during the project but remained above the desired range of 100 µg/g of soil (adequate level stated by SFI). The decrease in total bacteria was observed across other projects within the general locality of this project suggesting that bacteria was less resilient to environmental stresses from either climate and/or grazing management.

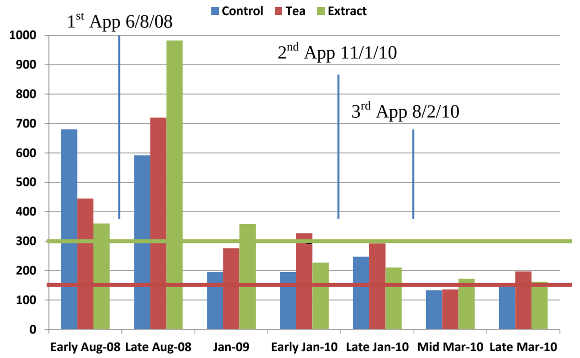

Figure 9: Average total bacteria biomass (ug/g) (0-10 cm) of individual treatments including dates of tea and extract applied. Desirable ranges are within the green line (upper) and red line (lower).

Total fungal levels (Figure 10) remained within or above the desired ranges but were highly dependent on soil moisture.

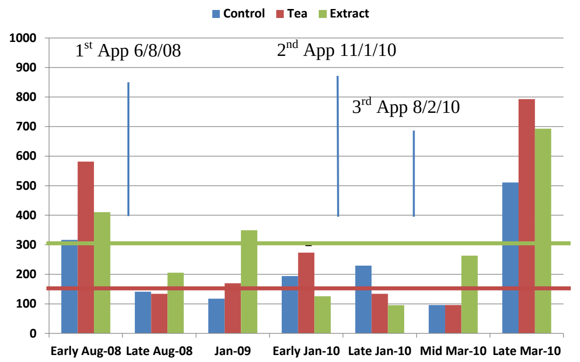

Figure 10: Average total fungi biomass (ug/g) (0-10 cm) including application dates of teas and extracts. Desirable ranges are within the green line (upper) and red line (lower).

Active bacteria (Figure 11) and fungi levels (Figure 12) showed a similar response to soil moisture levels indicating how influential the role of soil moisture is in maintaining biological activity. Active bacteria remained predominantly within or above the desired range but fungal activity was generally below acceptable levels.

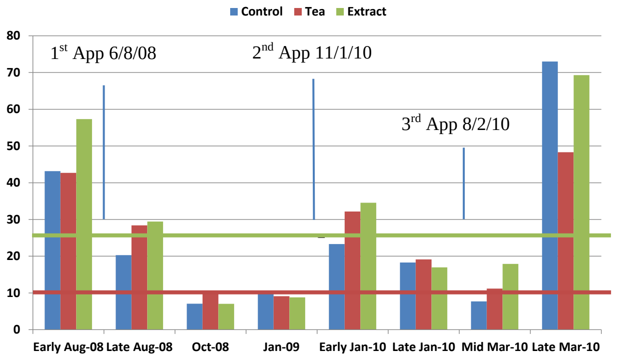

Figure 11: Average active bacteria biomass (ug/g) (0-10 cm) including application dates of teas and extracts. Desirable ranges are within the green line (upper) and red line (lower).

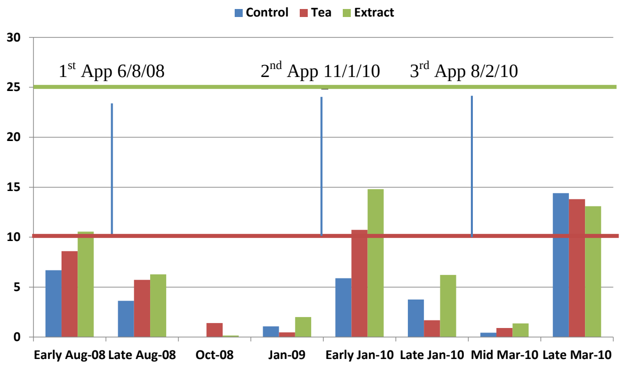

Figure 12: Average active fungi biomass (ug/g) (0-10 cm) including application dates of teas and extracts. Desirable ranges are within the green line (upper) and red line (lower).

Overall: The decline in total bacterial levels may indicate endemic bacterial communities are less resilient to climate and grazing effects than other biological groups. The ratio of bacteria to fungi was approaching 1:1 which is a symptomatic balance of these major soil biological organisms under a perennial pasture. Total bacterial biomass was less likely to be effected by soil moisture but may increase during times of lower soil moisture and temperature conditions. Apart from active fungi, biology levels within all treatments were at or above desired ranges.

There was no correlation that applications of either compost teas or extracts led to an increase in soil biology. Soil moisture was more influential on total fungal, active bacterial and fungal activity biomass levels than compost tea or compost extracts. Prolonging adequate soil moisture conditions may increase the beneficial role these organisms contribute to soil and pasture health.

9.3 Soil Nutrients

Compost teas and extracts were developed to increase available soil nutrient levels through applied soil biology, soluble nutrients to aid existing beneficial soil biology and foliar translocation (from leaf to roots) of soluble nutrients and applied biology. Plant available soil nutrients were monitored regularly within the topsoil (0-10 cm) in combination with either soil biology or plant nutrient levels. Annual monitoring of total soil nutrients to a depth of 110 cm were collected but have not been included in this report. Given the three year timeframe of the project, any changes to soil nutrient were likely to be observed within the topsoil.

Major Finding: There was no correlation that the application of compost teas and extracts increased the availability of major and minor plant available soil nutrients (Figure 13). For the majority of elements tested, there was little to no treatment effect (see Appendix 4 for full results). The addition of biological food sources applied in association with the compost teas and extracts did not increase plant available nutrient levels beyond that of the control treatment.

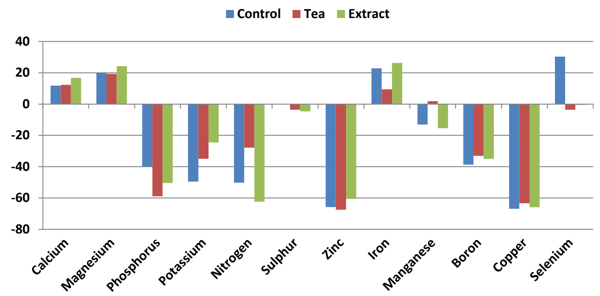

Figure 13: Percentage change (%) in major and minor plant available soil nutrients for individual treatments between August 2008 and April 2011.

Minor Finding: Available calcium, magnesium and iron levels increased within all treatments. Compost teas may have resulted in a lower decrease in soil nutrient availability of potassium and manganese compared to the control treatment.

Overall: The application of compost teas and extracts did not increase plant available soil nutrient levels when combined with specific biological food sources. Where increases in soil nutrients were observed in all treatments, grazing management and climate were considered key influential factors.

The addition of compost teas and extracts had no effect on biological activity and thus there was no positive response to increased soil nutrient levels.

9.4 Soil Carbon

Total soil carbon concentration (%) and stocks (t/ha) were analysed from regular soil nutrient testing (0-10 cm) and annually to a depth of 110 cm. The annual monitoring coincided with the larger Soil Carbon Project in Central Queensland managed by Farming and Beyond. Labile carbon concentration (%) was measured on three separate occasions in October 2009, October 2010 and April 2011.

Major Finding: Total soil carbon concentration levels (%) extracted with a manual corer decreased in all treatments within 0-10 cm (Figure 14). The compost tea treatment exhibited the greatest decline in carbon levels (26%), followed by the control treatment (17%) and the extract treatment (10%).

The extract treatment recorded similar levels of total carbon stocks (t/ha) to 110 cm between 2008 and 2010. The control treatment showed a slight reduction with carbon levels decreasing by 2% per year. The tea treatment experienced a 7% decrease from 2009 to 2010 after maintaining similar carbon levels between 2008/09 (Figure 15).

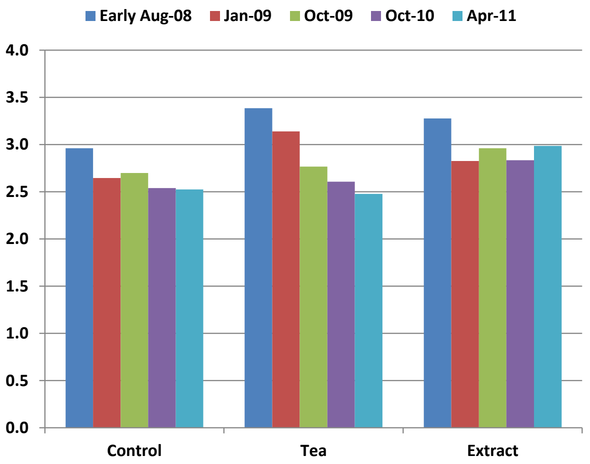

Figure 14: Average total soil carbon concentration (%) (0-10 cm) taken with a manual corer.

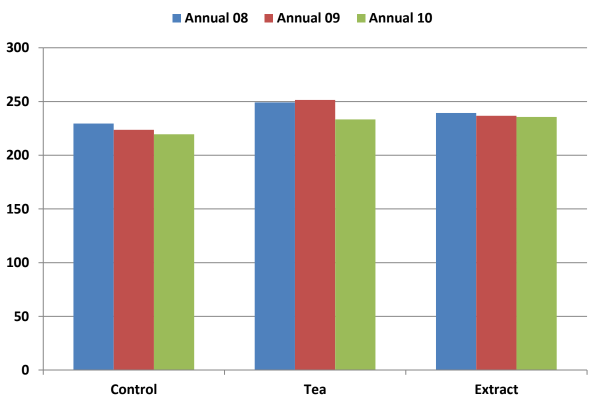

Figure 15: Average total soil carbon stocks (t/ha) (0-110 cm) measured in October 2008, October 2009 and November 2010.

Minor Finding: The control treatment showed the greatest increase in carbon levels of all treatments from 0-20 cm. The extract treatment increased in total carbon stocks (t/ha) between 30-60 cm (Figure 16) in contrast to both the compost tea and control treatments who recorded decreases of between 10 and 16%, respectively.

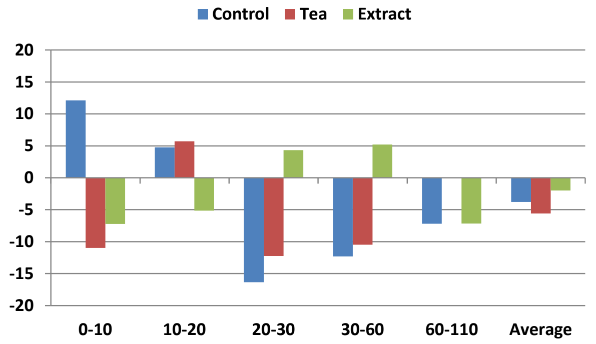

Figure 16: Percentage change of average total carbon stocks (t/ha) for individual soil depths (cm) (x-axis) between 2008 and 2010.

Labile soil carbon concentration (%) showed a decline in all treatments from October 2010 to April 2011 however little difference was noted across all treatments (Figure 17).

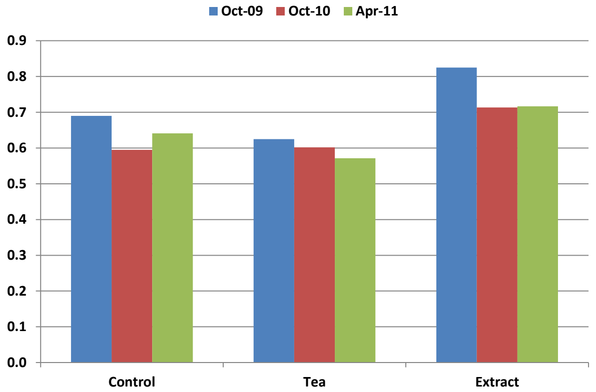

Figure 17: Labile soil carbon concentration (%) (0-10 cm) taken with a manual corer adjacent to buffel grass.

Overall: It was anticipated that short-term increases in soil carbon stocks from compost teas and extracts would occur in the topsoil (0 10 cm). Soil carbon stocks showed a negative effect from the application of compost teas to 60 cm apart from a minor increase in carbon levels between 10-20 cm. The compost extract treatment increased carbon levels between 30- 60 cm however overall all treatments experienced a slight decline in total carbon stocks.

The decline in soil carbon concentration for the 0-10 cm soil depth across all treatments is concerning. All soil samples were extracted near the basal area of American Buffel plants. Random samples taken during annual soil carbon sampling suggested that average decline in soil carbon across all treatments was lower. This suggests that with pastures dominated by American Buffel, the potential for soil carbon sequestration may be relatively low.

9.5 Plant Nutrients

Plant tissue was collected to assess whether compost teas or extracts would increase plant nutrient levels. American Buffel plants were cut at a height that represented the optimum level of grass detachment that would enhance rather than retard future regrowth. Plant tissue was not collected prior to March 2010 due to the project's main focus on soil biology. The major indices analysed for plant tissue analysis included crude protein, calcium, phosphorus, potassium, sulphur and various trace elements (see Appendix 5 for full results).

Major Finding: Crude protein levels were lower than the ideal level for sub-tropical pastures (12-14%) and did not show any improvements with the application of compost tea or extracts (Figure 18). Increases in plant available soil nutrient levels for calcium, magnesium and iron didn't translate into increases in plant nutrient levels under any treatment. There was no significant difference between treatments in major and minor plant nutrient levels.

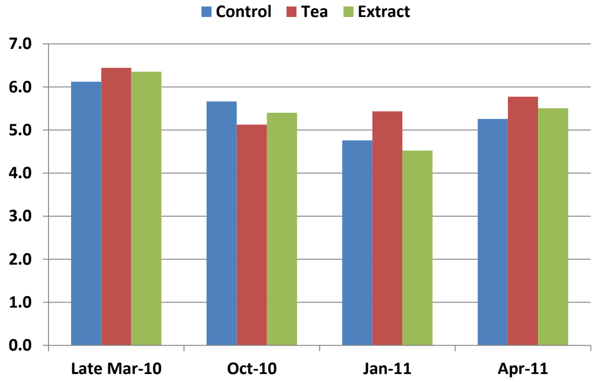

Figure 18: Average crude protein (%) of American Buffel from March 2010 to April 2011.

Minor Finding: Seasonal fluctuations in plant nutrient levels can be influenced by soil moisture conditions, temperature and stage of plant growth. Soil moisture conditions were not a limiting factor with above field capacity conditions experienced from October 2010 to April 2011. Daytime temperatures during spring and early summer were less than average due to cloudy conditions. Temperature had an effect on growth with little plant response until early summer.

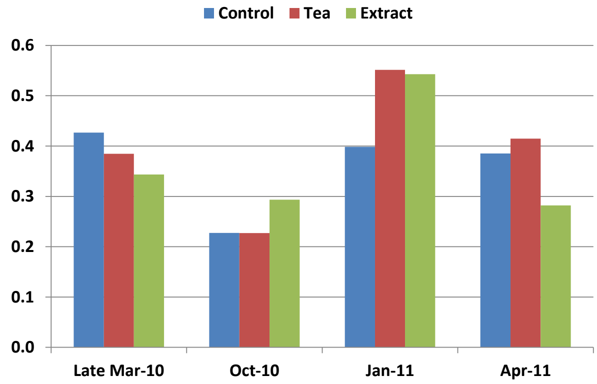

Figure 19: Average calcium levels (%) of American Buffel from March 2010 to April 2011. Ideal levels for calcium are 0.5%.

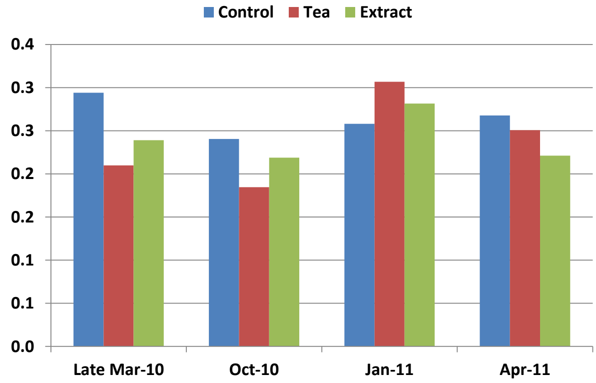

Figure 20: Average magnesium levels (%) of American Buffel from March 2010 to April 2011. Ideal levels for magnesium are 0.35%.

Overall: Plant nutrient levels were not influenced by compost teas or extracts nor was it observed that balancing of plant nutrient levels had occurred. Improvements in soil health can result in higher plant nutrition by increasing available soil nutrients and balancing plant nutrient levels. There was no treatment effect on plant available soil nutrient levels and consequently no change in plant nutrient levels.

The deficiencies in plant nutrient levels of American Buffel could be thwarted by hereditary traits. Past research employing a variety of techniques has shown little promise in reversing 'buffel rundown' currently experienced throughout Central Queensland. Monoculture ecosystems such as American Buffel pastures are unhealthy and require the introduction of complimentary plant species to counteract nutritional deficiencies.

9.6 Plant Feed Analysis

Plant feed analysis was monitored from March 2010 to April 2011 (see Appendix 6 for full results). Application of compost teas and extracts were limited by surface water within the trial from above average rainfall received between August 2010 and March 2011.

Major Finding: There was no treatment effect on plant feed quality. Ash levels which indicate total nutrient status of pastures were expected to increase through the use of compost teas and extracts (Figure 21). The addition of biological organisms was expected to increase digestibility (Figure 22) by transforming insoluble soil nutrients into plant available form. These assumptions did not eventuate through the period of testing.

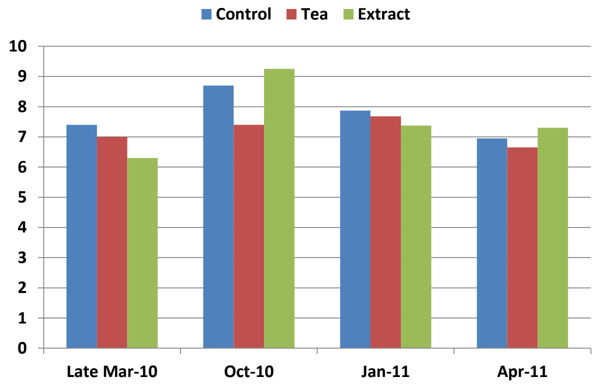

Figure 21: Average ash levels (%) of American Buffel from March 2010 to April 2011. Ideal levels for Ash are 13%.

Minor Finding: It is unknown whether the use of compost teas or extracts positively influenced other perennial pasture species. The project decided to focus on American Buffel species due to its dominance, productive and palatable characteristics within Central Queensland.

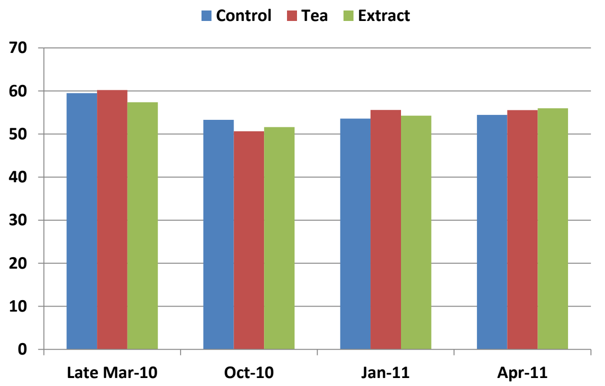

Figure 22: Average digestibility levels (%) of American Buffel from March 2010 to April 2011. Ideal levels for digestibility are 76%.

Overall: Pasture feed quality was not influenced by compost teas or extracts. Plant response may have been aided if buffel grass was healthier (higher and balanced nutrient levels). The majority of feed analysis indices tested (excluding crude protein) were within the expected range of district averages but low when compared to desired levels.

10.0 Discussion

Increases in soil and plant health did not occur with compost teas and extracts on broad acre grazing lands within Central Queensland. Soil moisture alone significantly biased soil fungal growth and active bacterial and fungal levels. The irrigation and horticultural industries have the ability to regulate soil moisture thus insuring optimum conditions for soil biological responses. In the broad acre dryland grazing environment within Central Queensland, graziers must create such an environment by their decision making alone.

The manufacturing process of compost teas is highly complex, temperature sensitive and can produce markedly variable results even under the guidance of experienced practitioners. Compost extracts require fewer man hours and experience with quality heavily reliant on the base compost product. The quantitative and qualitative assessment of compost, compost teas and extracts used within this trial suggested that most target biological species were at or above the desired range. Achieving such levels gave the project team a sense of optimism that the products were of a sufficient standard to encourage increases in soil and plant health.

Soil biology biomass and activity levels were greatly influenced by soil moisture. The value in soil biology monitoring must be assessed in relation to other soil and plant indices. Within the period of soil biological monitoring, an outcome of concern was the decline in bacterial biomass. This finding was repeated elsewhere in surrounding grazing properties within the local district. The initial perception from such a result could indicate bacteria are less resilient to the environmental and climatic conditions experienced during this period. The ratio of bacteria to fungi was approaching 1:1 which is a symptomatic balance of these major soil biological species under a perennial pasture.

It was anticipated that with little influence on soil biological biomass or activity from compost teas or extracts, plant available soil nutrients would show minimal changes to inherent levels. The addition of specific food sources to assist survival and growth of biology post application did not influence soil nutrient levels. Nor did the food sources invoke change in endemic soil organisms which were largely within the desired ranges.

The unpredictable nature of present day climate was a major challenge in providing ‘ideal’ conditions for applications of compost teas and extracts at the large property scale. In 2009 through to the mid 2010, extended periods of unseasonal dry weather followed by short bursts of high rainfall did not permit quarterly applications of compost tea or extracts. Uncharacteristic winter and spring rainfall in 2010 led to a wet, extended summer which isolated the trial area for months at a time. As a result, multiple applications occurred within a two to four week window of opportunity with extended time periods between subsequent applications.

Gross analysis figures were not costed into the manufacturing of the compost, application of compost tea and extract treatments and cattle production. An independent assessment of the manufacturing and application costs per hectare where teas only (no addition of food or soluble nutrients) were trialled on a grazing property within Central Queensland indicated the cost per application of between $15 to $20/ha. This figure however did not account for the purchase and depreciation of equipment and didn't fully cost the labour component.

The limited number of compost teas or extracts applied during the trial maybe considered normal practice for buffel pastures in a broad acre context. At the current rate of net return for beef cattle production on the most productive buffel country within Central Queensland, a maximum of two applications per year would be feasible subject to increased cattle production to offset this investment. Cattle production figures did not increase or justify the cost of applying either compost teas or extracts within this trial.

In the majority of cases where compost teas are applied to grazing lands is in the replacement of annual fertiliser applications (Young 2009). Proponents moving to an alternate biological approach have done so due to declining pasture and animal production from long-term synthetic fertiliser use. There is an immediate cost saving if removing fertiliser applications entirely and with ever increasing prices, the alternate practice of compost teas can be manufactured on farm with little external inputs. The limited data available suggests though that removing fertiliser and applying compost teas only does not improve soil and plant health. The fact that removing the fertiliser applications which is the cause of the problem is most likely why any response albeit visually, is likely to occur in the short to medium term.

For Central Queensland grass farmers at the broad acre scale, applying compost teas or extracts cannot be justified in relation to increasing soil or plant health. Soil moisture is a principal factor in sustained plant and soil biological activity that governs improvement in soil and plant health. To create such an environment where soil moisture is optimised would include but not be limited to the following actions:

- maximise rainfall infiltration by maintaining ground cover (standing active and laying decomposing on soil surface) at 100% all year round,
- minimise evaporation by sun and wind from bare soil by encouraging plants to establish and colonise these areas,
- build a permanent 'thatch' layer on the soil surface that retains soil moisture within the top soil (0–10 cm) where soil biological activity is concentrated,
- prolong plant activity for key plant/soil biology interactions to improve soil and pasture health, and
- encourage diversity in vegetation (perennial grasses, legumes, cereals, weeds, herbs, trees) with varying root structures, growth cycles and soil enhancement properties.

The creation of such an environment will require changes to grazing management and may involve establishing new plants. A holistic systems approach to managing grazing lands encompassing grazing management, ecosystem function and relationship of vegetation, soils and animals is required to create environments for improved soil and plant health. The adoption of targeted 'enhancement' products such as compost teas and extracts may then provide additional benefits in a healthier and functioning landscape.

11.0 Future Recommendations

Future research would be difficult to justify on review of soil and plant responses to foliar applications of compost teas or extracts on broad acre dryland grazing in Central Queensland. The benefit of applying such products may be warranted in combination with other practices aimed at regenerating run down pastures. Future research could be directed at the following areas which may demonstrate that compost teas and extracts have a role in broad acre dryland grazing systems aiding the establishment of new pasture species, these being:

- seed dressing to enhance germination of new species applied pre application if broadcasting via aerial means or ground applicators, or using liquid injection at planting into permanent or degraded pastures.
- addressing a significant decline in soil biology levels (e.g. fire, flood inundation)

where plant establishment is required from permanent death of once established species.

- targeting areas of higher cattle impact (e.g. waterholes) where multiple applications using high rates are concentrated on small areas and through cattle movement, biology is transported across the landscape.
- adding products directly to cattle watering points with cattle ingesting the biology and depositing it through the landscape via their by-products.

12.0 Acknowledgements

A sincere thank-you is extended to Mr Peter Attard for his willingness and devotion in being an innovator in the field of compost teas and extracts. His rare enthusiasm for stepping over the line makes us all the more appreciative of his efforts in tackling buffel rundown within Central Queensland.

To the Fitzroy Basin Association (FBA) who funded the project, thank-you for the opportunity in providing financial assistance to an area deemed too left field for main stream funding organisations.

13.0 References

Ingham. E. (2005). *The Compost Tea Brewing Manual. Fifth Edition.*

Recycled Organics Unit (2006). *Overview of Compost Tea Use in New South Wales*. Recycled Organics Unit, internet publication: www.recycledorganics.com

Young, R. (2009). *Final Report for project Number OG081758-Soil Biology - The Missing Link for regenerative production in our farming systems.*

Appendix 1: Soil Description

Project: CWRES **Site:** 67 **Observation:** 1 **Date:** 23/MAR/11

Location: GDA 94 ZONE 56 197541mE 7289952mN Lat: -24.47469 Long: 150.01613

Soil Name: No record Described By: Sue Burt (BURS)

Landscape:

Geology: No record

Landform: plain

Runoff: No record

Slope: .5 %

Rock Outcrops: No record

Surface Coarse Fragments: No record

Microrelief: No record

Permeability: No record

Drainage: No record

Surface Condition: Self-mulching, Periodic cracking

Disturbances: No record

Classifications:

ASC: EPISODIC, SELF-MULCHING, GREY, Vertosol, Non-gravelly, Medium Fine, Medium Fine, Deep

GSG:

Confidence:

PPF:

Vegetation:

Community Name: Tree, Acacia harpophylla

Tallest Stratum:

Species: Acacia harpophylla (brigalow); Eucalyptus cambageana (coowarra box)

Lower Stratum:

Species: Cenchrus ciliaris (buffel grass); Panicum maximum var. trichoglume (green panic)

Profile Morphology:

Horizon	Depth (m)	Colour	Mottles	Texture	Structure Grade	Structure Type	Structure Size	Coarse Fragments	Segregations	Boundary Distinct
A1	0.00 - 0.14	very dark grey (10YR31)	-	medium clay	moderate	subangular blocky	5-10mm	no coarse fragments 0%	no segregations	gradual
B21	0.14 - 0.37	dark grey (10YR41)	-	medium clay	moderate parting to strong	subangular blocky parting to lenticular	10-20mm parting to 2-5mm	no coarse fragments 0%	no segregations	gradual
B22	0.37 - 0.58	dark greyish brown (10YR42)	-	medium clay	moderate	lenticular	2-5mm	no coarse fragments 0%	no segregations	diffuse
B23	0.58 - 1.20	brown (10YR53)	-	medium clay	moderate	lenticular	2-5mm	no coarse fragments 0%	no segregations	-

Appendix 2: Soil, Tea and Extract Biological Results

Property	Treatment	Soil/Tea/Extract Sample	Application	Treat ID	Date	Dry Weight	Active Bacteria µg/g soil	Total Bacteria µg/g soil	Active Fungal µg/g soil	Total Fungal µg/g soil	Fungal Hyphal Diameter µm
Rainbow's End	Control 1	Soil	Baseline	RE9BCO	5/08/2008	0.83	52.9	1075	4.92	511	2.75
Rainbow's End	Control 2	Soil	Baseline	RE9CCO	5/08/2008	0.84	33.4	286	8.46	122	2.5
Rainbow's End	Tea 1	Soil	Baseline	RE9BCT	5/08/2008	0.81	55.9	575	9.32	614	3
Rainbow's End	Tea 2	Soil	Baseline	RE9CCT	5/08/2008	0.83	29.5	315	7.88	549	3.5
Rainbow's End	Extract 1	Soil	Baseline	RE9BEX	5/08/2008	0.80	60.1	501	15.47	396	2.75
Rainbow's End	Extract 2	Soil	Baseline	RE9CEX	5/08/2008	0.83	54.5	219	5.64	425	2.5
Applied Compost Tea and Extract to each paddock (except control) on 6/8/08, results of tea and extract below.											
	Compost Tea	**Tea**	**Tea Application 1**		**6/08/2008**		**18.7**	**1549**	**36.70**	**51.7**	**3**
	Extract	**Extract**	**Extract Application 1**		**6/08/2008**		**58.4**	**5888**	**0.46**	**3.14**	**2.75**
Both tea and extract was applied at 80L/ha, no record of products or amounts used in the manufacturing of each product.											
Soil tested 3 weeks post application											
Rainbow's End	Control 1	Soil	Post App 1	RE9BCO	27/08/2008	0.9	14.7	544	1.44	180	2.75
Rainbow's End	Control 2	Soil	Post App 1	RE9CCO	27/08/2008	0.9	25.9	640	5.83	102	2.5
Rainbow's End	Tea 1	Soil	Post App 1	RE9BCT	27/08/2008	0.87	29.5	732	5.58	73.9	2.5
Rainbow's End	Tea 2	Soil	Post App 1	RE9CCT	27/08/2008	0.89	27.3	708	5.88	194	2.5
Rainbow's End	Extract 1	Soil	Post App 1	RE9BEX	27/08/2008	0.87	29.85	851	4.65	209	2.88
Rainbow's End	Extract 2	Soil	Post App 1	RE9CEX	27/08/2008	0.88	29	1114	7.92	202	3
Soil tested 11 weeks post original application											
Rainbow's End	Control 1	Soil	Post App 1a	RE9BCO	28/10/2008	0.92	6.11	1287	0.00	49	2.5
Rainbow's End	Control 2	Soil	Post App 1a	RE9CCO	28/10/2008	0.92	8.04	1225	0.00	45	2.5
Rainbow's End	Tea 1	Soil	Post App 1a	RE9BCT	28/10/2008	0.89	11.8	1712	2.82	126	2.5
Rainbow's End	Tea 2	Soil	Post App 1a	RE9CCT	28/10/2008	0.92	8.04	1140	0.00	86	2.5
Rainbow's End	Extract 1	Soil	Post App 1a	RE9BEX	28/10/2008	0.9	6.82	1360	0.00	65	2.5
Rainbow's End	Extract 2	Soil	Post App 1a	RE9CEX	28/10/2008	0.91	7.29	904	0.31	74	2.5
Soil tested prior to 2nd application, no application occurred.											
Rainbow's End	Control 1	Soil	Post App 1b	RE9BCO	12/01/2009	0.91	11.20	206	2.14	102	2.50
Rainbow's End	Control 2	Soil	Post App 1b	RE9CCO	12/01/2009	0.92	8.20	183	0.00	133	2.50
Rainbow's End	Tea 1	Soil	Post App 1b	RE9BCT	12/01/2009	0.90	8.86	298	0.94	135	2.75
Rainbow's End	Tea 2	Soil	Post App 1b	RE9CCT	12/01/2009	0.91	9.40	254	0.00	204	3.00
Rainbow's End	Extract 1	Soil	Post App 1b	RE9BEX	12/01/2009	0.90	7.36	434	3.78	424	3.00
Rainbow's End	Extract 2	Soil	Post App 1b	RE9CEX	12/01/2009	0.89	10.23	283	0.23	275	3.00

Property	Treatment	Soil/Tea/Extract Sample	Application	Treat ID	Date	Dry Weight	Active Bacteria µg/g soil	Total Bacteria µg/g soil	Active Fungal µg/g soil	Total Fungal µg/g soil	Fungal Hyphal Diameter µm
Soil tested prior to 2nd application											
Rainbow's End	Control 1	Soil	Pre App 2	RE9BCO	11/01/2010	0.89	21.20	134	1.80	83	3.00
Rainbow's End	Control 2	Soil	Pre App 2	RE9CCO	11/01/2010	0.89	25.39	257	9.98	305	3.00
Rainbow's End	Tea 1	Soil	Pre App 2	RE9BCT	11/01/2010	0.87	41.80	523	16.00	319	3.00
Rainbow's End	Tea 2	Soil	Pre App 2	RE9CCT	11/01/2010	0.89	22.56	131	5.46	227	3.00
Rainbow's End	Extract 1	Soil	Pre App 2	RE9BEX	11/01/2010	0.87	26.27	326	8.38	62	2.50
Rainbow's End	Extract 2	Soil	Pre App 2	RE9CEX	11/01/2010	0.87	42.86	128	21.23	189	3.00
Applied Compost Tea and Extract to each paddock (except control) on 11 and 12/01/10, results of tea and extract below.											
	Compost Tea	**Tea**	**Tea Application 2**		**11/01/2010**		**8.51**	**333**	**53.00**	**68.3**	**3**
	Extract	**Extract**	**Extract Application 2**		**11/01/2010**		**8.7**	**755**	**0.7**	**5.78**	**3**
Rainwater 4000lts, 15lts Jack's compost, 2L Fish Hydro, 1L bull kelp, 0.5L KFF, 2L Oat Meal, 1L Apple Cider vinegar, brewing time 16-17 hours, application rate 200L/ha, commenced at 8:30am											
Rainwater 4000lts, 210L Jack's compost, brewing time 3 hours, application rate 200L/ha, commenced at 11:30am											
Soil tested 2 weeks post 2nd application											
Rainbow's End	Control 1	Soil	Post App 2	RE9BCO	25/01/2010	0.96	16.36	225	1.40	199	3.00
Rainbow's End	Control 2	Soil	Post App 2	RE9CCO	25/01/2010	0.96	20.20	269	6.13	260	3.00
Rainbow's End	Tea 1	Soil	Post App 2	RE9BCT	25/01/2010	0.95	10.40	339	0.00	88	3.00
Rainbow's End	Tea 2	Soil	Post App 2	RE9CCT	25/01/2010	0.96	27.85	246	3.37	180	3.00
Rainbow's End	Extract 1	Soil	Post App 2	RE9BEX	25/01/2010	0.94	17.19	241	7.40	100	3.00
Rainbow's End	Extract 2	Soil	Post App 2	RE9CEX	25/01/2010	0.96	16.73	180	5.04	91	2.50
Applied Compost Tea and Extract to each paddock (except control) on 8/02/10, no tea or extract sent to lab.											
Performed Qual assay instead following brewing. CT applied at 150l/ha with 5L/ha fish hydrolysate, 5l/ha seaweed, 3l/ha molasses and 2l/ha of Calsap.											
CT - Bacteria was 25-500, Fungi half a dozen pods per field with protozoas only 5% with one cilliate present. Used 5L of Jack's compost, 5L of own and 5L of previously used extract all activated prior to brewing.											
Applied extract @ 185L/ha with foods: 5L/ha fish hydrolysate, 5l/ha seaweed, and 3l/ha molasses. Used own compost 180L in 3700L of dam water.											
EX - not analysed by Peter Attard											
Soil tested 5 weeks post 3rd application											
Rainbow's End	Control 1	Soil	Post App 3	RE9BCO	16/03/2010	0.91	7.7	133	0.44	95.7	3
Rainbow's End	Tea 1	Soil	Post App 3	RE9BCT	16/03/2010	0.88	11.20	136	0.91	96	3.00
Rainbow's End	Extract 1	Soil	Post App 3	RE9BEX	16/03/2010	0.88	17.9	172	1.37	263	3
Soil tested 6 weeks post 3rd application											
Rainbow's End	Control 1	Soil	Post App 3a	RE9BCO	24/03/2010	0.81	73	147	14.4	511	3.5
Rainbow's End	Tea 1	Soil	Post App 3a	RE9BCT	24/03/2010	0.78	48.3	197	13.8	793	3
Rainbow's End	Extract 1	Soil	Post App 3a	RE9BEX	24/03/2010	0.78	69.3	162	13.1	693	3

Appendix 3: Example of Compost Biological Analysis

Compost Foodweb Analysis

Report prepared for:
Soil Foodweb International - R
Merline Olson
1 Crawford Road,
East Lismore, NSW 2480

merline@soilfoodweb.com.au

Report Sent: 18/11/2009
Sample#: 02-011273 | Submission:02-005482
Unique ID: SS Compost.
Plant:
Invoice Number: 1
Sample Received: 03/11/2009

For interpretation of this report please contact:
Local Advisor: or regional lab:
Soil Foodweb Institute Pty Ltd
contact@soilfoodweb.com.au
0266225150
Consulting fees may apply

Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		0.550	37.5	671	0.51	350	2.5
Comments		In Good Range	Above range	In range	Below range	Above range	
Expected Range	Low	0.45	15	100	15	100	
	High	0.85	25	3000	25	300	

		Protozoa (Numbers/g)			Total	Mycorrhizal Colonization (%)	
		Flagellates	Amoebae	Ciliates	Nematodes #/g	ENDO	ECTO
Results		50390	151175	1045	35.4	Not Ordered	Not Ordered
Comments		High	High	High	High		
Expected Range	Low	10000	10000	50	20		
	High			100	30		

Organism Biomass Ratios		Total Fungal to Tot.Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Act.Bacterial	Plant Available N Supply (lbs/ac)
Results		**0.52**	**0.001**	0.06	**0.01**	250+
Comments		Low	Low	Good	Low	
Expected Range	Low	0.75	0.01	0.01	0.75	
	High	1.5	0.1	0.1	1.5	

Nematode detail (# per gram or # per mL)
Classified by type and identified to genus.
(If section is blank, no nematodes identified.)

Bacterial Feeders		
Butlerius		1.81
Cuticularia		2.27
Diplogasteritus		2.72
Diploscapter		0.45
Fungal Feeders		
Eudorylaimus		11.33
Fungal/Root Feeders		
Filenchus		0.91

1 Crawford Road East Lismore, NSW 2480 Australia
0266225150 | contact@soilfoodweb.com.au
www.soilfoodweb.com.au

02-011273: Page 1 of 3

Appendix 4: Soil Nutrient Results (0-10 cm)

ALBRECHT AND REAMS SOIL ANALYSIS REPORT

			Soil Depth	0-10cm	0-10cm	0-10cm	0-10cm	0-10cm	0-10cm	0-10cm	0-10cm	0-10cm	0-10cm	0-10cm	0-10cm
			Block ID:	RE9BCO	RE9CCO	RE9BCT	RE9CCT	RE9BEX	RE9CEX	RE9BCO	RE9CCO	RE9BCT	RE9CCT	RE9BEX	RE9CEX
			Treatment	Control 1	Control 2	Tea 1	Tea 2	Extract 1	Extract 2	Control 1	Control 2	Tea 1	Tea 2	Extract 1	Extract 2
			Application	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline	Final	Final	Final	Final	Final	Final
			Date	5/08/2008	5/08/2008	5/08/2008	5/08/2008	5/08/2008	5/08/2008	12/04/2011	12/04/2011	12/04/2011	12/04/2011	12/04/2011	12/04/2011
	Nutrient		Units	JA4794/13	JA4794/12	JA4794/14	JA4794/15	JA4794/11	JA4794/16	B3640/1	B3640/4	B3640/3	B3640/6	B3640/2	B3640/5
Soluble Tests & Morgan 1 Extract	Calcium	Ca	ppm	1075	1066	1298	1050	1359	984	1253	1141	1162	1475	1602	1134
	Magnesium	Mg	ppm	425	391	455	396	401	361	524	454	494	521	474	473
	Potassium	K	ppm	187	146	277	182	181	170	101	67	95	203	119	147
	Phosphorus (Morgan)	P	ppm	2.9	1.5	2.1	2.4	1.2	0.7	2.9	2.7	2.7	3.2	3.0	3.1
	Phosphorus (Bray 1)	P	ppm	17	16	27	37	17	11	9.0	9.8	12.5	8.7	5.8	6.6
Soluble Tests & Colwell + Bray 2 Phoshorus Extract	Phosphorus (Colwell)	P	ppm	37	37	46	74	35	24	21	24	30	20	13	16
	Phosphorus (Bray 2)	P	ppm	26	27	38	61	27	17	19	21	27	19	13	14
	Nitrate	N	ppm	3.9	2.7	3.2	2.3	4.5	2.0	1.2	2.1	2.6	1.4	1.2	1.3
	Ammonium	N	ppm	3.5	3.8	3.7	2.8	3.5	3.3	3.4	4.6	3.6	5.7	4.3	5.2
	Sulphate Sulphur	S	ppm	10	8	9	7	11	8	7.6	7.7	5.2	10.5	7.5	5.0
	pH (1:5 water)		units	6.28	6.56	6.71	6.42	6.60	6.33	6.54	6.30	6.29	6.37	6.20	6.13
	Conductivity (1:5 water)		µS/cm	106	102	170	98	104	96	0	0	0	0	0	0
	Organic Matter		%	5.67	4.70	6.77	5.08	6.44	5.03	4.52	4.32	3.84	4.83	4.81	5.64
Ammonium Acetate Equiv. Extract	Calcium	Ca	$cmol^+/Kg$	15.41	15.04	17.76	15.97	19.66	14.14	12.70	10.87	10.53	15.69	15.18	11.31
		Ca	kg/ha	6906	6736	7958	7155	8807	6336	5692	4869	4717	7031	6800	5066
		Ca	ppm	3083	3007	3553	3194	3931	2829	2541	2174	2106	3139	3036	2261
	Magnesium	Mg	$cmol^+/Kg$	7.60	7.16	8.31	7.47	7.45	6.29	7.25	5.75	5.96	7.08	6.18	6.11
		Mg	kg/ha	2043	1924	2234	2009	2003	1691	1948	1545	1602	1903	1662	1642
		Mg	ppm	912	859	997	897	894	755	870	690	715	849	742	733
	Potassium	K	$cmol^+/Kg$	1.21	0.96	1.73	1.22	1.21	1.08	0.57	0.38	0.51	1.12	0.66	0.79
		K	kg/ha	1053	841	1514	1063	1056	943	500	334	443	975	577	688
		K	ppm	470	375	676	475	471	421	223	149	198	435	257	307
	Sodium	Na	$cmol^+/Kg$	0.88	0.60	1.14	0.73	0.81	0.77	1.04	0.93	0.87	1.29	0.83	0.77
		Na	kg/ha	455	309	589	376	419	394	536	477	447	664	426	396
		Na	ppm	203	138	263	168	187	176	239	213	200	296	190	177
	Aluminium	Al	$cmol^+/Kg$	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.02
		Al	kg/ha	4	3	3	3	4	4	4	5	4	6	5	5
		Al	ppm	2	1	1	1	2	2	2	2	2	3	2	2
Acidity Titration	Hydrogen	H^+	$cmol^+/Kg$	0.05	0.00	0.00	0.05	0.02	0.05	0	0.03	0.05	0.04	0	0.07
		H^+	kg/ha	1	0	0	1	0	1	0	1	1	1	0	1
		H^+	ppm	1	0	0	0	0	1	0	0	1	0	0	1
	Cation Exchange Capacity		$cmol^+/Kg$	25.18	23.77	28.96	25.46	29.17	22.35	21.6	18.0	17.9	25.3	22.9	19.1
Percent Base Saturation	Calcium	Ca	%	61.2	63.2	61.3	62.7	67.4	63.3	58.9	60.4	58.7	62.2	66.4	59.3
	Magnesium	Mg	%	30.2	30.1	28.7	29.4	25.5	28.1	33.6	32.0	33.2	28.0	27.0	32.0
	Potassium	K	%	4.8	4.0	6.0	4.8	4.2	4.8	2.7	2.1	2.8	4.4	2.9	4.1
	Sodium	Na	%	3.5	2.5	3.9	2.9	2.8	3.4	4.8	5.2	4.8	5.1	3.6	4.0
	Aluminium	Al	%	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1
	Hydrogen	H+	%	0.2	0.0	0.0	0.2	0.1	0.2	0.0	0.2	0.3	0.2	0.0	0.3
	Calcium/ Magnesium Ratio		ratio	2.03	2.10	2.14	2.14	2.66	2.25	1.8	1.9	1.8	2.2	2.5	1.9
SMP	BUFFER pH		units	0.00	0.00	0.00	0.00	0.00	0.00	..	..	..	..	..	..
Micronutrients- DTPA +Hot $CaCl_2$ Extracts	Zinc	Zn	ppm	4.0	4.1	3.0	4.8	3.9	3.1	1.0	1.8	1.4	1.1	1.1	1.6
	Manganese	Mn	ppm	100.1	108.0	50.9	111.4	92.8	73.7	54	127	115	50	57	84
	Iron	Fe	ppm	80.3	67.2	59.6	89.4	74.1	70.5	87	95	93	70	66	117
	Copper	Cu	ppm	5.9	6.9	5.0	7.4	6.5	4.8	1.8	2.4	2.3	2.2	1.9	1.9
	Boron	B	ppm	0.71	0.59	0.68	0.51	0.72	0.53	0.61	0.44	0.44	0.57	0.49	0.50
Acid Extract	Molybdenum	Mo	ppm	0.14	0.19	0.09	0.17	0.11	0.07	0.28	0.42	0.52	0.36	0.32	0.33
	Cobalt	Co	ppm	5.32	14.19	4.47	13.60	5.64	5.83	5.42	15.16	19.00	6.12	6.31	6.44
	Selenium	Se	ppm	0.24	0.48	0.24	0.41	0.34	0.27	0.29	0.65	0.42	0.21	0.27	0.33
$CaCl_2$ Extract	Silicon	Si	ppm	95.8	73.0	82.2	68.1	83.8	82.5	94.9	59.7	68.1	77.6	76.5	81.3
Total Nutrients	Total Carbon	C	%	3.24	2.69	3.87	2.90	3.68	2.87	2.58	2.47	2.19	2.76	2.75	3.22
	Total Nitrogen	N	%	0.25	0.21	0.25	0.22	0.27	0.21	0.21	0.19	0.16	0.22	0.20	0.25
	Carbon/ Nitrogen Ratio		ratio	13.0	13.1	15.4	13.5	13.7	13.4	12.3	12.9	13.4	12.7	13.6	12.8
	Texture	t		Loam	Loam	Loam	Loam	Loam	Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam	Clay Loam
	Colour	c		Grey	Grey	Grey	Grey	Grey	Grey	Brownish	Brownish	Brownish	Brownish	Brownish	Brownish
	Labile Carbon		%							0.6	0.7	0.5	0.7	0.7	0.7
	Chloride Estimate		ppm	68	65	109	63	66	61	52	47	46	72	52	48

Appendix 5: Plant Nutrient Results

			Plant	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel	Buffel
			Treat ID:	**RE9BCO**	**RE9BCT**	**RE9BEX**	**RE9BCO**	**RE9CCO**	**RE9BCT**	**RE9CCT**	**RE9BEX**	**RE9CEX**	**RE9BCO**	**RE9CCO**	**RE9BCT**	**RE9CCT**	**RE9BEX**	**RE9CEX**	**RE9BCO**	**RE9CCO**	**RE9BEX**	**RE9CEX**	**RE9BCT**	**RE9CCT**
			Treatment	**Control 1**	**Tea 1**	**Extract 1**	**Control 1**	**Control 2**	**Tea 1**	**Tea 2**	**Extract 1**	**Extract 2**	**Control 1**	**Control 2**	**Tea 1**	**Tea 2**	**Extract 1**	**Extract 2**	**Control 1**	**Control 2**	**Tea 1**	**Tea 2**	**Extract 1**	**Extract 2**
			Application	**Post App 3**	**Post App 3**	**Post App 3**	**Post App 3b**	**Post App 3b**	**Post App 3b**	**Post App 3b**	**Post App 3b**	**Post App 3b**	**Post App 3c**	**Post App 3c**	**Post App 3c**	**Post App 3c**	**Post App 3c**	**Post App 3c**	**Post App 4**	**Post App 4**	**Post App 4**	**Post App 4**	**Post App 4**	**Post App 4**
			Date	**24/03/10**	**24/03/10**	**24/03/10**	**4/10/10**	**4/10/10**	**4/10/10**	**4/10/10**	**4/10/10**	**4/10/10**	**31-Jan**	**31-Jan**	**31-Jan**	**31-Jan**	**31-Jan**	**31-Jan**	**12-Apr**	**12-Apr**	**12-Apr**	**12-Apr**	**12-Apr**	**12-Apr**
	Nutrient		Units	A7910/1	A7910/2	A7910/3	B0974/1	B0974/4	B0974/3	B0974/6	B0974/2	B0974/5	B2473/1	B2473/2	B2473/3	B2473/4	B2473/5	B2473/6	B3641/1	B3641/4	B3641/2	B3641/5	B3641/3	B3641/6
TOTAL Nutrients (Acid Digest/ Combustion)	Nitrogen	N	%	0.98	1.03	1.02	0.77	1.05	1.01	0.63	0.91	0.81	0.82	0.70	0.96	0.78	0.77	0.68	0.74	0.94	0.99	0.85	1.04	0.72
	Phosphorus	P	%	0.43	0.47	0.35	0.22	0.25	0.25	0.27	0.28	0.31	0.31	0.35	0.31	0.32	0.54	0.38	0.47	0.35	0.34	0.33	0.44	0.28
	Potassium	K	%	3.24	3.76	3.10	1.27	2.46	1.77	1.05	1.47	1.82	2.20	1.75	2.41	2.17	1.79	2.23	2.40	2.05	2.38	2.33	2.60	1.64
	Sulphur	S	%	0.13	0.14	0.12	0.14	0.16	0.15	0.11	0.14	0.13	0.11	0.11	0.12	0.13	0.13	0.12	0.15	0.16	0.15	0.17	0.20	0.15
	Carbon	C	%	40.9	41.0	41.3	42.4	42.7	42.5	43.5	43.3	41.3	39.8	41.5	40.0	39.7	40.3	40.6	41.5	41.1	42.1	41.4	42.0	42.7
TOTAL Salts (Acid Digest)	Calcium	Ca	%	0.43	0.38	0.34	0.19	0.26	0.24	0.21	0.28	0.30	0.43	0.37	0.57	0.53	0.67	0.42	0.40	0.37	0.51	0.32	0.29	0.27
	Magnesium	Mg	%	0.29	0.21	0.24	0.20	0.28	0.18	0.19	0.19	0.24	0.28	0.24	0.27	0.35	0.29	0.28	0.26	0.28	0.25	0.25	0.20	0.24
	Sodium	Na	%	0.04	0.06	0.05	0.02	0.04	0.03	0.03	0.04	0.03	0.03	0.07	0.03	0.05	0.05	0.03	0.01	0.02	0.02	0.02	0.02	0.05
TOTAL Metals (Acid Digest)	Copper	Cu	ppm	17	13	14	6.4	7.5	7.0	6.4	8.1	6.5	6	6	6	6	8	5	8	6	7	7	6	7
	Zinc	Zn	ppm	18	18	17	34	40	29	31	32	33	22	25	18	22	27	22	25	29	23	27	25	32
	Manganese	Mn	ppm	84	51	60	94	112	93	133	64	83	198	150	152	169	233	149	150	136	113	118	74	175
	Iron	Fe	ppm	208	143	167	271	213	287	244	317	352	223	164	96	243	487	166	261	280	235	293	168	531
	Boron	B	ppm	4	4	3	2.5	3.5	2.8	2.5	3.6	3.3	7	4	8	6	6	6	4	3	4	4	3	4
	Molybdenum	Mo	ppm	0.6	0.8	0.6	0.2	0.1	0.4	0.1	0.3	0.4	0.4	0.6	0.5	0.4	0.6	0.5	0.4	0.5	0.8	0.3	0.6	0.3
	Cobalt	Co	ppm	0.2	0.3	0.2	0.1	0.1	0.2	0.3	0.4	0.2	0.2	0.2	0.1	0.3	0.4	0.1	0.2	0.3	0.2	0.2	0.2	0.4
	Silicon	Si	ppm	617	565	574	724	913	738	892	693	820	199	181	283	798	857	751	576	451	455	190	451	206
Calculations/ Ratios	Nitrogen : Sulphur Ratio		units	7.6	7.3	8.6	5.5	6.6	6.7	5.5	6.7	6.5	7.3	6.3	7.8	6.2	6.1	5.5	5.1	5.9	6.6	5.2	5.1	5.0
	Nitrogen : Phosphorus Ratio		units	2.3	2.2	2.9	3.4	4.2	4.0	2.4	3.3	2.6	2.7	2.0	3.1	2.4	1.4	1.8	1.6	2.7	2.9	2.6	2.3	2.6
	Nitrogen : Potassium Ratio		units	0.3	0.3	0.3	0.6	0.4	0.6	0.6	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.5	0.4	0.4	0.4	0.4
	Carbon : Nitrogen Ratio		units	41.7	39.8	40.6	55.4	40.8	42.1	68.8	47.3	50.7	48.4	59.1	41.7	50.9	52.5	59.6	55.9	43.6	42.3	48.5	40.5	59.0
	Crude Protein[see note 5]		%	6.1	6.4	6.4	4.8	6.5	6.3	3.9	5.7	5.1	5.1	4.4	6.0	4.9	4.8	4.3	4.6	5.9	6.2	5.3	6.5	4.5

Appendix 6: Plant Feed Analysis Results

DATE	Treat ID	Treatment	Plant	ADF	Ash	DDM	DM	Fat	ME	Moisture	NDF	CP	DMI
				%	%	%	%	%	MJ/kg	%	%	%	%
24/03/10	RE9BCO	Control 1	Buffel	39	7.4	60	28	3.0	8.5	72	66	11.6	1.8
24/03/10	RE9BCT	Tea 1	Buffel	38	7.0	60	27	3.1	8.6	73	64	12.0	1.9
24/03/10	RE9BEX	Extract 1	Buffel	39	6.3	57	32	2.5	8.2	68	67	8.6	1.8
4/10/10	RE9BCO	Control 1	Buffel	40	8.6	54	31	2.9	8.1	69	68	8.2	1.8
4/10/10	RE9CCO	Control 2	Buffel	41	8.8	53	26	2.5	7.9	74	68	7.8	1.8
4/10/10	RE9BCT	Tea 1	Buffel	38	5.1	56	32	3.6	8.4	68	61	9.8	2.0
4/10/10	RE9CCT	Tea 2	Buffel	50	9.7	45	36	1.3	6.8	64	74	5.7	1.6
4/10/10	RE9BEX	Extract 1	Buffel	41	8.4	53	25	2.7	8.0	75	68	7.5	1.8
4/10/10	RE9CEX	Extract 2	Buffel	45	10.1	50	49	9.8	7.5	52	69	8.9	1.7
31/01/11	RE9BCO	Control 1	Buffel	41	7.9	53	48	4.3	8.0	52	69	8.6	1.7
31/01/11	RE9CCO	Control 2	Buffel	40	7.9	54	48	1.7	8.1	52	66	7.6	1.8
31/01/11	RC9BCT	Tea 1	Buffel	39	7.7	56	38	1.9	8.5	62	65	11.6	1.8
31/01/11	RE9CCT	Tea 2	Buffel	40	7.7	55	38	1.9	8.2	62	67	9.5	1.8
31/01/11	RE9BEX	Extract 1	Buffel	41	6.8	53	41	2.4	8.0	59	68	8.3	1.8
31/01/11	RE9CEX	Extract 2	Buffel	40	8.0	55	41	2.4	8.3	59	66	10.5	1.8
12/04/11	RE9BCO	Control 1	Buffel	39	6.3	55	28	3.3	8.2	72	73	7.7	1.6
12/04/11	RE9CCO	Control 2	Buffel	40	7.6	54	28	3.2	8.1	72	71	7.8	1.7
12/04/11	RE9BCT	Tea 1	Buffel	39	8.4	56	24	3.0	8.4	76	69	10.4	1.8
12/04/11	RE9CCT	Tea 2	Buffel	39	4.9	55	30	3.3	8.2	70	71	8.8	1.7
12/04/11	RE9BEX	Extract 1	Buffel	40	6.8	55	27	3.2	8.2	74	73	9.2	1.7
12/04/11	RE9CEX	Extract 2	Buffel	38	7.8	57	25	3.4	8.6	75	70	11.2	1.7