(Principal Component Analysis)

Circular Economy Research and Development Fund - Project Final Report

Research project title – Quantifying Mineralisation and Biological Status from Organic Amendments and Soil.

Lead organisation – Agpath Pty Ltd

ACKNOWLEDGEMENTS

To the team at Agpath, University of Melbourne, Sustainability Victoria (SV), suppliers of products and team from CORE: the project has generated some remarkably interesting data that has been used in conference presentations and the field day. The final report will be available on the Victorian Government website, and a comprehensive report will be published in 2026. Thank-you to SV for funding the project and supporting the researchers through the 2 and a half years of trying weather.

Executive Summary

Two sources of agricultural and urban waste, feedlot manure and FOGO, are the basis of this research project and how these resources can be utilised in a circular economy and blended to produce products that are fit-for-purpose for the agricultural and horticultural industries removing them from landfill. A key outcome from this project was most effective blend of the raw materials to provide a fit-for-purpose product for agriculture from vegetables to pastures, orchards, etc. A 50:50 blend provided effective composting, easy to measure and carry out on-farm. Fresh FOGO and aged manure mixed well is achievable on-farm using tractors with front-end bucket and round bale fork.

Time efficient composting relies on moisture and carbon: nitrogen ratios. The field & replicated trials concentrated on blending commercial composted products with the waste streams to determine the carbon: nitrogen ratios that would provide cost effective organic input into the farming sector as well as identifying the role soil biota had in improving plant nutrient levels after application of these organic products. Data collected showed that the 50:50 blend of feedlot manure and FOGO gave good results and was the easiest for a farmer to adapt to the everyday farming enterprise. The commercial composts can be used as delivered.

The EPA is concerned with odour in the early processing of FOGO.

The proposed outcomes (direct and indirect) of the project were:

- To divert organic material from landfill and transform into a valuable resource such as feedstock/ compost/organic soil amendments.
- Identify better fit-for-purpose products.
- Demonstrate decreased susceptibility to pest and disease and increased productivity.
- Increase confidence of users in products – inadequate information on presence of toxic contaminants.
- Address carbon capture by improving organic matter in soils.
- Improve resilience of current farming systems to increasing climate variability.
- Contribute to improved national standards for organic products.
- Determine cost-benefit to user.
- Substitute conventional finite resources with environmentally compatible recycled organic materials.
- Reduce energy input into the food production system by replacing energy intensive inputs with environmentally compatible recycled organic materials.

Abbreviations

Abbreviation	Name
CEC	*Cation Exchange Capacity*
C:N	*Carbon to Nitrogen*
UTC	*Untreated Control*
FLM	*Feedlot Manure*
DD	*Dutson Downs Compost*
FOGO	*Food Organics, Green Organics*
BLEND	*50:50 Blend of FLM and FOGO*
CT	*Compost Tea (High Quality Fungal Dominated)*

Project background

As recycling gains momentum, Australians are looking to recycle organic streams by composting in some form to keep these valuable materials away from landfill. Victorian State Government through Earth Resources Victoria (https://resources.vic.gov.au) (is looking increasingly to projects involving Environmental groups, community education, land holders and industry to improve the concept of recycling and reuse of all important renewable resources.

Worldwide, communities are addressing recycling of food organics and green organics as cities increase in size and landfill sites become less available. The alkaline nature of many recyclable organics makes them an alternative to lime application on agricultural land. An added advantage is increasing organic matter in the soil and increasing microbial activity (Goswami & Sarma, 2008).

Reuse of organics is the obvious way to recycle essential plant nutrients to improve soil health and fertility while protecting the environment from unwanted contamination. Hossain et al (2016) showed plant by-products such as green organics, composts, etc, could substitute for phosphates and nitrogenous synthetic fertilisers in crop production. They note outcomes such as increased pH, improved CEC value in soil and more availability of P and K for agricultural crops. A further outcome was their use as soil conditioners resulting in better soil porosity, increased aggregate stability and reduced soil erosion. The C:N ratio improves with use of organic materials as does general plant, environmental and human health. This same paper reported increased seed germination, biological and chemical soil properties, improved growth and yield in crops, better soil structure and much less disease in the crops compared with a conventional control. Gao, Hang (2017) demonstrated that uncomposted processed urban food waste (PUFW) was phytotoxic to seed germination.

Organic materials have a great impact on pasture and turf as well as in cultivated agricultural systems. Boulter et al (2002) demonstrated that composted organic amendments from municipal council organics have a positive impact on many diseases in turf, pasture and cropping. Applications of 100kg/100m2 reduced some pasture diseases by 50%. Disease suppression, however, was not consistent across all diseases. Any use of natural products that will reduce or eliminate the use of herbicides, pesticides and fungicides is a positive outcome for the increased use of organics in farming systems.

Cole (2021) demonstrated the positive impact of compost tea made from high quality thermal aerobic composted green material on improved soil structure, microbial balance and weed management. Fungal dominated compost made into fungal dominated compost tea also reduced disease pressure in vineyards which led to removal of herbicides and most fungicides from the annual management programme both in the vineyards and the grazing property.

Yan et al (2013) determined that the major compounds attributing to odour gases in food waste were trimethylamine and ethyl thioether. Ethylbenzene and citric acid were also present at the standard threshold. Gas chromatography-mass spectrometry and chemical methods were used to analyse food organics emissions both qualitatively and quantitatively.

Piqueres et al (2006) demonstrated improved soil aggregate structure and water holding capacity of soils. They did find that response was particularly soil type dependent, but in all soils, there was a positive response. Similar improvements in soil structure, water holding capacity, P and N availability to plants through increased mobilisation of nutrients due to microbial activity were noted (Tra Thi Thanh Suong, 2013).

Feedlot manures are high in N, so lignite was used as an amendment in composting manure to minimise the environmental release of ammonia (NH3) from the manure. Shown as an effective, practical, and potentially long-term method for minimising N loss from the feedlot composted organics, Impraim (2021) found that this introduction of lignite facilitated the use of the feedlot aged manures from intensive livestock production systems as another valuable resource for farming enterprises.

As the world transitions from coal and oil-based products, agricultural inputs based on organic raw materials should become more in demand. This invites an ever-expanding market for trade in renewable, composted amendments for agriculture globally. Populations will not decrease in the near future so municipal organics will not decrease. Composting organics in some form could provide a revenue stream for councils if they chose to compost on site. The large commercial operators have capacity to improve the quality of products coming from raw organics. Value-added products made specifically fit-for-purpose for different agricultural sectors would attract a premium. Best practice agriculture is looking to compost application to improve many of the soil and plant attributes already mentioned. Regenerative agriculture, biological farming, pasture cropping are all names for the same outcome: more detailed data and less synthetic chemistry in the form of fertilisers, pesticides, herbicides and the use of more organic amendments leading to healthier crops, environment and humans.

Hypothesis

We sought to develop recipes for the use of feedlot manure and FOGO waste streams (resource streams) that would result in fit-for-purpose products for animal and crop farming that fitted into the circular economy of Victoria and abroad.

Waste streams can be made into fit-for-purpose products to benefit the circular economy. Researching the benefits of these products to the soil and agriculture was the focus of this project:

We identified problems:

- Lack of information on the influence of FOGO on green organic matter recycling in soil.
- Lack of information on nutrient levels and mineralisation of organic products
- Lack of information on microbial status of organic products
- Lack of information on nutrient levels and mineralisation rates of organic products on soil.
- Lack of information on biological status of organic products in soil.
- Lack of product-specific information on the influence of recycled organics on soil and plant health.

In systems where FOGO is part of the green organic recycling, there appears to be little or no information about the impact of this material on unacceptable levels of odour emission. There is a need for quantified data around mineralisation, nutrient levels and biological status of organic products and their influence in the soil. Accordingly, the project sought to determine if an e-nose can provide suitable information for odour management of FOGO for EPA regulation adherence.

Objectives

Anticipated outcomes:

- Better fit-for-purpose products.
- Decreased susceptibility to pest and disease and increased productivity.
- Increased confidence of users in products – inadequate information on presence of toxic contaminants.
- Address carbon capture by improving organic matter in soils.
- Improved resilience of current farming systems to increasing climate variability.
- Contribute to improved national standards for organic products. AS4454 standards are currently being reviewed.
- Determine cost-benefit to end users.

- Substitute conventional finite resources with environmentally compatible recycled organic materials.
- Reduce energy input into the food production system by replacing energy intensive inputs with environmentally compatible recycled organic materials.
- Although this point is not directly related to this project, an extension of the project outcomes would result in diverting organic material from landfill and transform into a valuable resource such as feedstock/ compost/organic soil amendments.

There are problems in agriculture from the methods of industrial farming and use of high volumes of synthetic nitrogenous fertiliser. Despite the many recycled organic products currently available in Australian horticultural and broadacre farming, there is limited scientific research quantifying the influences of these products on soil health (e.g. soil microbiology) and plant response. Nutrient release and mineralisation of most of these products has not been well quantified but needs to be carried out for a more precise application in the field. Product-specific recommendations that are based on comprehensive research into the impact of a product on soil microbiology and how this in turn affects nutrient release in the soil as well as plant yield are not available for the majority of the commercial recycled organic products. As a result, the optimum benefit associated with the application of organic amendments to soil is not realised.

A major indirect outcome of this project is diverting organic matter from landfill and transforming it into a valuable resource. Biological activity is not well addressed in the Australian standard on organic amendments, (AS4454). A suitable quantifiable unit such as fungal: bacterial ratio could be part of organic matter classification.

Scope

Partners in this research project offered as part of their in-kind, mature feed lot manure, finished compost and FOGO from Melbourne urban and wider Victorian sources.

Project team

Name	Organisation	Role in project
Dr Mary Cole and staff	Agpath Pty Ltd	Lead researcher
Dr. Alexis Pang (UoM lead); Wenyi Chen (Masters student) Natalie Harris & Vasiliki Summerson (Research Assistants); Advisory: A/Prof. Ranjith Unnithan & A/Prof Sigfredo Fuentes	Univ of Melbourne	Research partner
Eric Love	CORE	Lead partner
Unknown contact	SORF	Product supplier
Ashley Sheahan	Charlton Feedlot	Product supplier
Gerhard Grasser	Agri Solutions	Partner

Literature Review

Organic waste recycling into soil amendments has gained prominence due to increasing pressure for sustainable agricultural practices and improved waste management. Compost and compost-based products such as compost teas and organic blends are widely studied for their effects on soil health, plant productivity and environmental impact.

Studies show that organic amendments can enhance soil structure, nutrient content and microbial activity. For instance, Duong (2013) found that compost application improved soil water-holding capacity, nutrient availability and plant growth. Similarly, Hossain *et al.* (2016) emphasised the potential of plant-derived organic wastes to act as both soil conditioners and fertilisers, contributing to soil organic carbon and microbial biomass. Compost also has disease-suppressive properties. Boulter *et al.* (2002) demonstrated that compost could suppress turfgrass diseases such as *Fusarium Patch* and *Typhula Blight*, potentially reducing reliance on chemical fungicides.

Compost teas, which are aqueous extracts of compost, are increasingly used in both conventional and organic systems. Cole (2021) reported promising results in suppressing broadleaf weeds in agricultural systems through compost tea application. Similarly, Perez-Piqueres *et al.* (2006) highlighted that compost amendments can shift soil microbial communities in beneficial directions, promoting resilience and disease suppression.

Food organics and garden organics (FOGO) compost is becoming a popular amendment due to its local availability and environmental benefits. Gao (2017) evaluated fast-processed urban food waste and found it to be effective in enhancing soil quality, though the maturity of the compost influenced performance. Goswami and Sarma (2008) cautioned that improperly processed municipal waste can degrade soil quality, highlighting the importance of composting standards and monitoring.

Odour emissions from composting processes and organic waste amendments can raise environmental concerns. Several studies have examined the use of electronic noses (e-noses) and analytical instruments to monitor odour compounds. For example, Baby *et al.* (2000) and Gonzalez-Viejo *et al.* (2020) explored the use of e-noses in detecting volatile organic compounds in environmental settings and agricultural products, while Sironi et al. (2007) used e-nose technology to continuously monitor odour emissions at composting facilities. Similarly, Davoli *et al.* (2003) and Bruno *et al.* (2007) used SPME and GC/MS to characterise odour emissions from landfills and solid waste treatment plants, identifying key compounds such as ammonia, sulphides and organic acids. Yan *et al.* (2013) further analysed odorous compounds during food waste treatment, highlighting temporal variability in emissions depending on process stage and treatment method.

Lignite has also been proposed as an amendment for stabilising nutrients during composting. Impraim (2021) demonstrated that lignite could reduce nitrogen losses during manure composting and influence nutrient release patterns, potentially improving the agronomic efficiency of compost-based fertilisers.

Together, these studies underpin the scientific basis for using compost, compost teas, FOGO and other organic amendments in agriculture, while highlighting considerations around odour management, microbial dynamics and application timing. This literature provides essential context for assessing the effects of different organic treatments on soil quality and sustainability in farming systems.

Methodology

FIELD TRIALS

To evaluate treatment effects under practical commercial farming conditions, two farms were selected: one managed conventionally and the other organically. On each farm, quarter-hectare field plots were marked out within designated pasture paddocks. Six different treatments were applied:

- UTC (Untreated Control)
- FLM (Feedlot Manure)
- DD (Dutson Downs Compost)
- FOGO (Food Organics, Green Organics)
- BLEND (50:50 Blend of FLM and FOGO)
- CT (Compost Tea – High Quality Fungal Dominated)

Treatments were applied without replication to reflect typical on-farm application practices. Each paddock continued to be grazed according to standard farm management throughout the trial.

Several applications of the treatments were made over the course of the project. In general, treatments were applied well before the soil sampling events, allowing time for incorporation and interaction with the soil and plant systems prior to analysis.

REPLICATED TRIALS

To enable statistical comparison under controlled conditions, replicated trials using a randomised block design were conducted on both farms.

PASTURE TRIALS

On each farm, plots measuring 1.3 m x 10 m were marked out in ungrazed sections of pasture. The same six treatments (UTC, FLM, DD, FOGO, BLEND, CT) were randomly assigned and replicated across the plots five times. All pasture plots were clearly labelled and fenced off from grazing to avoid variability due to livestock disturbance.

VEGETABLE TRIALS

Due to exceptionally wet conditions in 2022, working with in-field vegetable plots became unmanageable. With permission from SV, vegetable trials were shifted to raised beds using two distinct soil types to allow for controlled, consistent growing conditions.

A total of 30 metal beds (measuring 900 mm x 500 mm x 200 mm) were set up and arranged in a randomised block design, matching the layout of the pasture trials. All six treatments were applied, with five replicates per treatment.

As with the field trials, treatments were applied multiple times during the growing cycle, timed to optimize uptake and simulate practical management. Soil sampling for analysis was conducted after the final application, allowing for a representative understanding of treatment impacts on soil properties.

E-NOSE

Field component

Four FOGO-manure composting windrows located on paddock at Agpath Pty Ltd. Garfield, each with differing FOGO-Manure ratios (C1 - 100:0; C2 - 75:25; C3 - 50:50; C4- 25:75) were "sniffed" using an electronic nose (E-nose) device developed by the University of Melbourne (Gonzalez-Viejo et al., 2020). On-windrow and distance-from-windrow readings were taken, viz. including 0 m, 1.4 m, 2.8 m, 3.2 m, 6 m, 8.8 m, and 11.6 m away from the composting windrow. The measurements were taken in the same way on three days: 17th, 20th and 23rd Feb 2023 late summer when odour would be of greatest concern. We noted that distance measurements were subject to high fluctuations due to inconsistent wind directions and strength. E-nose collected readings at 2 datapoints per second for 9 gases/gas groups, with exposure for 60 seconds for each position. The collected data was subjected to pairwise t-test, post-hoc Tukey's HSD, Principal Components Analysis (PCA) and machine-learning modelling using Artificial Neural Network (ANN) algorithm.

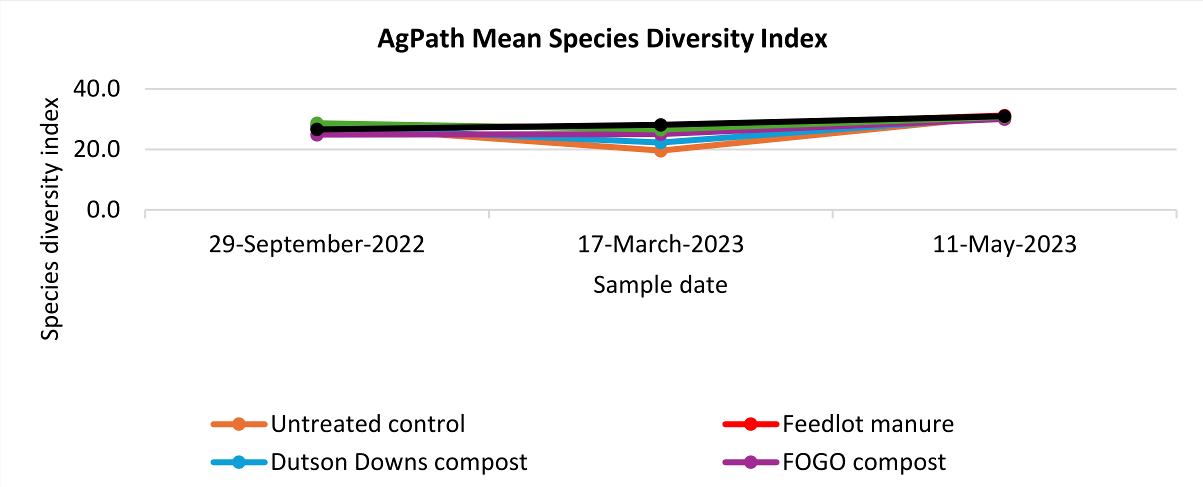
Laboratory component

Samples were collected from 8 positions across the 100% FOGO windrow into buckets with the rationale of determining the odour emission profiles from the highest malodour risk source. The samples were transferred and stored in cold room conditions (5°C) at the University of Melbourne facilities. From each bucket 10 subsamples (ea. ~70 g) were obtained and cut finely into ~10 mm dimensions and recomposited. E-nose was used to "sniff" this sample from a 500 mL borosilicate glass beaker. Then, the sample were re-subsampled into 3 replicates each ~0.56 g and inserted into a 20 mL airtight glass vial for Gas chromatography–mass spectrometry (GC-MS) using solid phase microextraction (SPME) method. The identity and proportion of total of the odour-associated VOCs were determined from the chromatographs generated from the analysis.

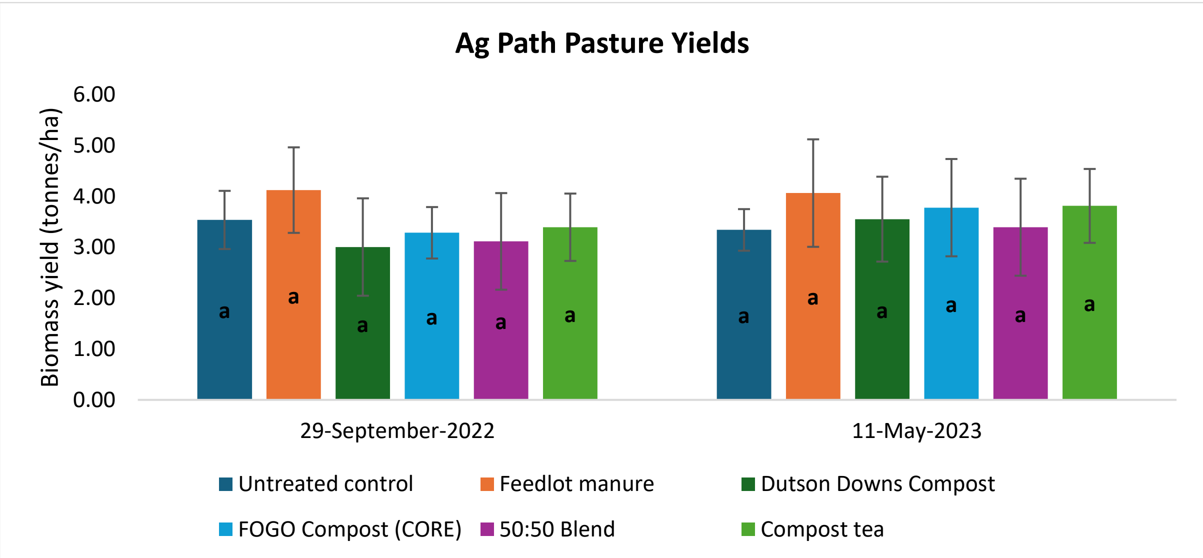
Results

SOIL BIOLOGY AND CHEMISTRY RESULTS

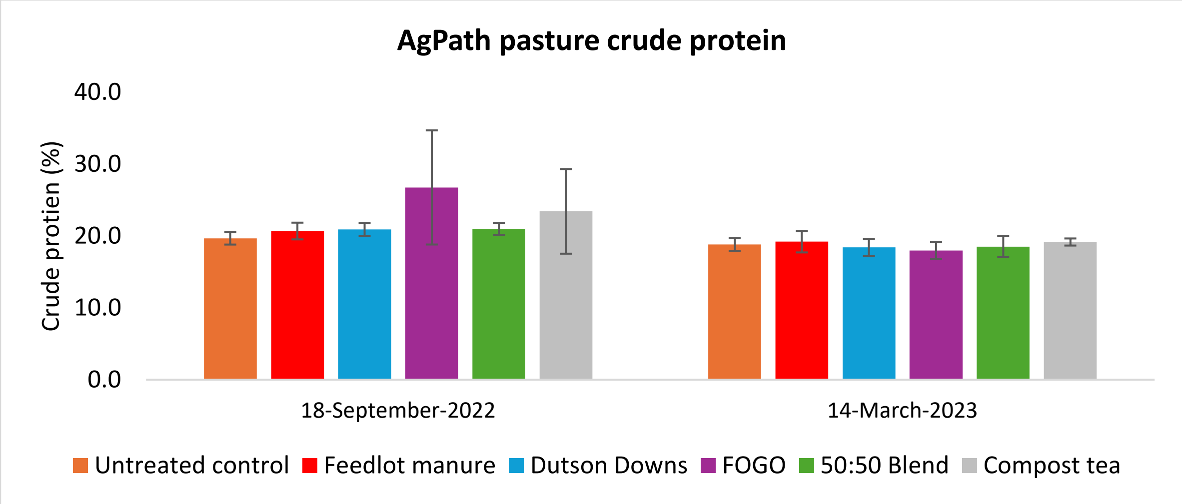
AGPATH PASTURE TRIALS



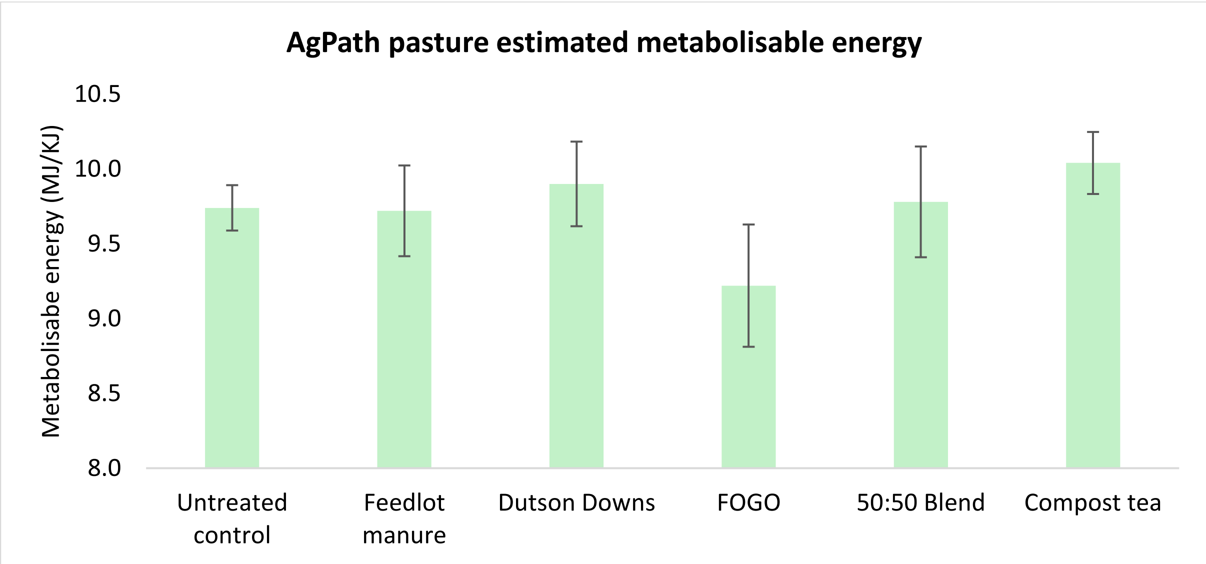
There were three harvests spring, late summer, and autumn. September 2022 and May 2023 harvests followed high rainfall months. March 2023 followed low rainfall months with higher-than-average temperatures. Diversity has responded to available soil moisture but has shown an increasing trend to greater diversity after time to assimilate nutrients from the treatments over a period of 8 months. The untreated control, followed by Dutson Downs compost and FOGO showed the greatest loss while the blend and feedlot manure showed minimal decline in species diversity. Compost tea showed no obvious decline in species diversity suggesting that increased microbial activity and mycorrhizal biomass may be holding soil moisture and allowing soil biota to continue to supply nutrients to the plant species through the drier period.



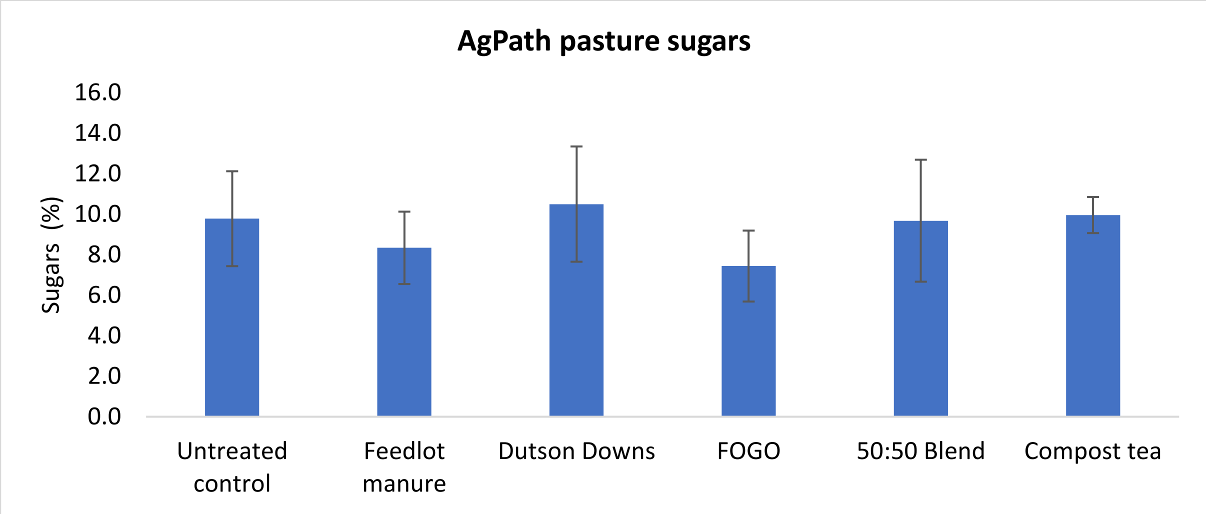
These pasture plot results for spring and autumn offer no statistical difference between the treatments. These results are showing that choice of organic input would be an economic decision only because the nutritional benefits are similar among all products. It is useful to note how well compost tea results made from high quality thermal aerobic compost has measured against the other products.



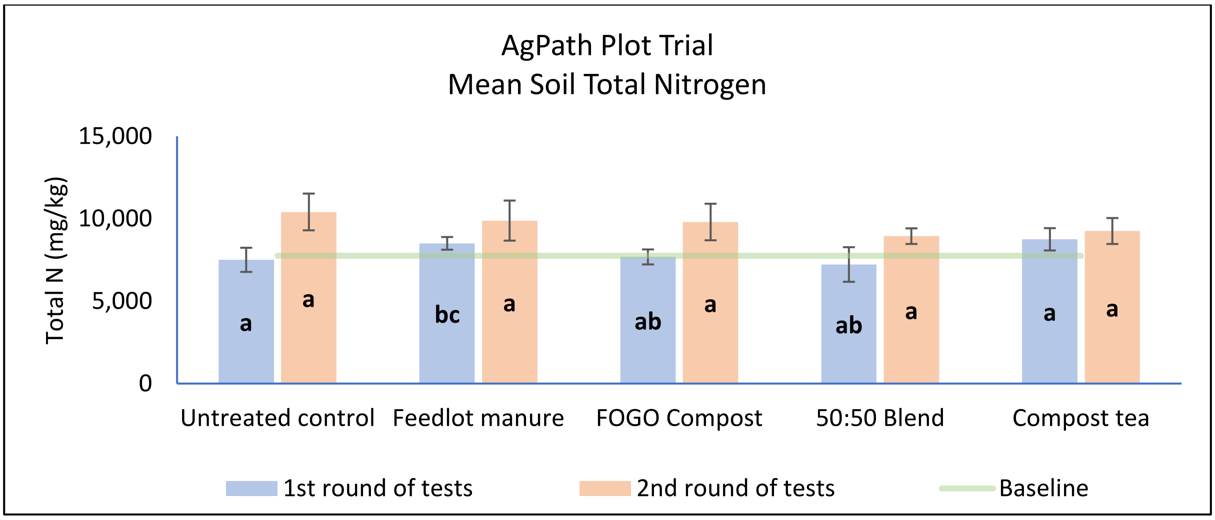
Spring and autumn results show little difference within treatments for each season. Compost tea treatment is similar to other inputs. Crude protein measures of total protein content of the pasture including both true protein (from amino acids) and non-protein nitrogen sources like nitrates and ammonia. Agpath soils have been 50 years regenerative/ biological with high organic matter so inputs do not generate the response that would be seen in a nutrient depleted soil.



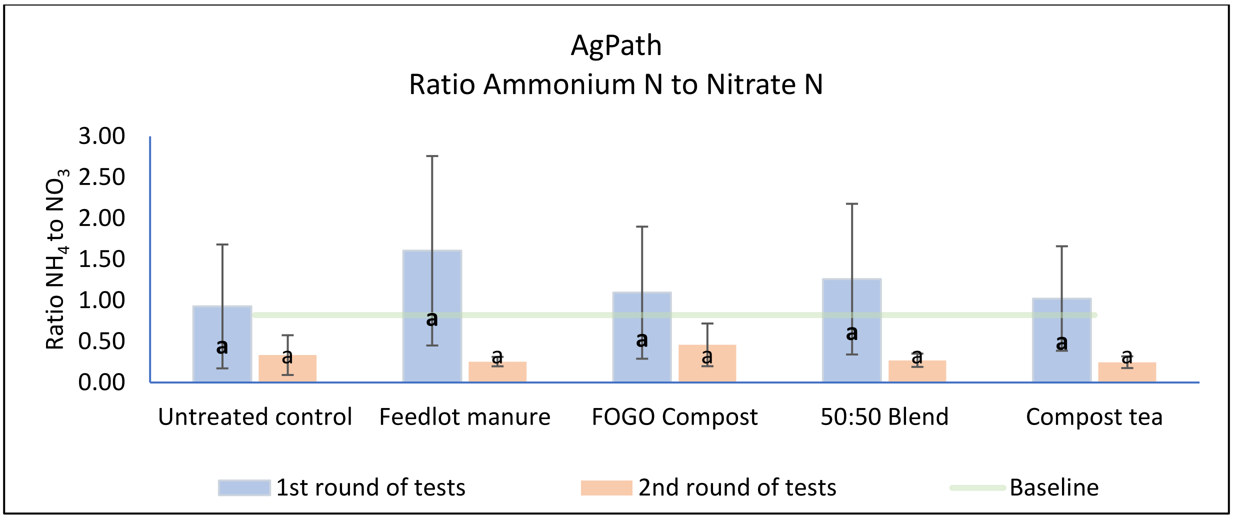
Estimated metabolizable energy (ME) is a measure of the energy from food that is available to an animal to utilise after accounting for energy losses in the faeces and urine. FOGO is significantly less than the other treatments. The other treatments are similar but again compost tea is competing effectively on animal nutrient basis and economics. Energy left after digestion and absorption. The 50:50 blend of FLM:FOGO is comparable with the control and FLM.



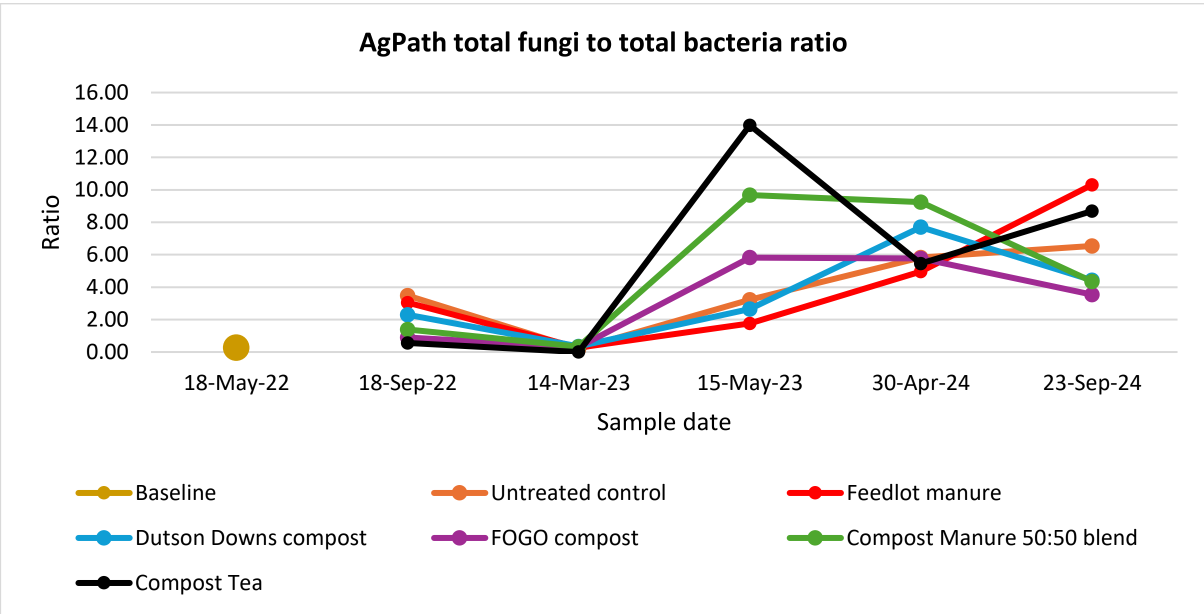
Pasture sugars, known as non-structural carbohydrates (NSC), are sugars produced by plants through photosynthesis and stored for energy. They are simple sugars like glucose and sucrose, the storage form in cool-season grasses is fructans. There is little difference in the amounts produced by the various treatments with Dutson downs compost and compost tea equally the best of the set. Dutson Downs finished compost, the blend of 50: 50 FLM:FOGO and compost tea are all similar to the untreated control. This suggests the inputs have not had an impact on an already highly microbial active soil.



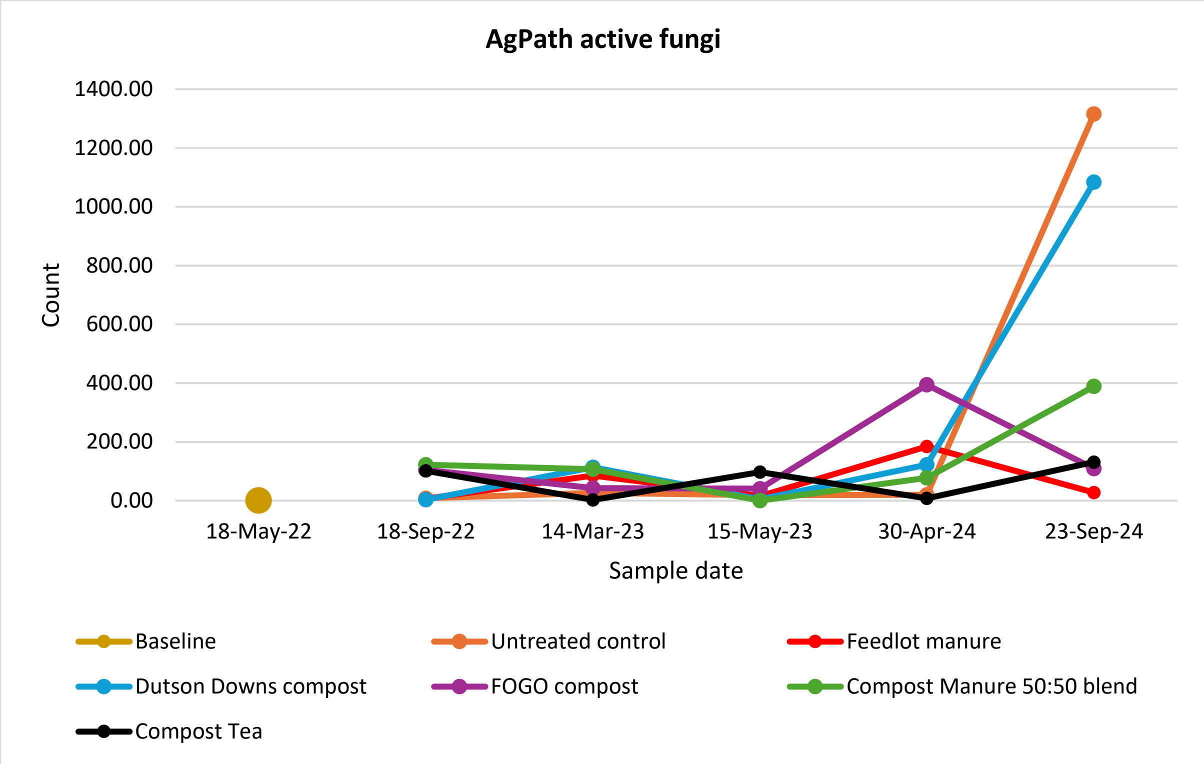
There has not been an increase in total N from the first treatments relative the base line response (green line). All treatments including the untreated control have responded better than the base line.



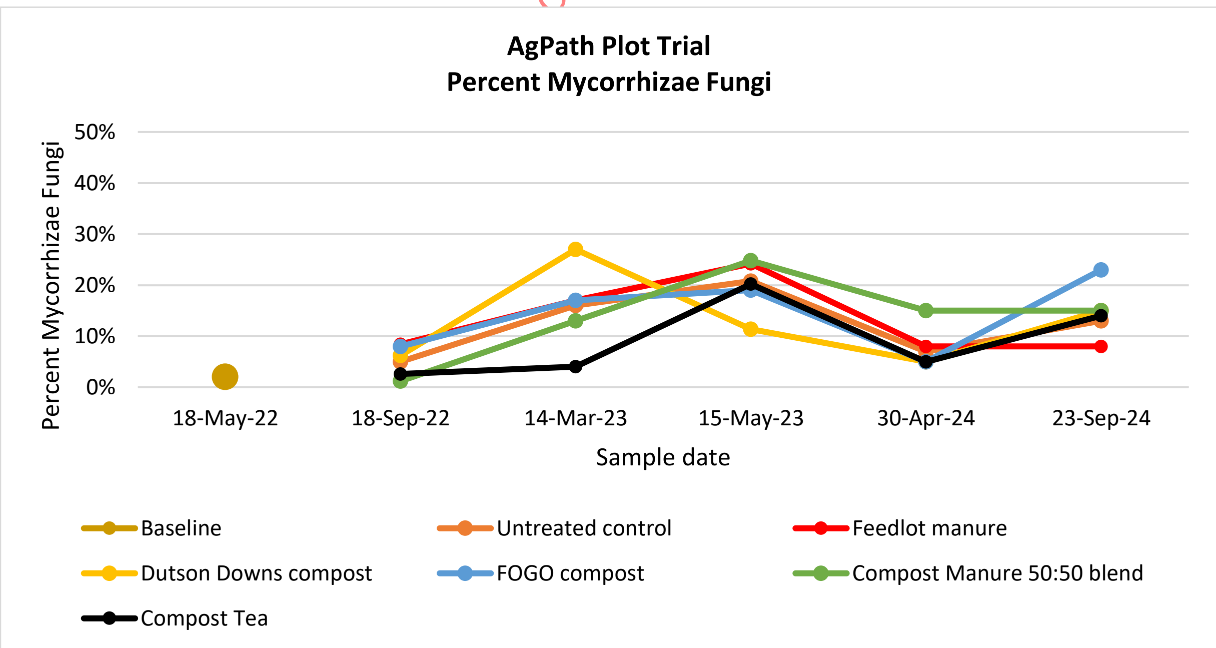
In the Agpath soil, the ratio of NH_4:NO_3 shows all treatments above the baseline and better than the untreated control although statistically there is no difference. The second treatments are all below the baseline and this is influenced by the weather pattern prior to the sampling. The higher ratio manifests in the Agpath pastures not having any weedy species eg capeweed, and stronger photosynthesis in the green leafy tissue.



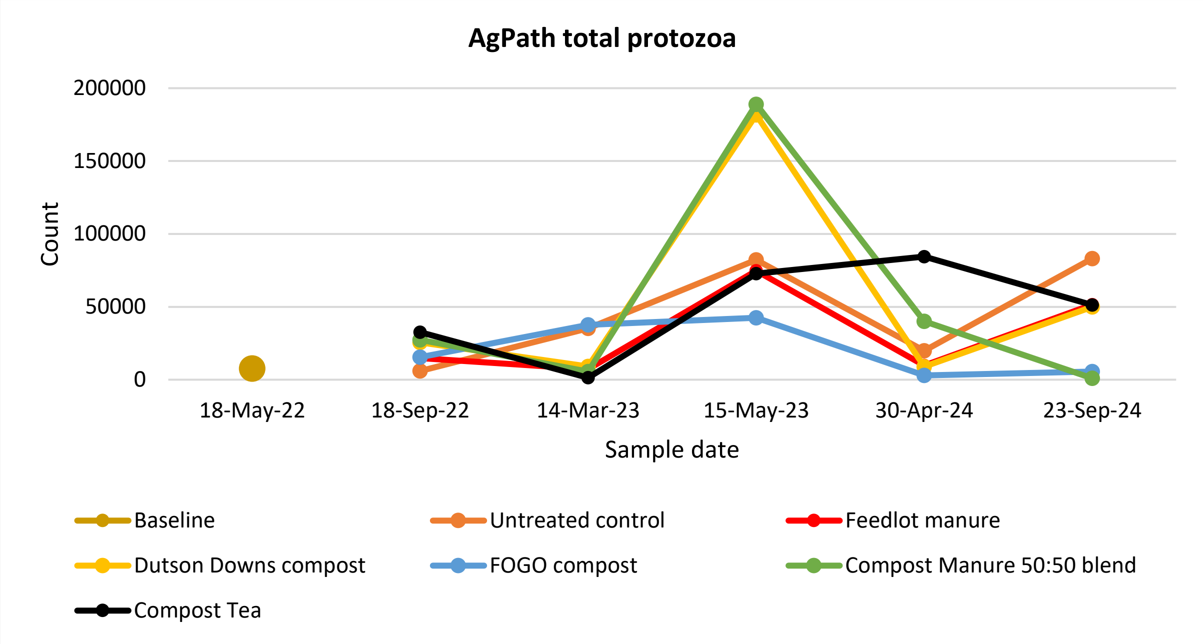
Total fungi to total bacteria is a good indicator of microbial activity in the soil and of soil health. The results on the graph are a twelve-month period spring to spring. Variation is normally based on soil moisture and soil temperature. September 2022 to March 2023 was a very wet summer for this part of Gippsland. Into the winter period, May 2023 was wet and cold and compost tea and the blend gave the greatest microbial activity. All the treatments improved the TF:TB ratio in the 12 months September 2023 to September 2024. Addition of a blend of the raw materials would be cost effective organic input on the farms.



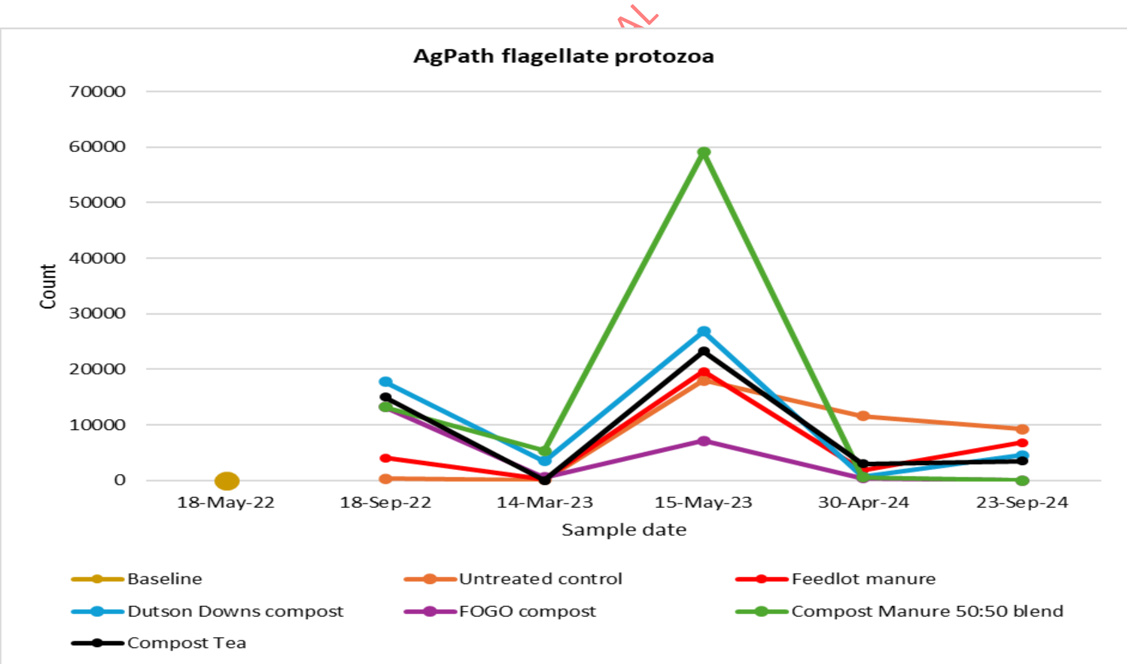
Active fungal pools have not altered much across the 2-year period with Dutson Downs compost and the untreated control showing the greatest increase in Spring 2024. This result suggests that active fungi are not contributing to soil or plant health from the population size alone.



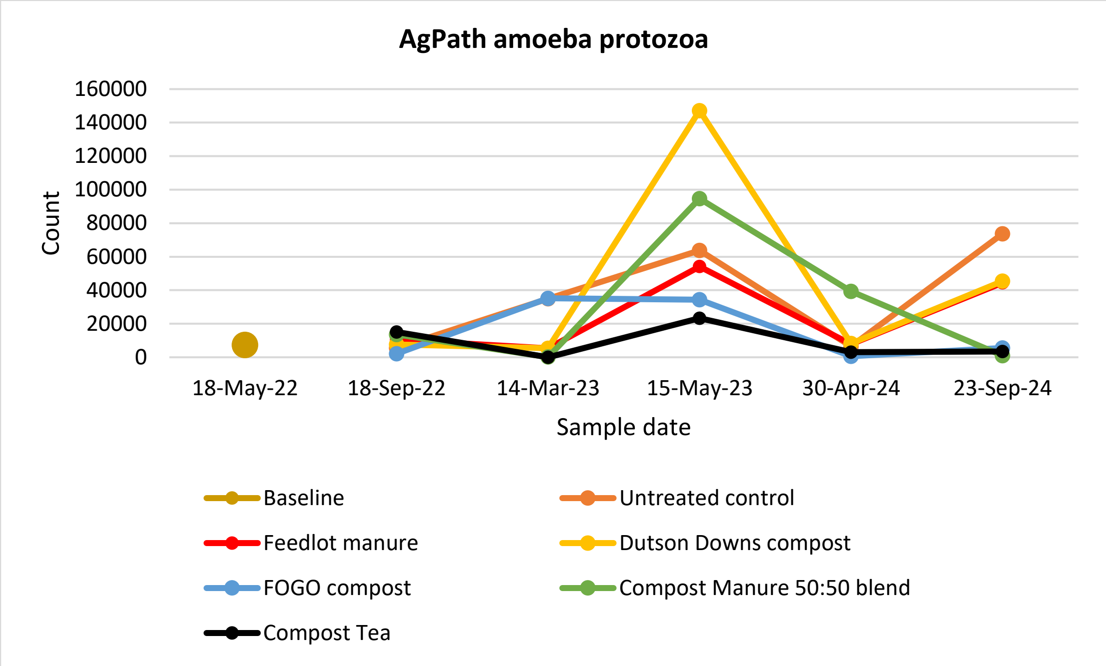
All treatments are similar to the untreated control. The Agpath property has not been cultivated in 50 years, so the mycorrhizal population has established and is stable regardless of the organic inputs. The variation is due to seasonality and soil moisture.



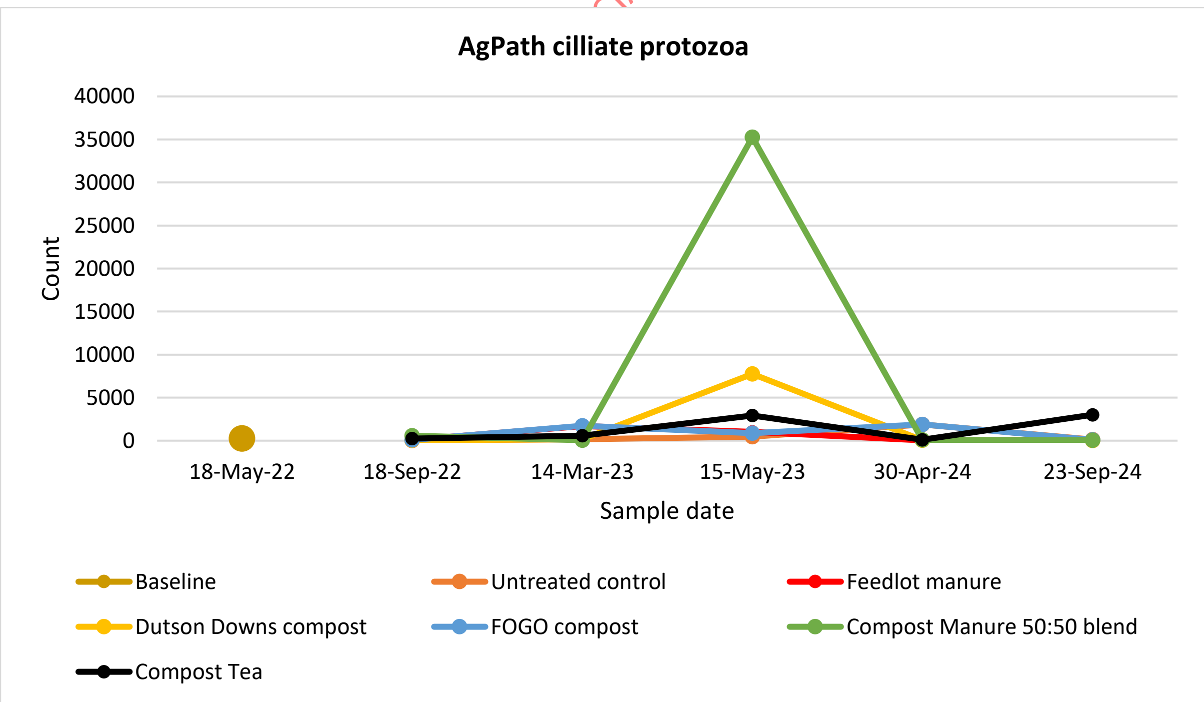
Dutson Downs compost and compost manure blend have shown highest protozoa stimulation in May 2023. Over the 2-year period all populations in the treatment improved. The blend of 50:50 FLM:FOGO from the waste streams is a good product for agriculture. Protozoan activity produces good plant available nitrogen reducing or eliminating the need for external synthetic input.



Flagellates in the compost blend have shown the greatest increase among the treatments. Dutson downs compost and compost tea not different from the majority of the treatments but they still stand above the other treatments. Several of the biologial pools have been stimulated during this May 2023 to April 2024 year providing good plant available nutrients for plants.

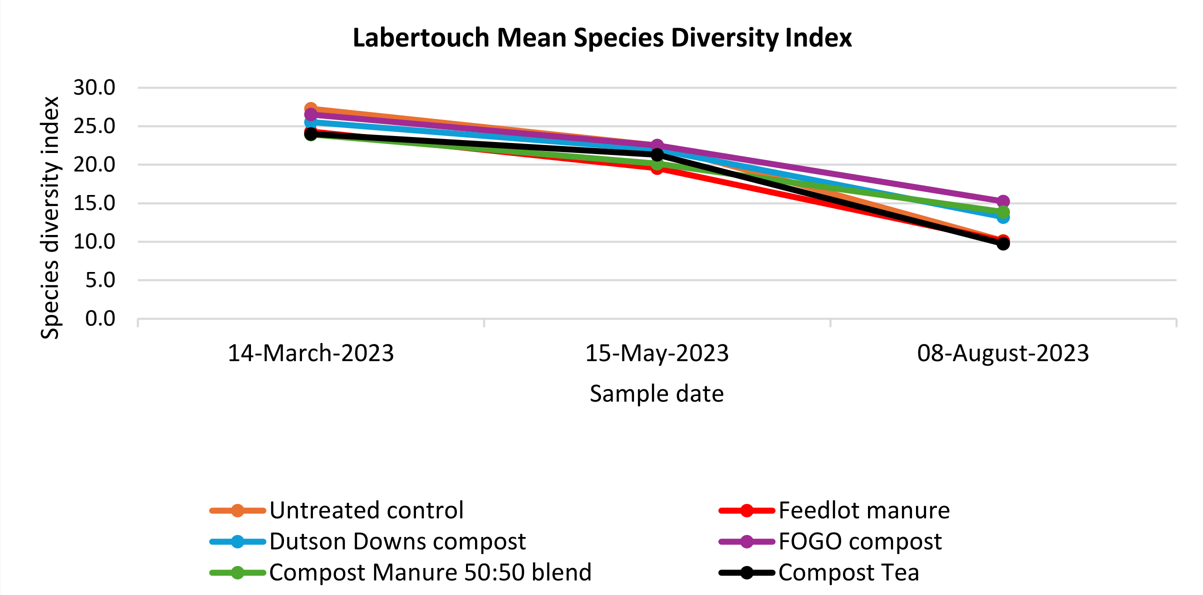


Amoeba have also responded to a stimulus around the autumn period in 2023. Dutson Down compost has responded best of the treatments with blend next. Compost tea has not responded well for amoeba populations. Amoeba ingest large populations of bacteria resulting in the potential for useful amounts of plant available nitrogen being released into the soil-plant root profile.

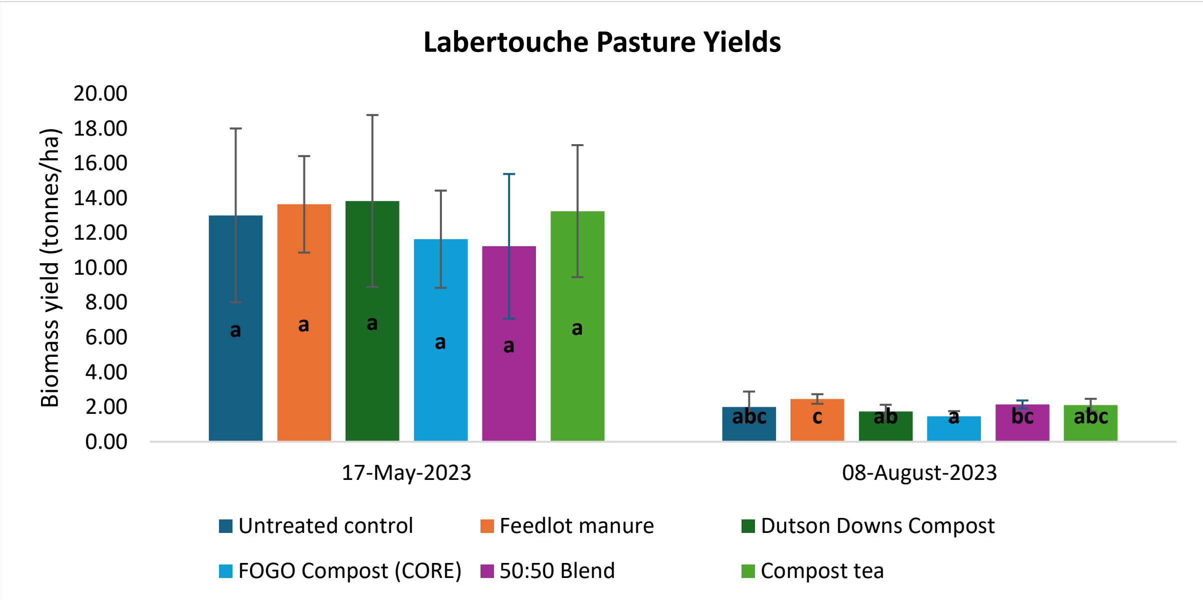


Same peak in activity in the autumn of 2023. Blend is showing highest reading, and this suggests highly anaerobic conditions. This high ciliate reading shows high anaerobic conditions resulting from waterlogging in the high rainfall during the May 2023 period. The generally low readings across the test period shows the soil is generally aerated.

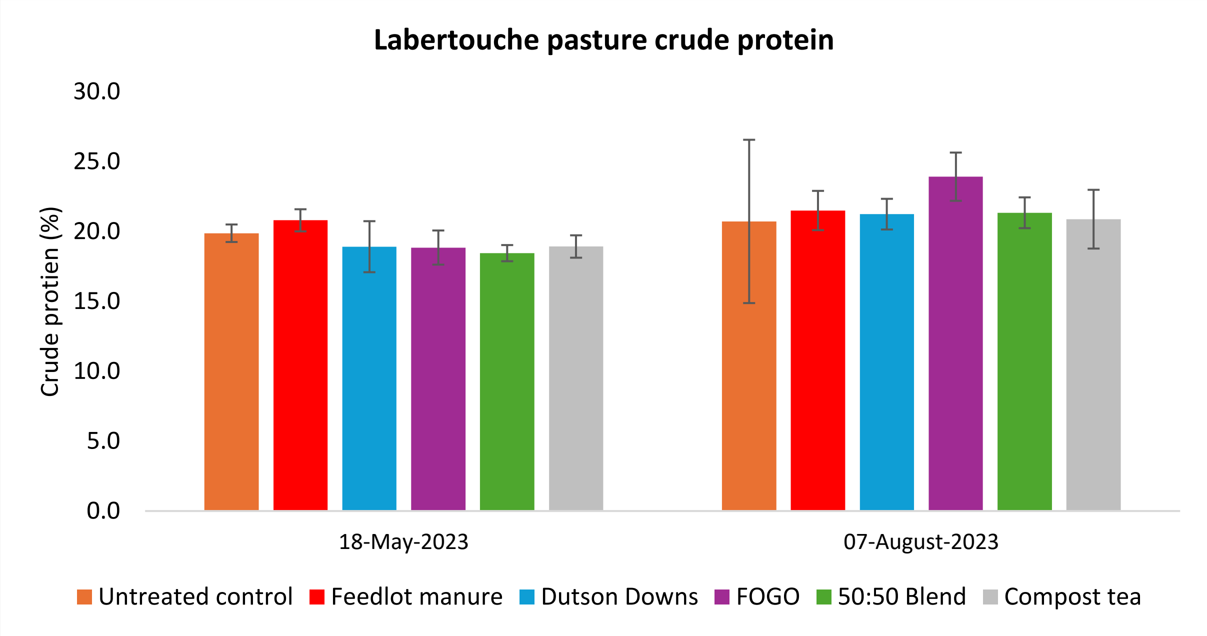
LABERTOUCHE PASTURE TRIALS



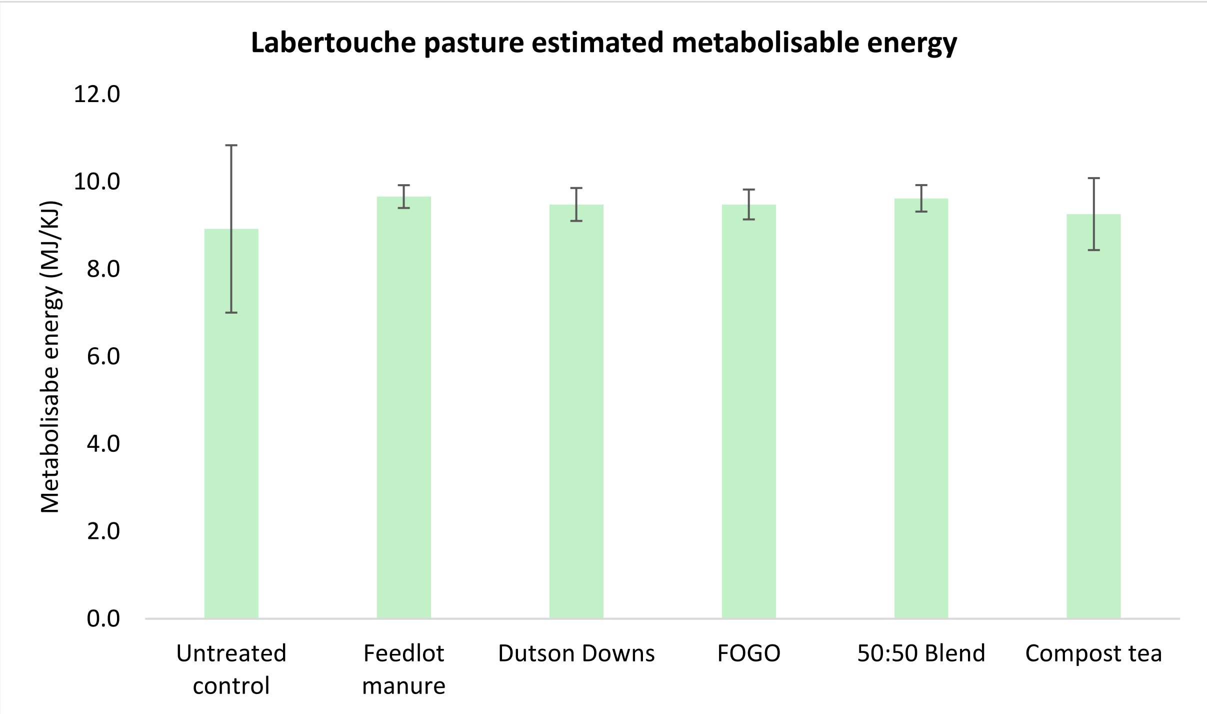
This property has high synthetic chemical inputs and cultivation. 2023 was a wet year and cultivation into a wet soil causes significant damage to soil biota and plant species. This is manifested in these results. Species diversity has declined despite nutrients from the treatments and the annual input of N,P,K fertiliser.



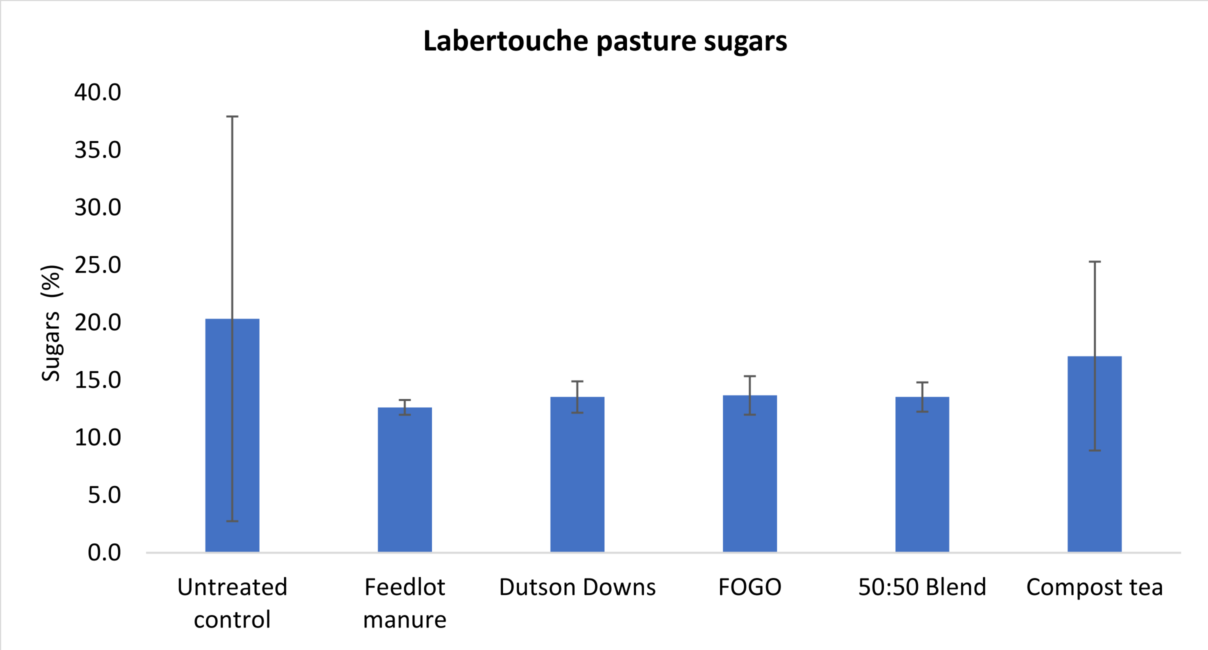
These are autumn and winter results. May 2023 was very wet. Cattle did graze this paddock but not in the period leading up to harvest. There is no statistical difference in the response to the treatments but compost tea and Dutson Downs finished compost were marginally better than the untreated control. August 2023 was wet but not exceptionally, and the soil was pugged from cattle foot traffic from rain in earlier months. Soil damaged by excess synthetic chemical input loses soil biota and with it loss of soil structure. 2023 was generally a wet year and anaerobic conditions may have led to low pasture growth. This is evidence that conventional pasture has little resilience when conditions are marginal. Compare this result with the continued production of pasture on the Agpath site where yield continues in marginal conditions because of the well protective soil biota.



This is showing that the treatments are similar to the untreated controls. The feedlot manure was best in the autumn sampling and FOGO in the winter sampling. In both compost tea was equally successful. Consider costs in these results and compost tea is as good. Although the pasture volume was less (see previous graph Pasture Yields), the quality of the pasture was as good as a previous harvest.

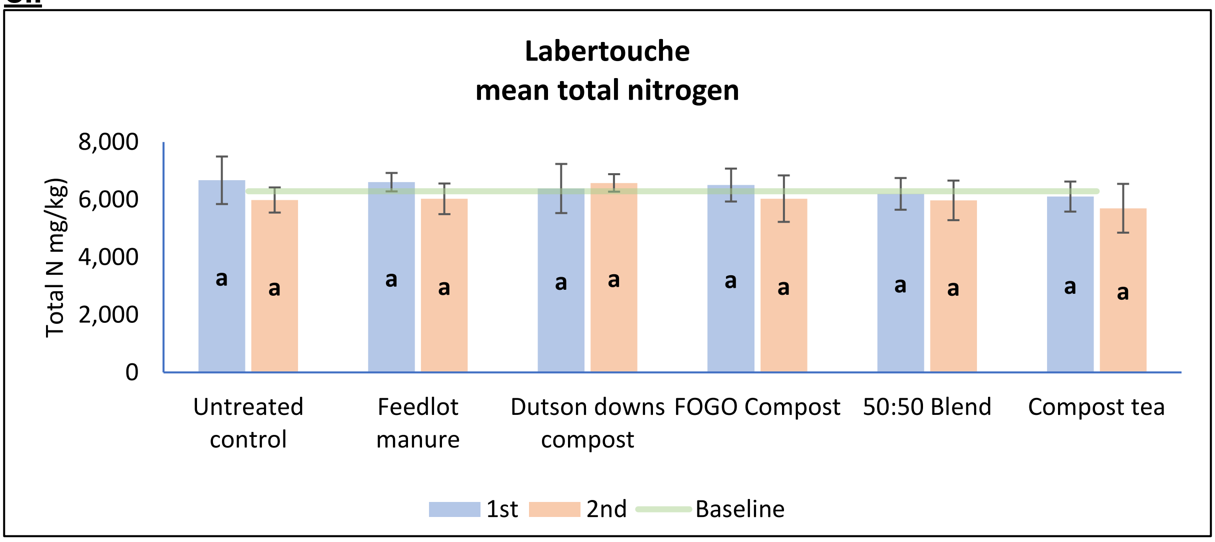


Results from harvest august 7th 2023. All the treatments provided similar results suggesting any one of these products could be used effectively including compost tea.

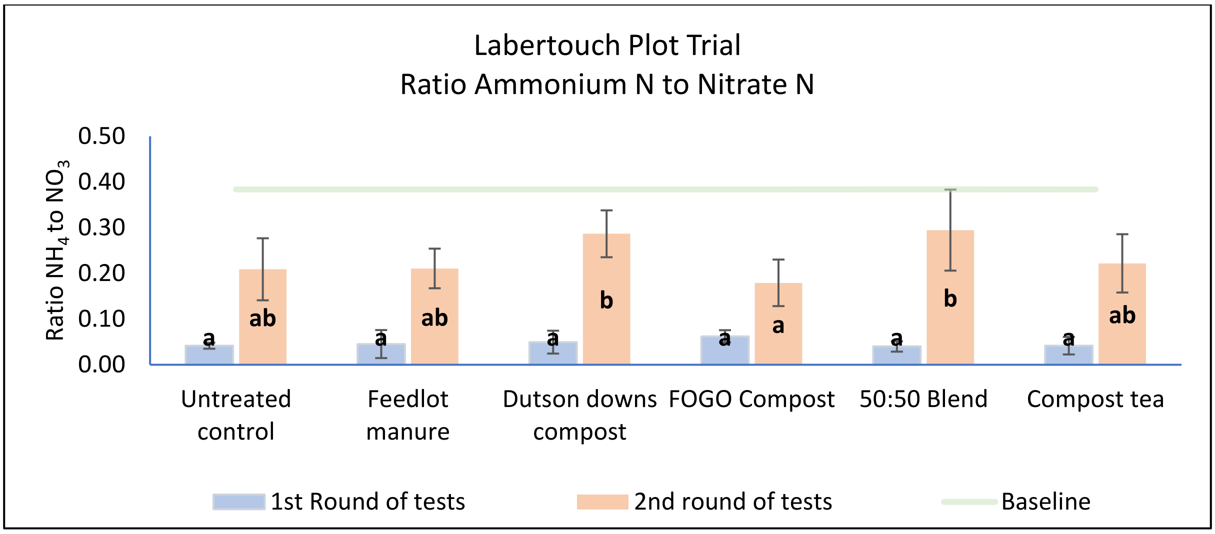


These results are from harvest Aug 7th, 2023. The data suggests that the treatments did not improve the Brix levels of the pasture species compared with the untreated control. This result is one point in time and shows the variability when working with soil biota. Ideally more data would clarify the impact of the various treatments on the response from microbes Compost tea again is comparable and the least expensive for the farmer. The sugars are in the same range as Agpath results. The difference is that the Agpath response is due to treatments and biological activity at a low cost compared with the cost of the annual N,P,K inputs at Labertouche.

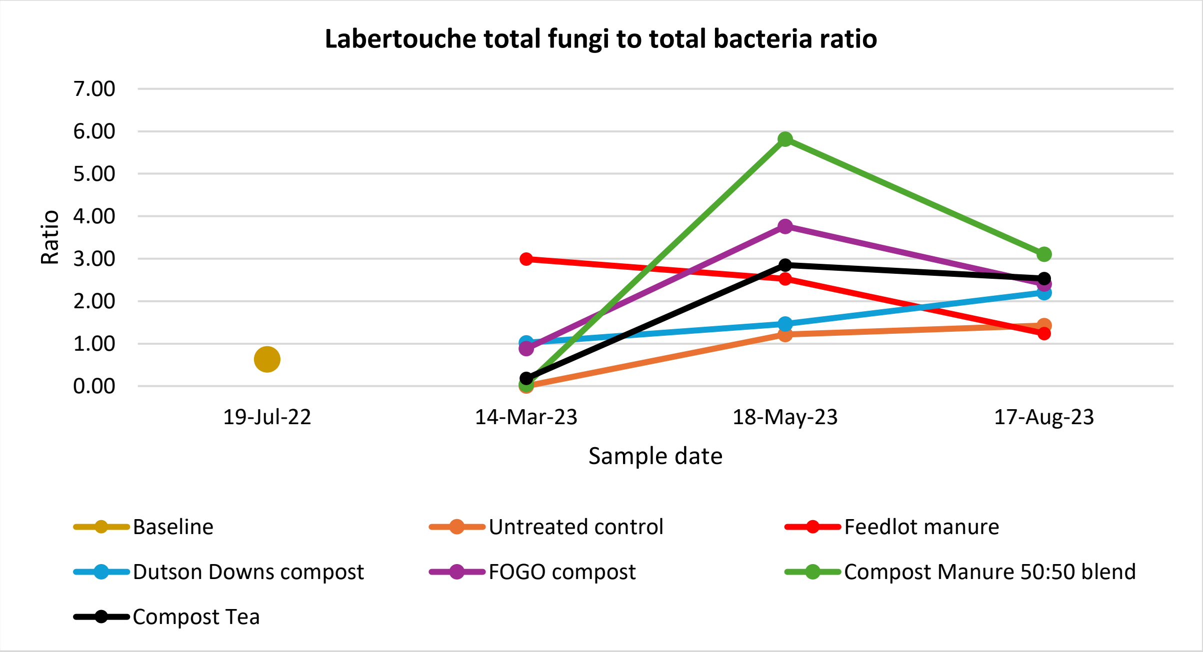
On



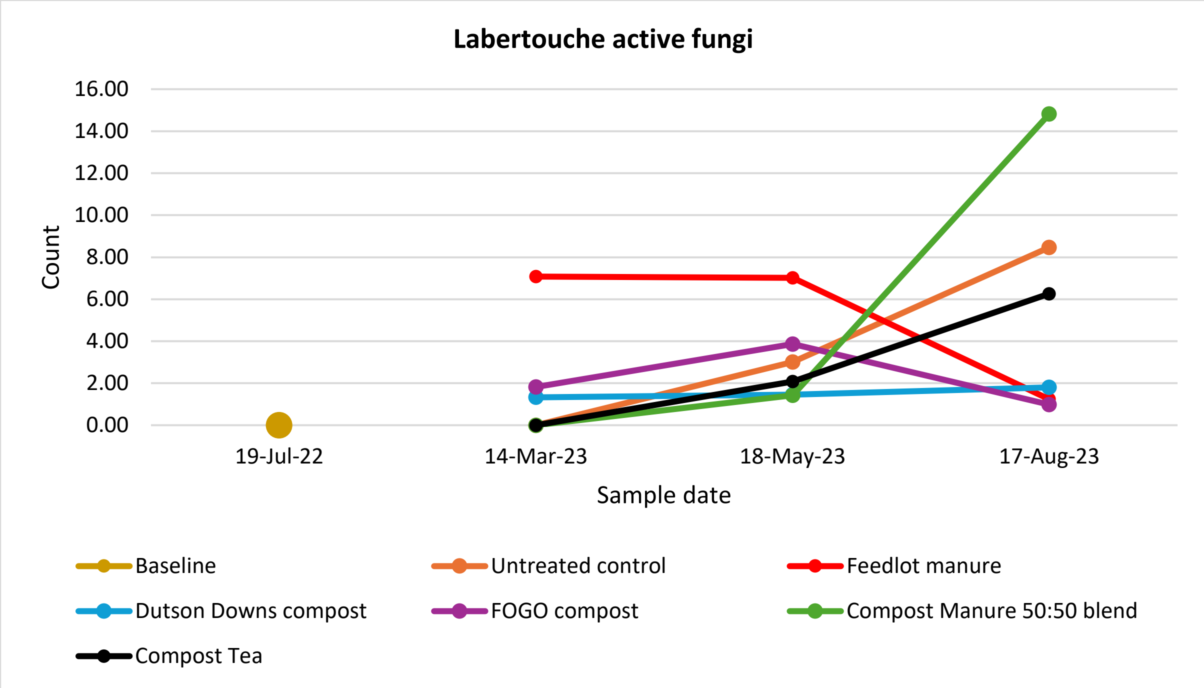
On the Labertouche site, applications of all treatments had no impact on the baseline data and compared with the untreated control. Labertouche is a high synthetic chemical input farm with cultivated soil.



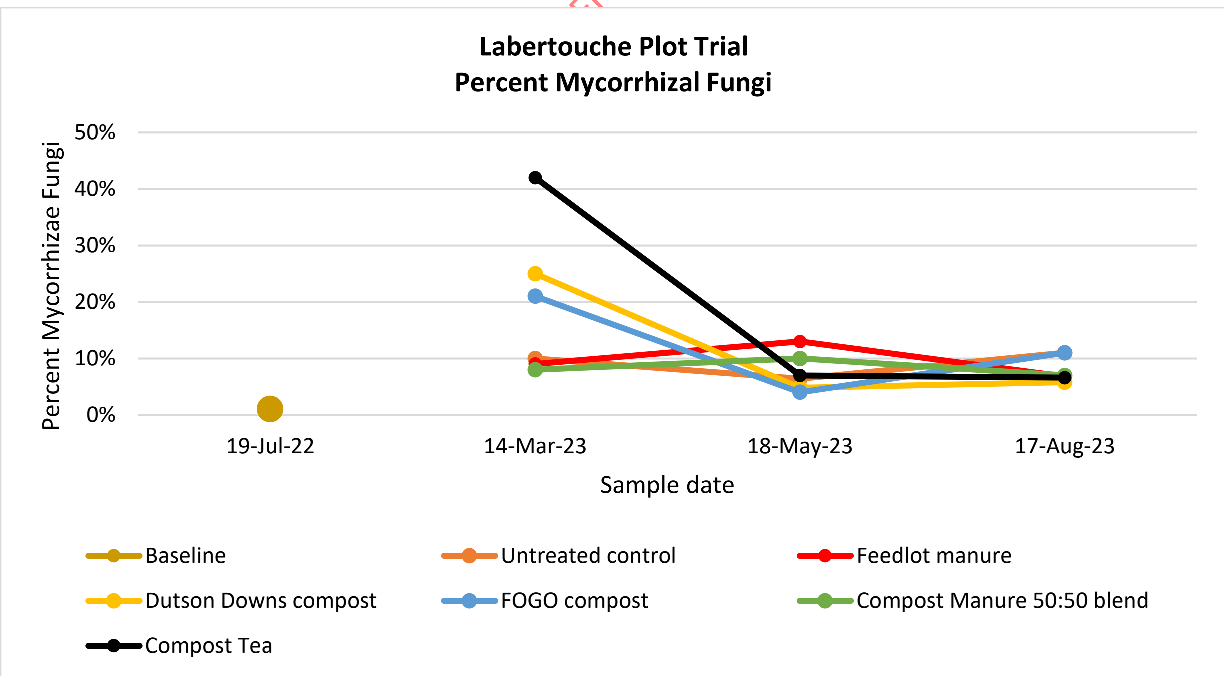
In a biological perennial system, nitrogen in the ammonium form is generally higher than nitrogen in the nitrate form. Baseline results are similar across all the treatments. Application of the treatment has increased the NH4:NO3 ratio across the treatments with most response from Dutson Downs compost and the blend. Increased nitrogen in ammonium form reduces weedy species in perennial systems a regenerative farming system.



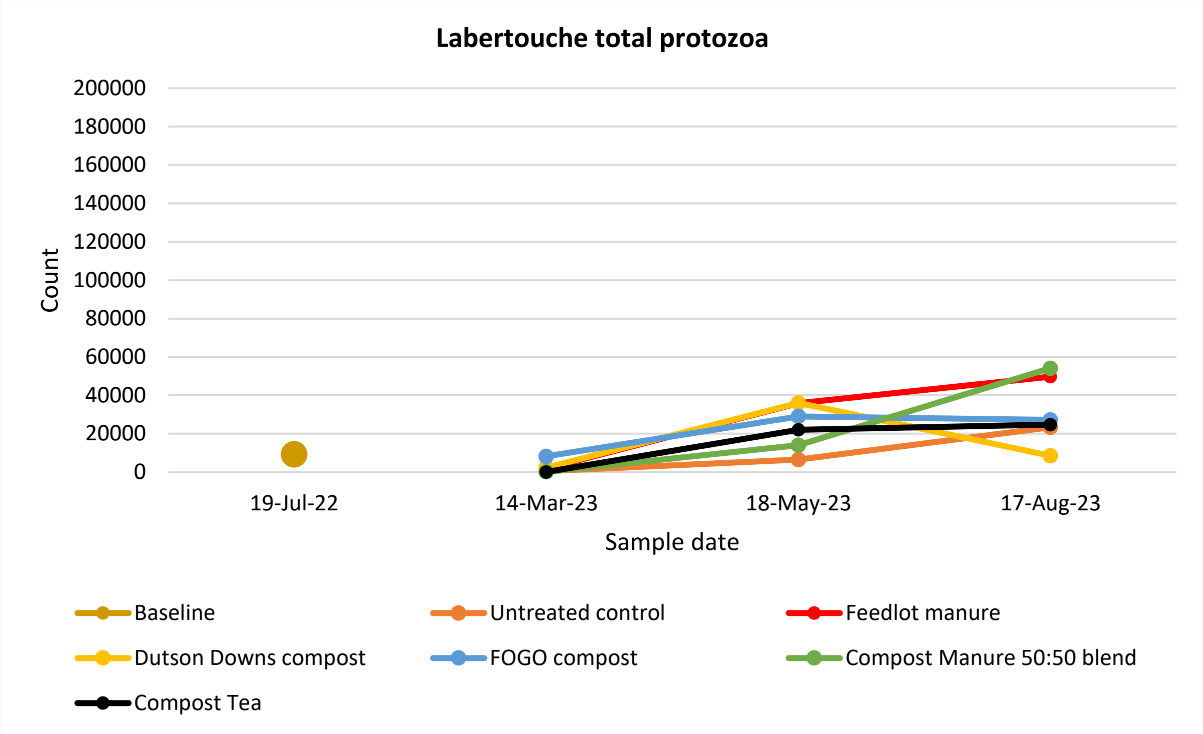
Labertouche soil biota have responded to the same stimulus as Agpath soils in this autumn 2023 period. May 2023 was a very wet month, but it has stimulated the protozoa population on both properties. All treatments are better than the control. The recommended ratio is 1-2 so only Dutson Downs and the control are actually within range. This means the fungal or bacterial pools in the other treatments are out of balance.



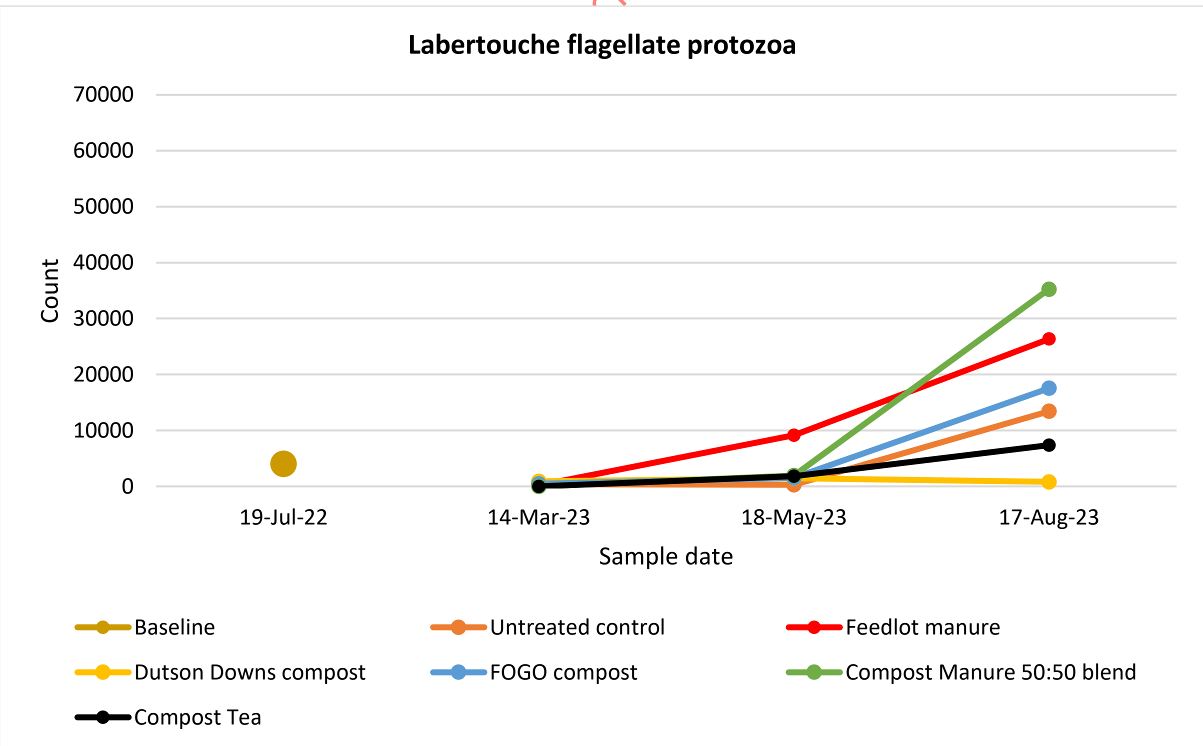
The blend, control and compost tea have responded best to increasing fungal activity. The blend is a useful fit-for-purpose product from the Victorian waste streams if FOGO can be cleaned. The high active fungal pool suggests that there will be high mineralisation and rapid breakdown of plant material with increasing soil health.



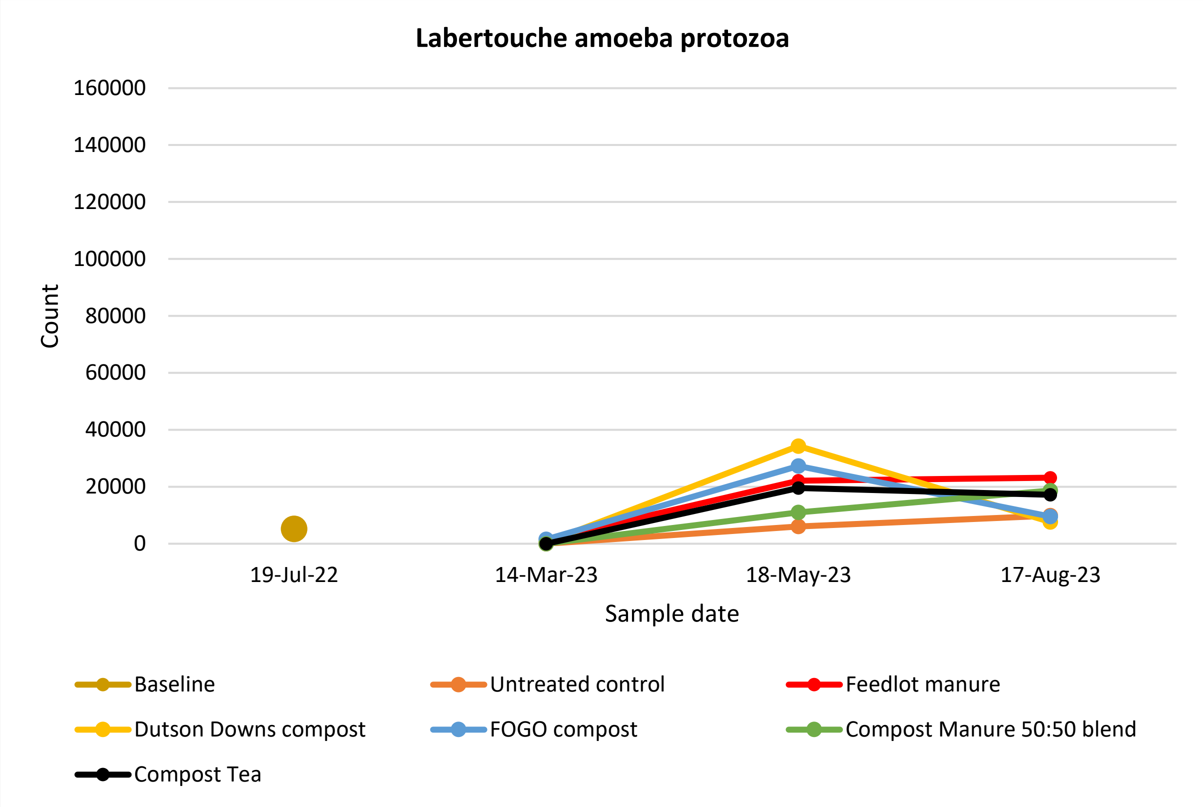
Active fungi in the previous graph have increased over the same time scale as the mycorrhizal fungi have decreased in the same period. Mycorrhizal fungal species are more sensitive to external phosphorus than are the saprophytic fungi. All treatments were above the baseline but not sufficient to provide a useful amount of plant available phosphorus to the plants.



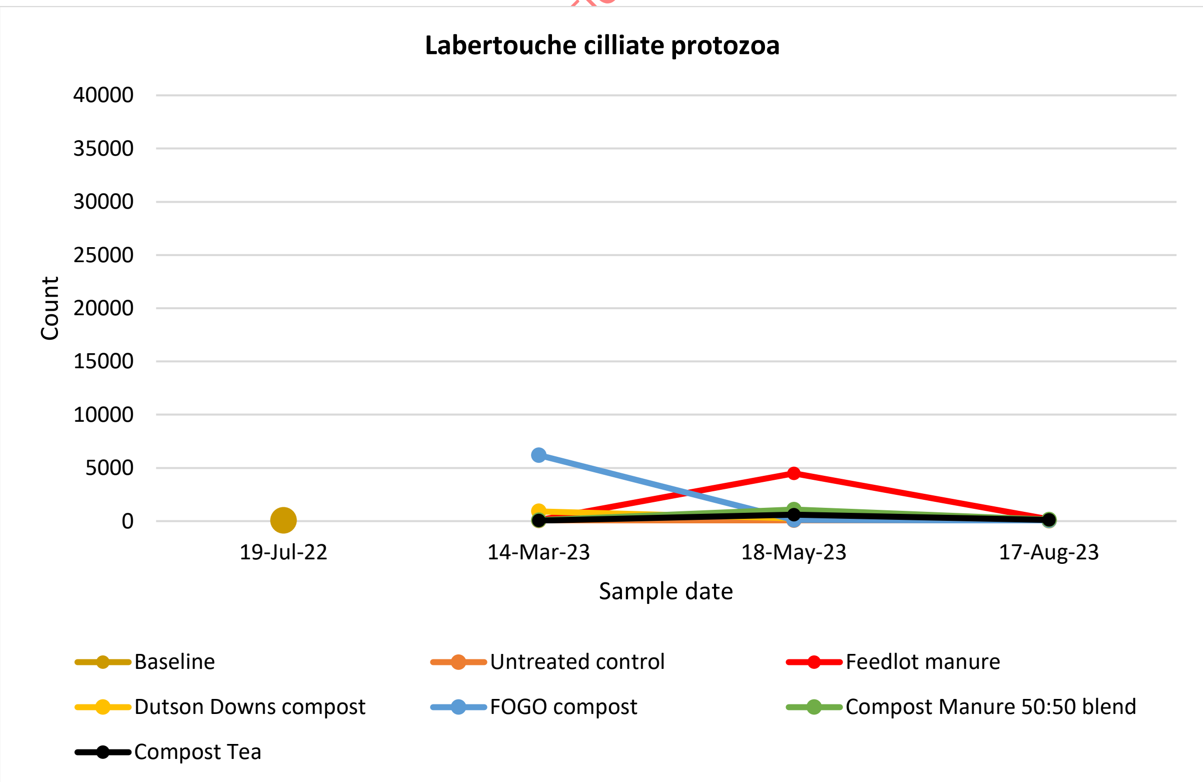
There has been a small increase in the total protozoan populations over the treatment period except for Dutson Downs. The differences are small. The blend of 50:50 performs better than other treatments.



Flagellates which require aerobic conditions have increased over the trial period with blend being the best.



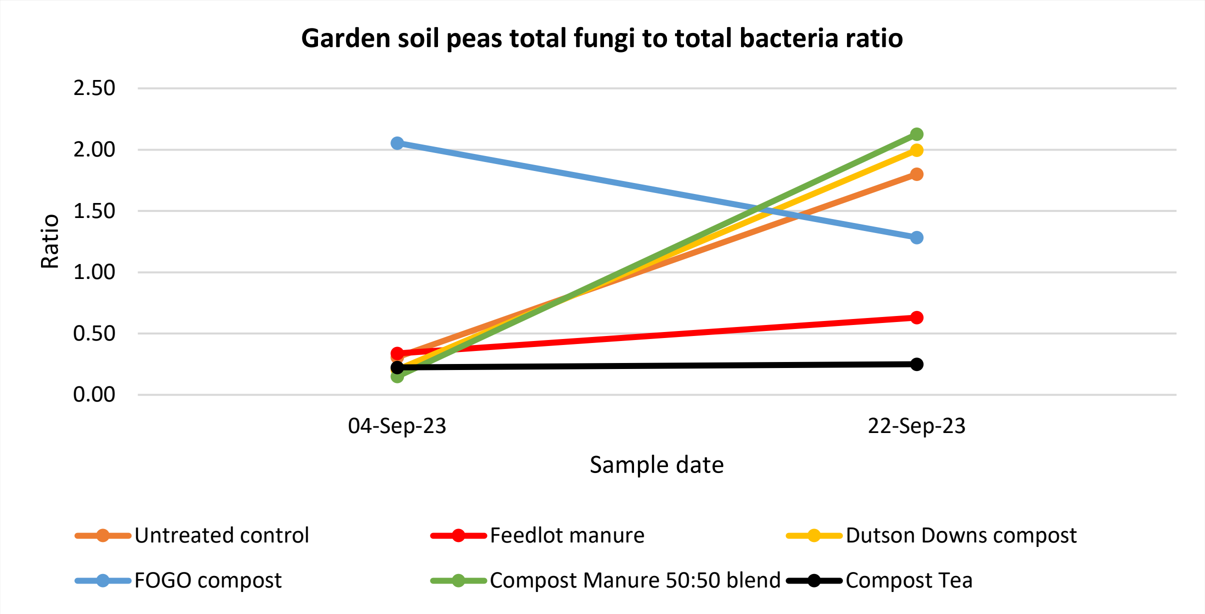
Amoeba require aerobic conditions for maximum activity. Feedlot manure and compost tea with the blend show most activity and contribution to providing plant available nitrogen.



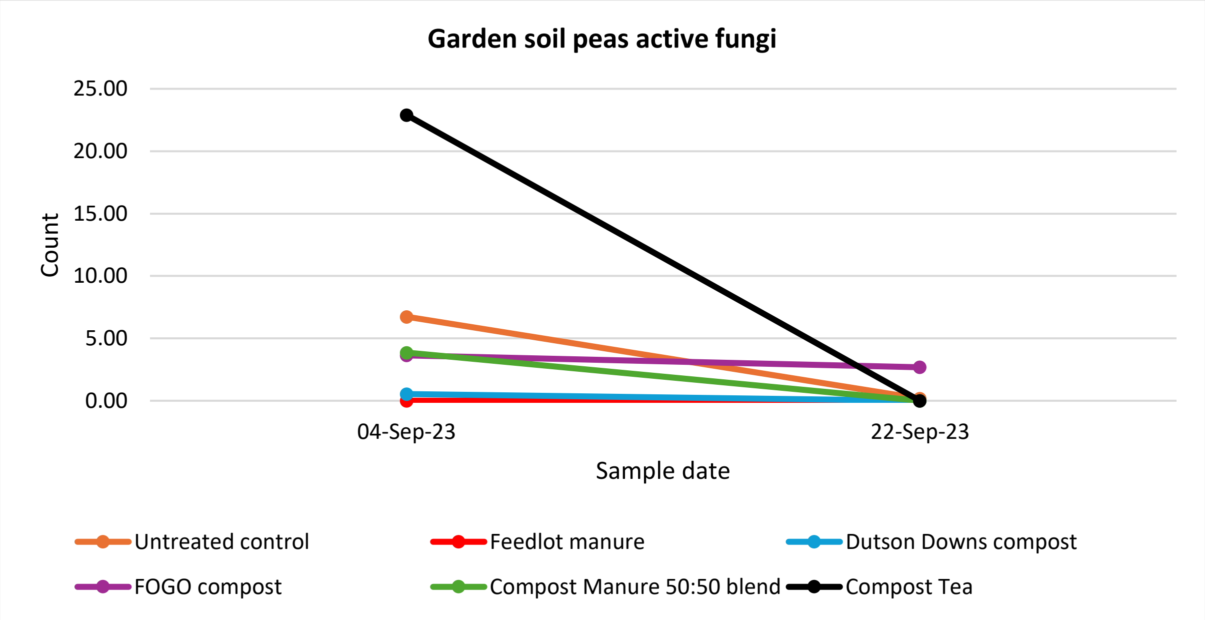
Ciliates are microaerobic and the fact that the populations have not increased or decreased suggests the soil is aerated.

VEGETABLE TRIALS

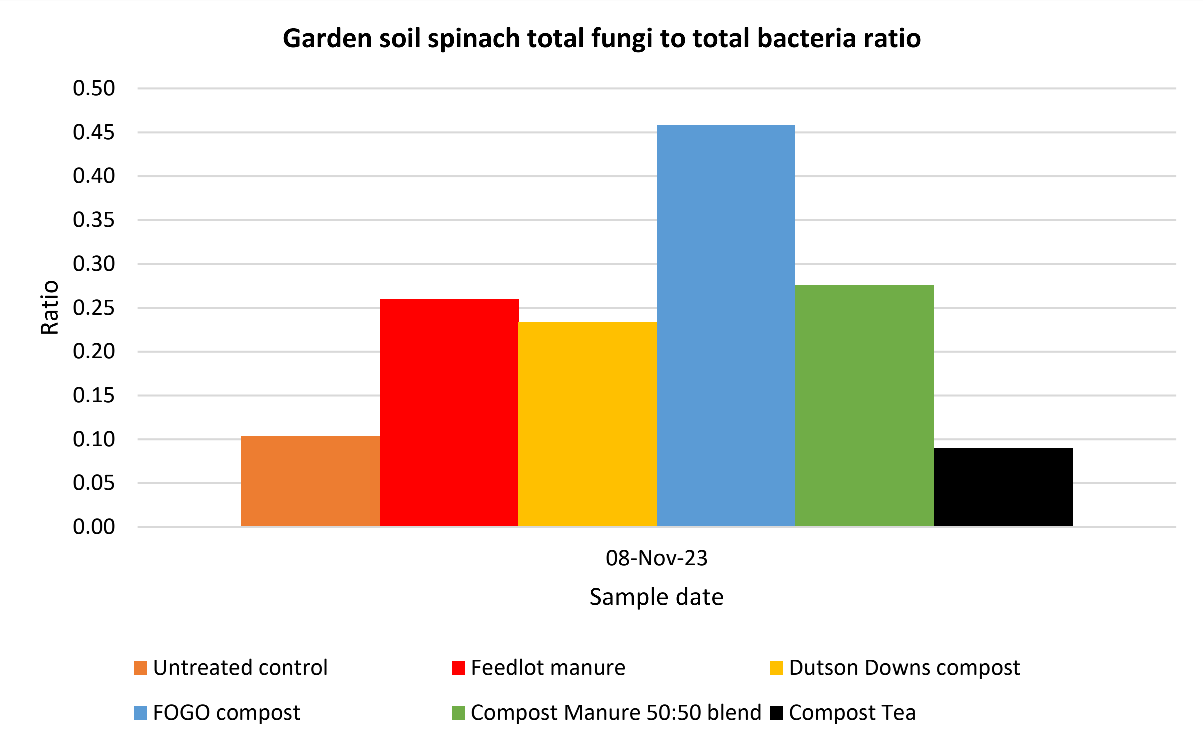
GARDEN SOIL



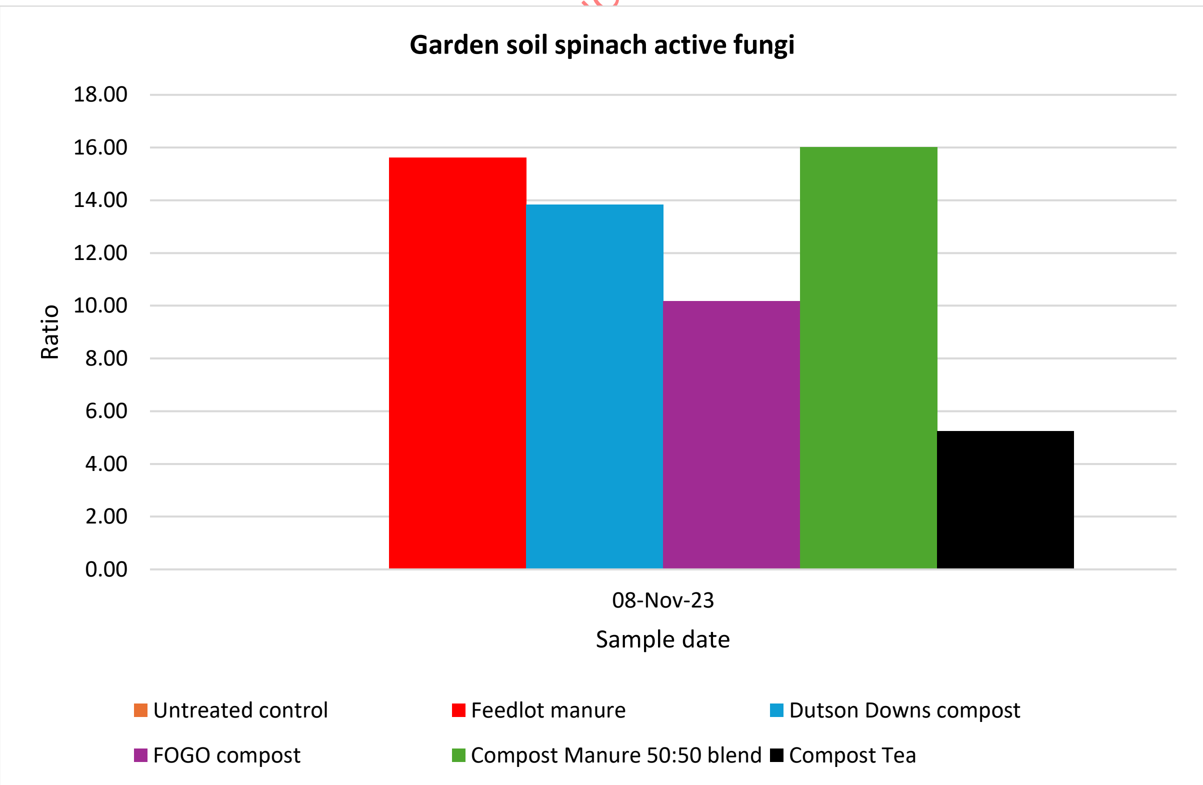
Fresh FOGO stimulated microbial activity because of the fresh readily available simple sugars used by bacteria to generate nutrients available for plants. Compost tea and feedlot manure are closer to acceptable range for healthy soil mineralisation than are the control, Dutson Downs or Blend.



This garden soil was largely sand with poor nutrient holding capacity (low CEC) and low organic matter content. Fungal activity requires a good source of carbon which is missing from the soil. The amendments were not sufficient to improve activity in the time between these harvests.

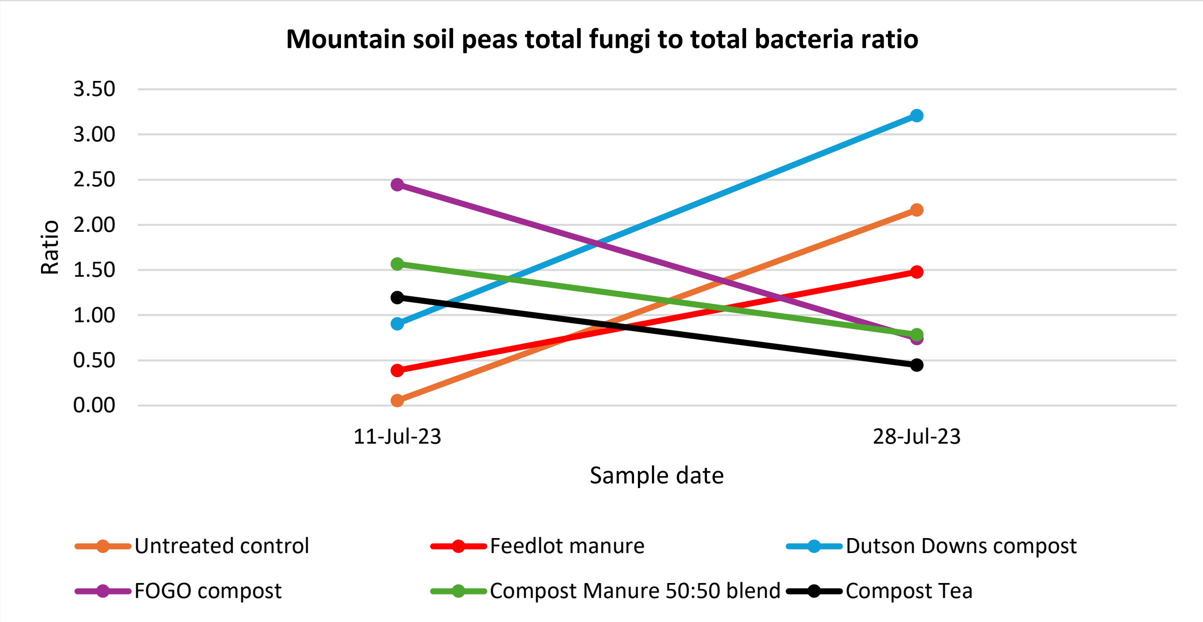


Feedlot manure, Dutson Downs and blend are closer to the expected ratio than are compost tea, control or FOGO.

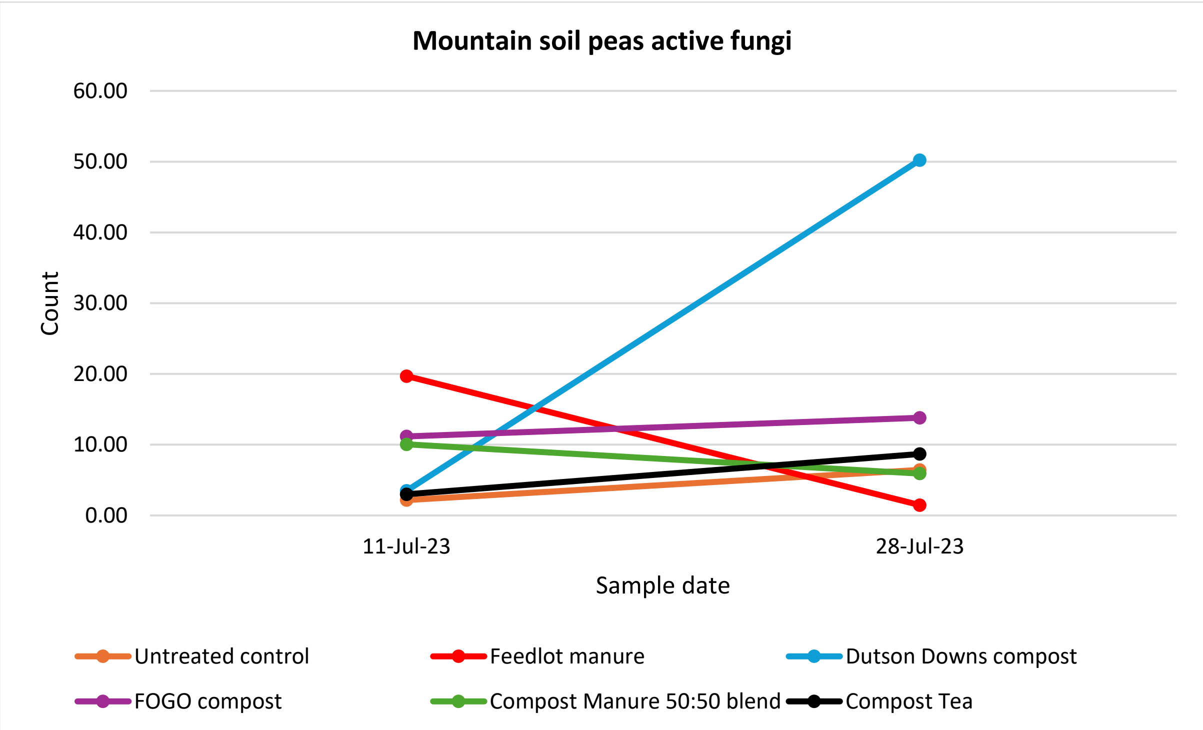


The blend is like Feedlot manure and Dutson Down is better than FOGO and compost tea on this one result.

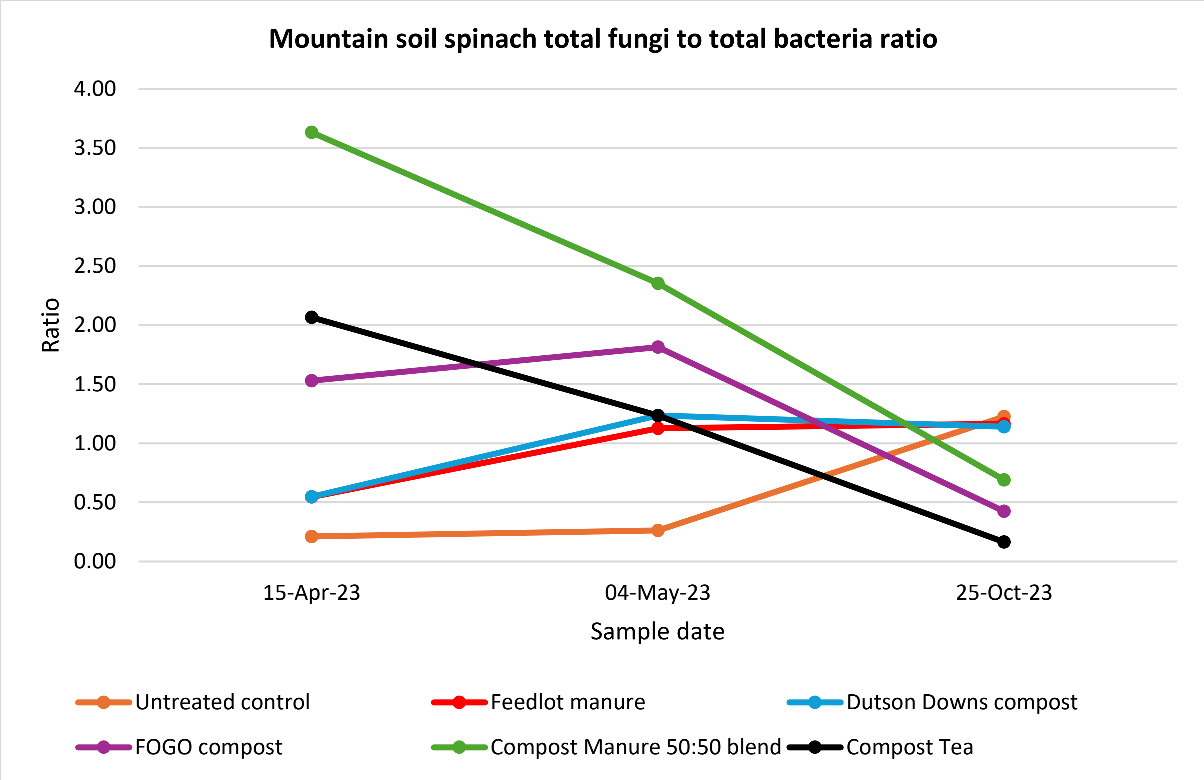
MOUNTAIN SOIL



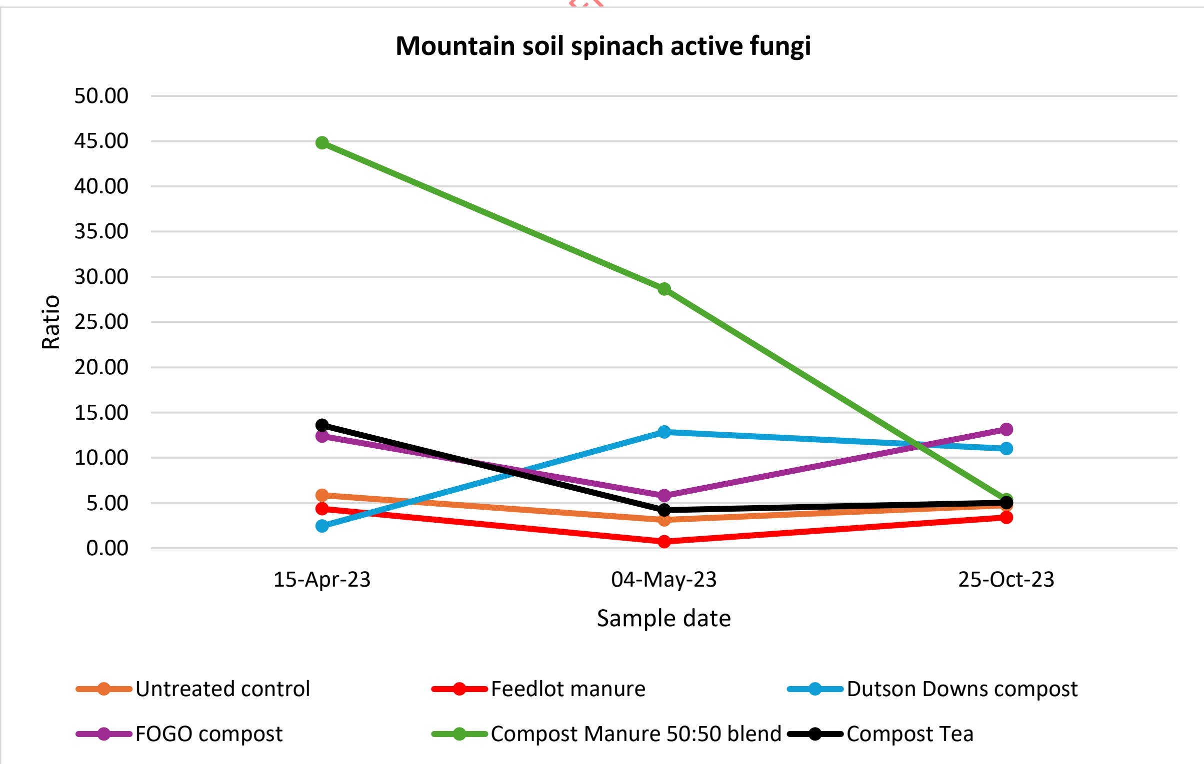
These results are only 17 days apart. This is a short time to expect differences in microbial activity. These results are difficult to interpret.



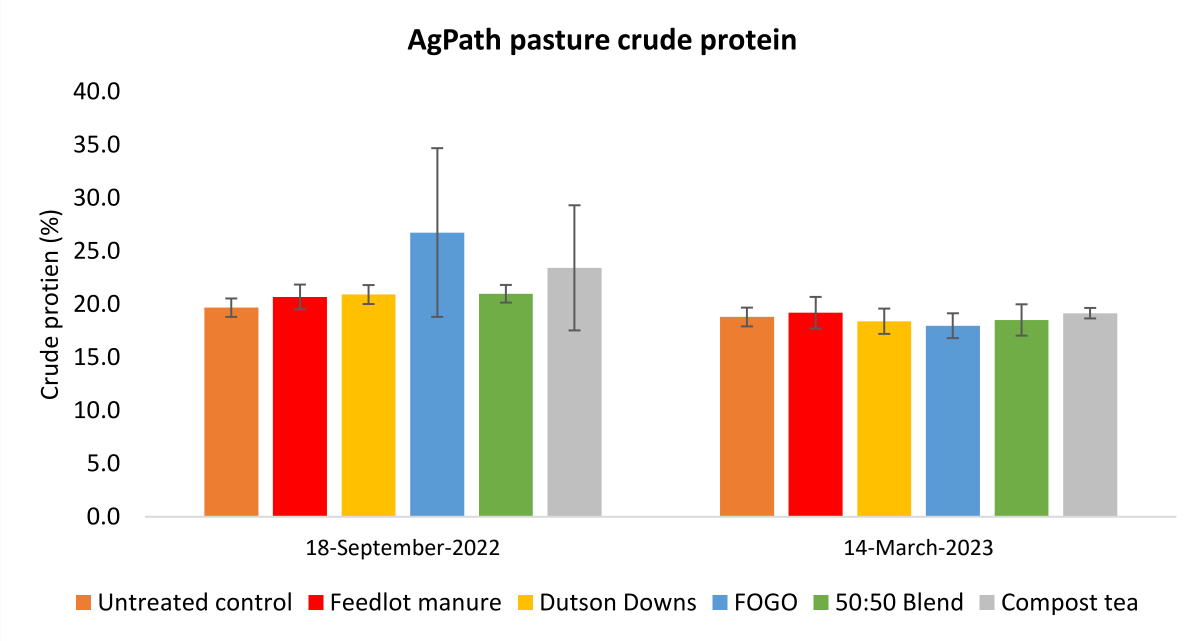
Dutson Downs compost has had the most effect on the active fungal pool in the 2 weeks between these samplings. The other treatments have not altered the populations significantly.

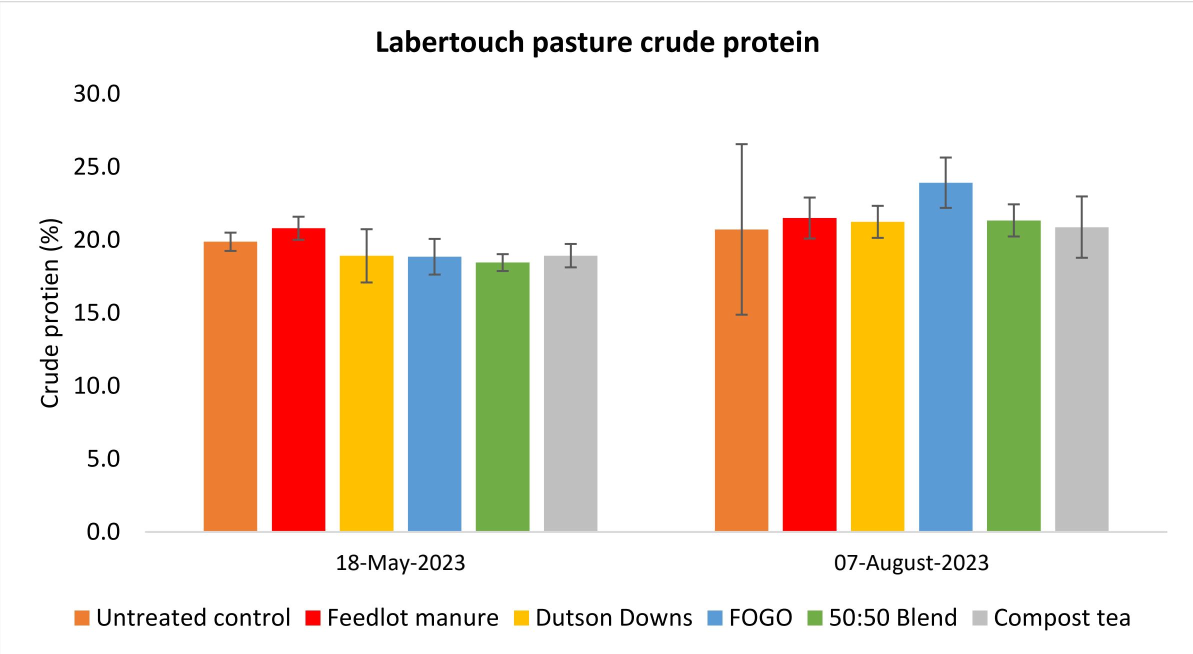


There has been a decrease back towards an acceptable ratio following the treatments so there has been a balancing of the pools which is positive. Dutson Downs, blend and untreated control have moved into the balanced range.



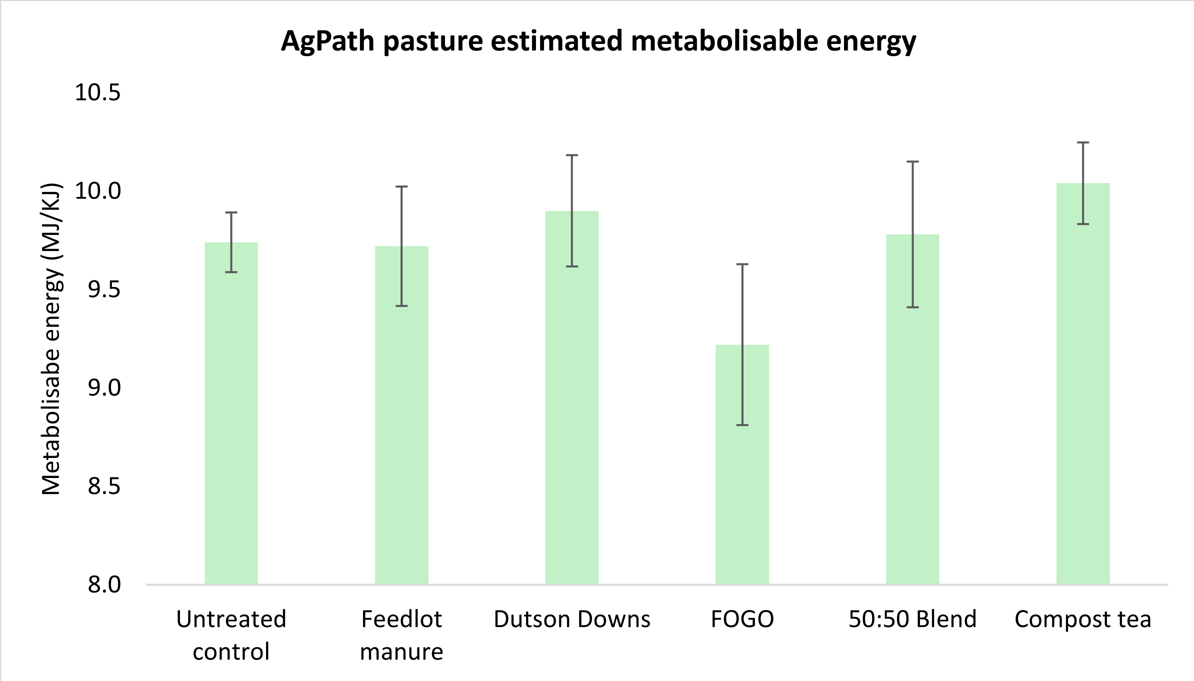
Only the blend has shown a significant change in activity. Dutson Downs and FOGO have stimulated the active fungi better than the other treatments.

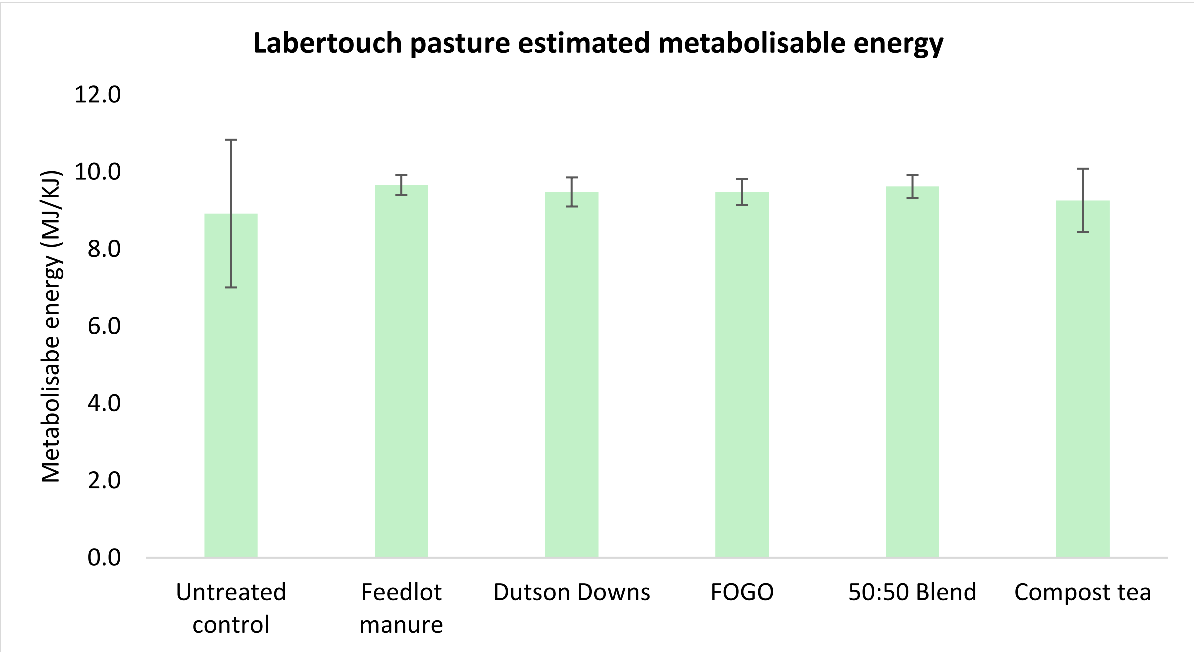




Crude protein is a calculation of the amount of nitrogen in the forage. Crude protein from the Agpath site is consistent across the treatments in a year that was extremely wet. All treatments were similar to the untreated control, so the treatments had no effect on the crude protein levels in this very wet year. Nutrient livestock requirements depend on whether a female is lactating or growing. For cattle and sheep crude protein levels of 8% dry matter to 15% dry matter is accepted. The Agpath site fell well within that range with all treatments and at minimal cost to the farmer.

The Labertouche site is showing higher values across all the treatments with not much improvement on the untreated control if at all. 2023 was a drier year more conducive to good pasture growth. Labertouche is a conventionally managed farm with cultivation, planting of annual fodder species and input of synthetic chemistry. The cost of production compared with the low input regenerative farm (Agpath) has not justified the cost of production on the return to the farmer.

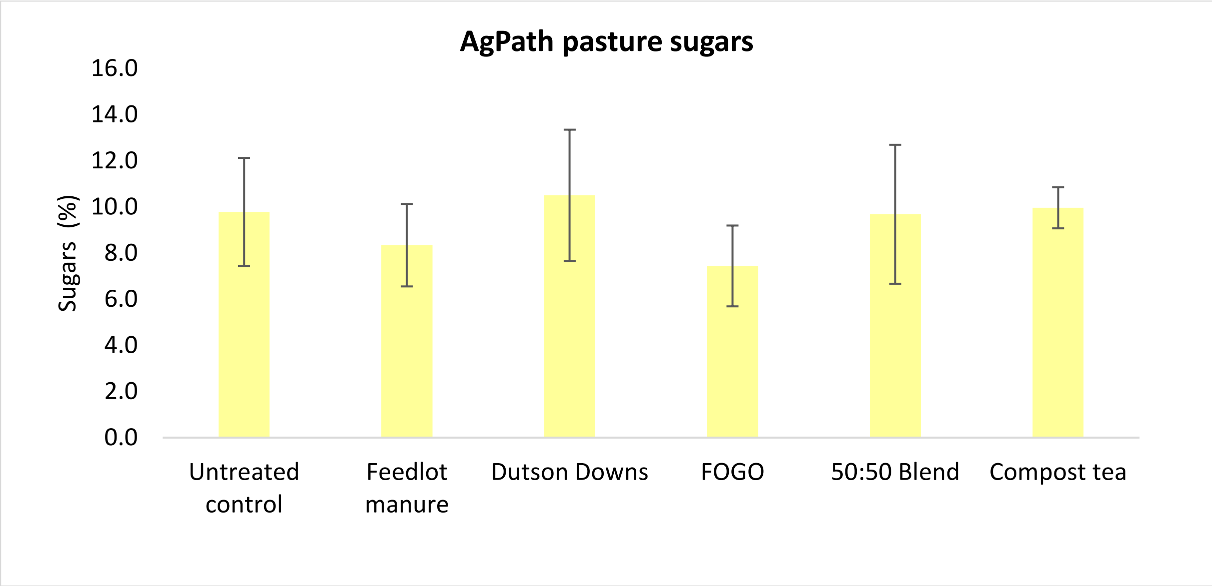


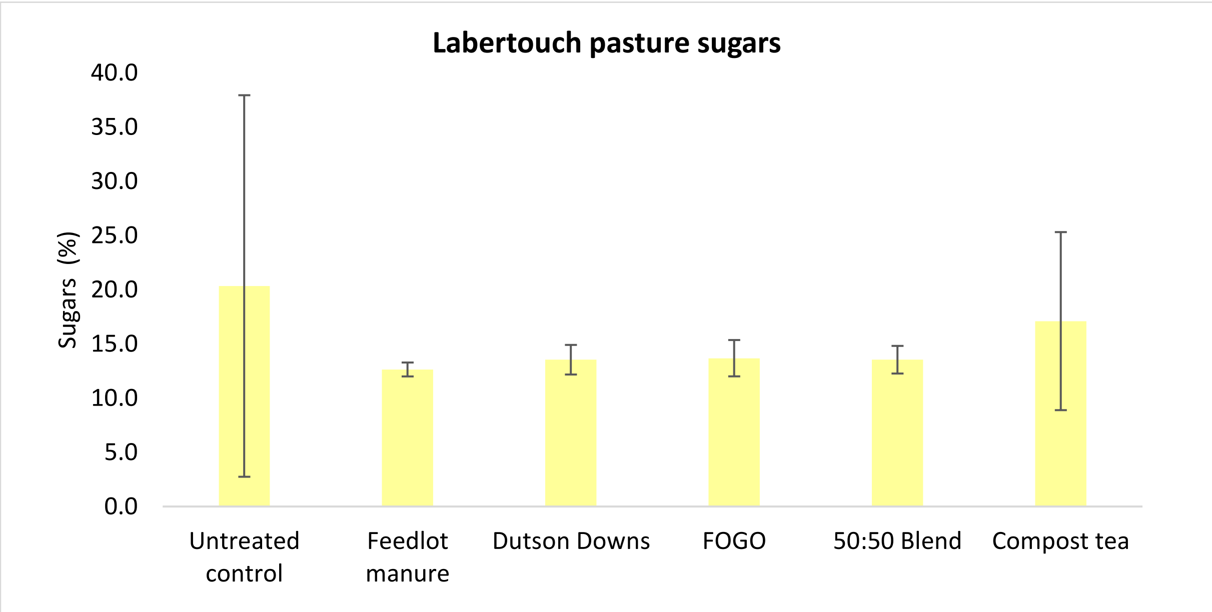


Metabolisable Energy (ME) is a measure of the ability of forage to maintain the function and productivity of the animal. The higher the value of energy, the better the quality of the forage.

On the Agpath site the response to the treatments is variable. FOGO is least effective with aged feedlot manure and the blend similar in response. On the Agpath site the treatments were no better than the untreated control. The ME was suitable for grazing animals not in the accepted range for lactating animals.

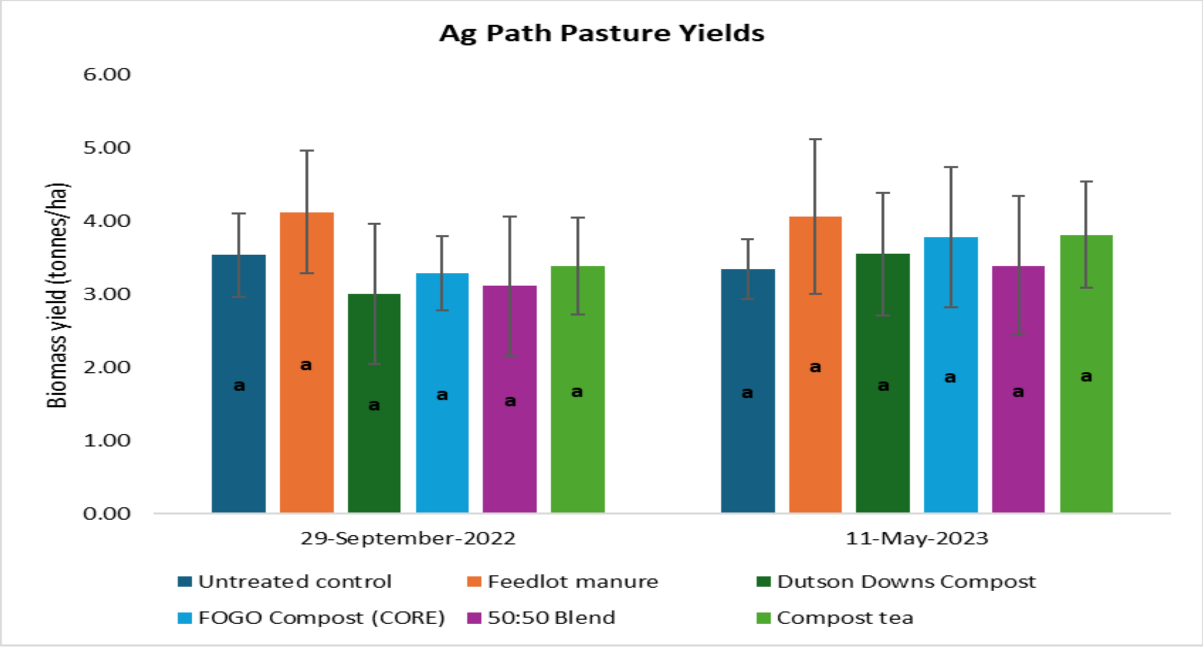
The Labertouche site was more consistent across the treatments, but the treatments were similar to the untreated control. The results were also similar to the Agpath results. The cost to the farmer and the negative impact on the soil biota from the synthetic inputs and soil disturbance through cultivation, make the regenerative farm more profitable than the synthetic input farm for return on production costs.

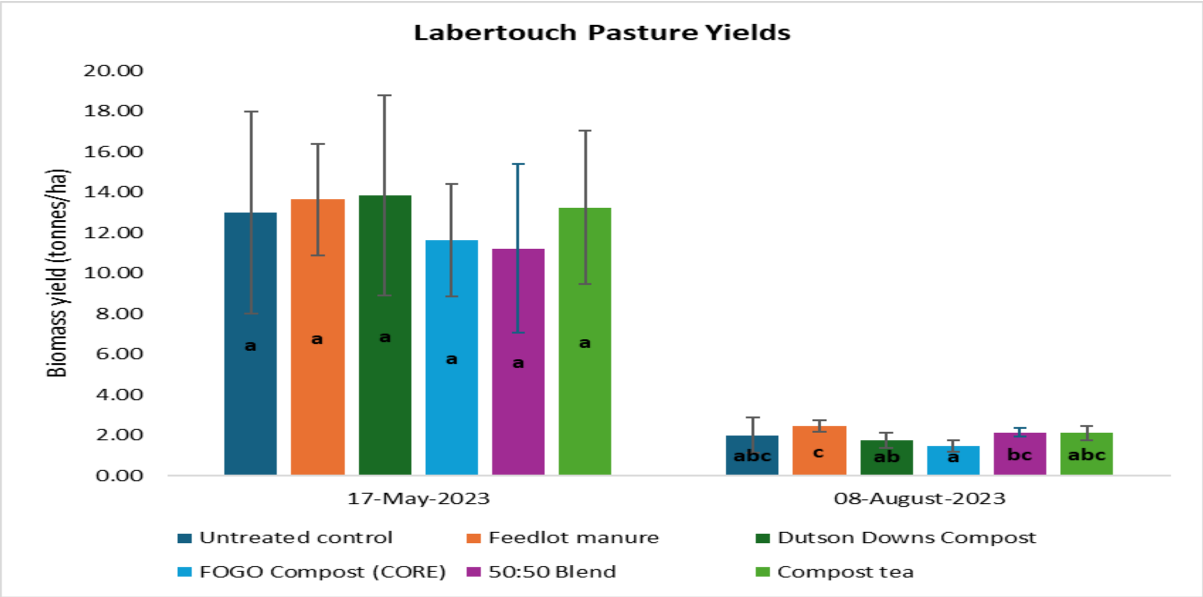




Sugars in plant tissue result from photosynthetic activity. All treatments were similar to the untreated control with FOGO lower. The treatments have no significant effect on the values, but the blend could be seen as useful to a farming enterprise and cost effective.

In the conventional synthetic input farm, none of the treatments compared with the untreated control. Cost of inputs were not translated to return on investment for the farmer in this year.





On the Agpath site there was no significant difference in response to the treatments compared with the untreated control. Pasture growth across the spring – autumn period of 2020-2023. Good soil biota activity maintains a consistent growth of pasture/fodder through the seasons.

Labertouche results are autumn – winter 2023. Rainfall was consistent through the periods of harvests. The conventional synthetic input farm di not hold the pasture growth in the same way as did the regenerative farm. The treatments had no effect on the growth relative to the control, so costs again are higher with lower returns to the farmer.

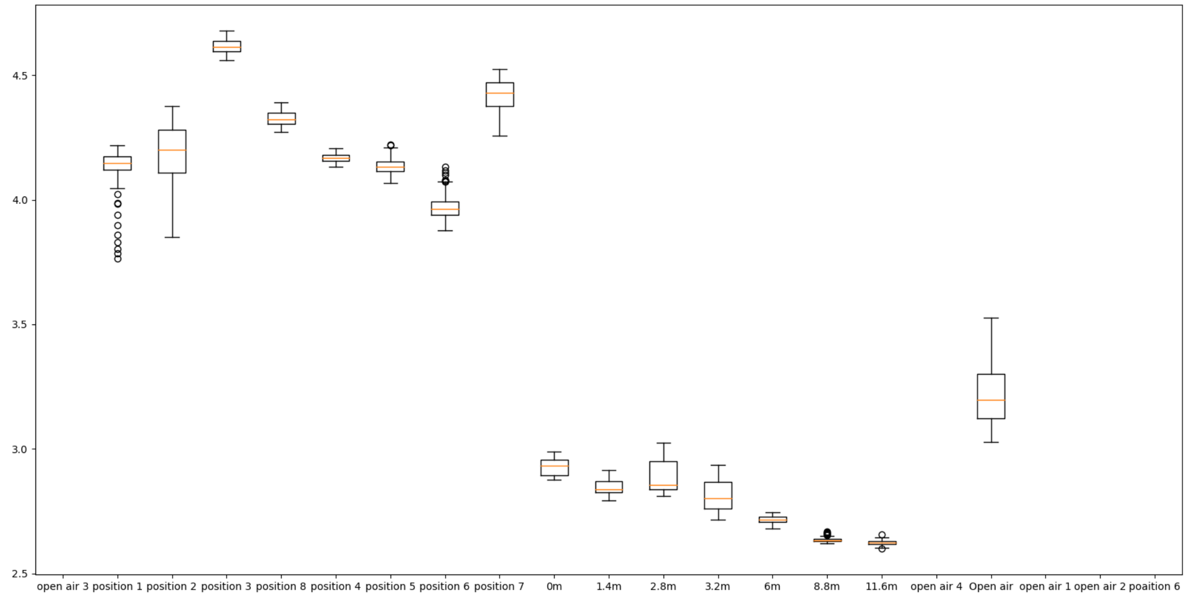
E-NOSE RESULTS

Field component – Key findings

Pairwise t-test & Tukey's HSD

i. Carbon monoxide (CO) cannot be differentiated by using pairwise t-test for all conditions.
ii. E-nose could differentiate most of the gases within the on-windrow condition.
iii. E-nose could differentiate most of the gases under open air, on-windrow and distanced conditions.
iv. E-nose could not differentiate most of the gases under the distanced condition.
v. E-nose could detect the difference between C1 vs C2, 3 & 4
vi. E-nose could not differentiate between C2, C3 and C4.

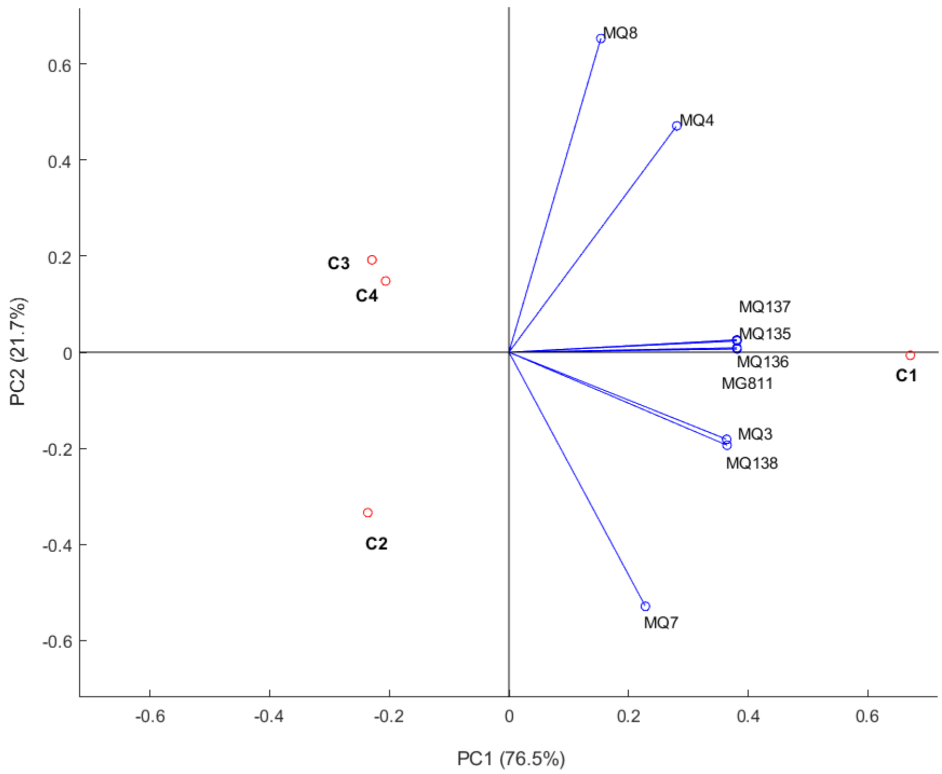
Figure below shows the distribution and differences for ammonia gas (NH_3) for (a) different positions on the same windrow (100% FOGO); (b) increasing distance from windrow; (c) open-air condition, noting that shifting wind directions meant measurement position was not always directly downwind from windrow. Y-axis values are in mV corresponding to e-nose sensor detection of gas concentration.



PCA (Principal Component Analysis)

i. C3 and C4 are clustered, e-nose found that there was minimal difference in their emissions profile.
ii. PCA of e-nose data could distinguish between C1, C2 and C3&C4.
iii. Ammonia (MQ137); Ammonia, Alcohol, Benzene (MQ135); Hydrogen sulfide (MQ136); Carbon dioxide (MG811) were strongly associated with C1 and C2
iv. No gases were strongly associated with C3 and C4 (this indicated biological and chemical stability in contrast with C1 and C2).

Figure below shows the outcomes of the PCA, for four FOGO:manure combinations, with sensors MQ136 Hydrogen Sulfide (FL= 0.3811), MQ137 Ammonia (FL=0.3810), MQ811 Carbon dioxide (FL=0.3810) and MQ135 Ammonia/alcohol/benzene group (FL=0.3808) accounting for the majority of differences between C1 to C4; noting that minimal differences were found between C3 and C4.



Artificial Neural Networks (ANN) classification

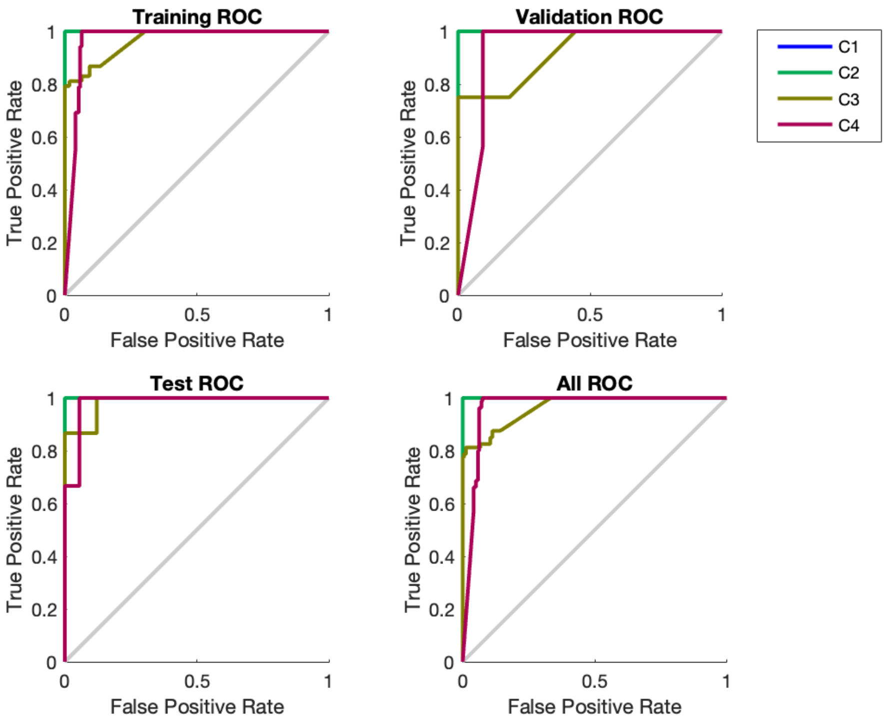
i. No overfitting of the algorithm.
ii. High overall accuracy 94.4%.
iii. E-nose combined with the ANN could classify C1, C2, C3 and C4.

Table below presents the confusion matrix indicating good performance of ANN model developed and tuned to discriminate between C1 to C4 emissions

Statistical results for the artificial neural networks pattern recognition models.

Stage	Samples (no.)	Accuracy %	Error %	Performance - Mean Squared Error (MSE)
Training	213 (60%)	95.1	4.9	0.00
Validation	45 (20%)	93.8	6.2	0.04
Testing	44 (20%)	91.7	8.3	0.04
Overall	302	94.4	5.6	-

This model displayed high accuracy in classifying the e-nose readings according to the treatments, with an overall accuracy of 94.4% Models 1 presented 93.8% validation accuracy close to the training stage with 95.1% accuracy. Furthermore, performance values for training (MSE < 0.01) were lower than the validation (MSE = 0.04) and testing (MSE = 0.04); this indicates that there were no signs of overfitting for this model. Figure 14 descripts the receiver operating characteristic (ROC) curves for the ANN model developed. Model showed high true-positive rates (sensitivity) and low false-positive rates (specificity) for classifying the e-nose readings according to the four compost windrow treatments.



Full details of background, methodology, results and discussion for this section can be found in Wenyi Chen's Masters Thesis available upon request at this link: Wenyi Chen_1031488_Major Project Thesis pdf.

Lab component – Key findings

GC-MS results found 72 Volatile Organic Compounds (VOCs) in total (Table 2). The entire dataset was filtered to identify the top 10 VOCs according to their occurrence and proportion for each triplicate set (Table 3)

Table 1. The 72 volatile organic compounds identified by gas chromatography – mass spectroscopy (GC-MS).

Volatile organic compounds	Volatile organic compounds
.alpha.-Caryophyllene	Bicyclo[3.1.1]heptan-3-one, 2,6,6-trimethyl
.alpha.-Cubebene	Bicyclo[4.1.0]hept-2-ene, 3,7,7-trimethyl-
.alpha.-Phellandrene	Bicyclo[4.2.0]octa-1,3,5-triene
.beta.-Myrcene	Bicyclo[7.2.0]undec-4-ene, 4,11,11-trimeth
.beta.-Phellandrene	Camphene
.beta.-Pinene	Caryophyllene
.gamma.-Elemene	Cedrol
1,4-Cyclohexadiene, 1-methyl-4-(1-methyle	Copaene
1,4-Methano-1H-indene, octahydro-4-meth	Cycloheptasiloxane, tetradecamethyl-
1,6-Octadien-3-ol, 3,7-dimethyl-	Cyclohexane, 1-ethenyl-1-methyl-2,4-bis(1
1-Butanol, 3-methyl-	Cyclohexanemethanol, 4-ethenyl-.alpha.,.al
1H-Cycloprop[e]azulen-4-ol, decahydro-1,1	Cyclohexanol, 5-methyl-2-(1-methyletheny
1H-Cycloprop[e]azulen-7-ol, decahydro-1,1	Cyclohexanone, 2-methyl-5-(1-methylethen

1H-Cycloprop[e]azulene, 1a,2,3,4,4a,5,6,7b	Cyclohexanone, 5-methyl-2-(1-methylethyl
1H-Cycloprop[e]azulene, 1a,2,3,5,6,7,7a,7b	Cyclohexasiloxane, dodecamethyl-
1H-Cycloprop[e]azulene, decahydro-1,1,7-t	Cyclohexene, 3-(1,5-dimethyl-4-hexenyl)-6
1-Hexanol	Cyclooctasiloxane, hexadecamethyl-
1-Naphthalenol, 1,2,3,4,4a,7,8,8a-octahydr	Cyclopentasiloxane, decamethyl-
1-Octanol	D-Limonene
2-Cyclohexene-1-carboxaldehyde, 2,6,6-tri	Estragole
3-Carene	Eucalyptol
3-Cyclohexen-1-ol, 4-methyl-1-(1-methylet	Furan, tetrahydro-2,2,4,4-tetramethyl-
5-Hepten-2-one, 6-methyl-	Guaiol
Acetic acid, 1,7,7-trimethyl-bicyclo[2.2.1]h	Ledol
Azulene, 1,2,3,3a,4,5,6,7-octahydro-1,4-dim	Naphthalene, 1,2,3,4,4a,5,6,8a-octahydro-7
Azulene, 1,2,3,5,6,7,8,8a-octahydro-1,4-dim	Naphthalene, 1,2,3,4,4a,7-hexahydro-1,6-di
Benzene, 1,3-dimethoxy-	Naphthalene, 1,2,3,4-tetrahydro-1,6-dimeth
Benzene, 1-methyl-2-(1-methylethyl)-	Naphthalene, 1,2,3,5,6,7,8,8a-octahydro-1,
Benzene, 1-methyl-4-(1-methylethyl)-	Naphthalene, 1,2,4a,5,6,8a-hexahydro-4,7-
Bicyclo[2.2.1]heptan-2-one, 1,3,3-trimethyl	Spiro[5.5]undec-2-ene, 3,7,7-trimethyl-11-
Bicyclo[2.2.1]heptan-2-one, 1,7,7-trimethyl	Spiro[5.6]dodecane
Bicyclo[2.2.1]heptane, 2-methyl-3-methyle	Thujone
Bicyclo[3.1.0]hexan-3-ol, 4-methyl-1-(1-m	Thujopsene
Bicyclo[3.1.0]hexan-3-one, 4-methyl-1-(1-	Tricyclo[2.2.1.0(2,6)]heptane, 1,3,3-trimeth
Bicyclo[3.1.1]hept-2-ene, 2,6-dimethyl-6-(4	Tricyclo[2.2.1.0(2,6)]heptane, 1,7-dimethyl
Bicyclo[3.1.1]heptan-3-ol, 6,6-dimethyl-2-	Ylangene

Table 2. The top ten volatile organic compounds groups identified by GCMS, with the associated aromas and maximum area percentage values. Only two to three could be considered offensive.

Compound Groups	Associated Aroma*	Maximum (area %)
Eucalyptol	Eucalyptus / Herbal / Camphoreous	39.96
Benzene	Phenolic / Spicy / Clove / Guaiacol	26.85
3-Carene	Citrus / Herbal / Pine / Woody	20.79
Naphthalene	Moth Balls / Pungent	14.95
Caryophyllene	Sweet / Woody/ Spicy / Clove	12.59
Limonene	Citrus / Terpenic / Camphoreous / Sweet	12.59
Elemene	Sweet	9.56
Cubebene	Herbal / Waxy	5.73
Copanene	Woody / Spicy / Honey	2.54
Pinene	Herbal / Minty / Terpenic / Pine / Earthy	2.46

*Associated aromas were retrieved from The Good Scents Company (TGSC).

Figure 4 show the mean values for the compost position sample for each of the nine gas sensors. The results show that the e-nose could discriminate between different positions as there was significant differences ($p<0.05$) between all samples. For all positions, the highest voltage values were alcohol, followed by ammonia with the lowest voltages of carbon monoxide and hydrogen.

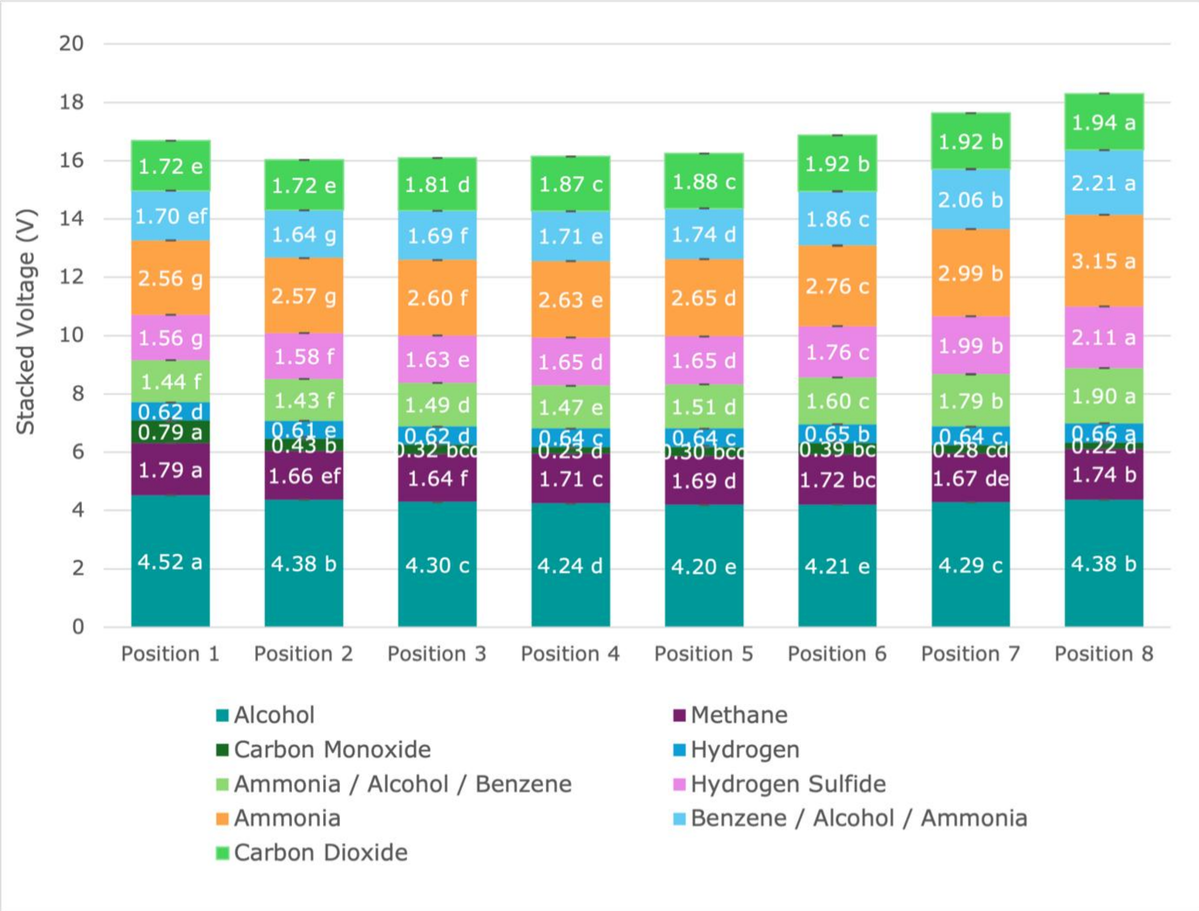


Figure 4. Stacked graph showing the mean voltage and standard error of the nine different gas sensors for the electronic nose. Different letters a-g depict differences between the eight positions based on ANOVA and Fisher's least significant difference (LSD) post hoc test ($\alpha = 0.05$).

In support of the results found for the field component, different positions on the 100% FOGO composting windrow had different gas emission profiles as shown in Table 4 below. For instance, Position 1 had low emissions of Benzene (2.55%), Carene (0%) and Naphthalene (3.12%) but high emissions of Eucalyptol (26.15%) and Limonene (8.88%) in contrast to Position 5 with high emissions of Benzene (13.5%), Carene (10.22%) and Naphthalene (6.59%) but relatively lower emissions of Eucalyptol (12.32%) and Limonene (6.93%; though non-significant difference).

Table 4. Mean percentage area for the top ten volatile aromatic compound groups detected with gas chromatography-mass spectroscopy (GC-MS). Different letters a-d depict differences between positions based on ANOVA and Fisher's least significant difference (LSD) post hoc test ($\alpha = 0.05$). Abbreviations: NS: non-significant.

Position	Benzene	Carene^{NS}	Caryophyllene	Copaene^{NS}	Cubebene^{NS}	Elemene^{NS}	Eucalyptol^{NS}	Limonene^{NS}	Naphthalene	Pinene
1	2.55 bc	0.00	5.68 ab	1.02	2.22	2.32	26.15	8.88	3.12 cd	0.62 bc
2	2.29 c	1.00	2.49 bc	2.04	1.00	0.97	16.62	4.79	2.95 cd	2.07 a
3	9.39 abc	0.00	3.28 bc	0.34	3.18	0.11	14.07	6.41	9.70 a	0.00 c
4	9.54 ab	0.38	5.56 ab	1.41	2.12	2.32	20.46	6.27	8.39 ab	0.28 bc
5	13.50 a	10.22	7.49 a	0.59	2.85	4.39	12.32	6.93	6.59 abc	0.50 bc
6	3.25 bc	6.86	5.62 ab	0.47	3.10	0.39	22.44	4.53	4.99 bcd	0.75 bc
7	7.56 abc	3.43	1.61 c	1.12	2.12	0.197	19.63	6.18	2.50 d	1.27 ab
8	10.83 a	0.12	2.38 bc	1.11	0.77	0.57	15.91	5.13	4.45 cd	0.00 c

This also highlights the heterogeneity of the material and emissions across the windrows that is able to be sensed to a good level of accuracy by the e-nose.

The ANN regression model (Table 2) showed high overall accuracy (R=0.98) based on the correlation coefficient for predicting volatile organic compounds. The slopes of all stages were high (0.97) with no signs of underfitting or overfitting since the MSE values of the training stage (1.05) was lower than the testing stage (1.32). Figure 5 shows the overall ANN regression model with the 95% prediction bounds and outliers (5%; 120 out of 2400 data points).

Table 2. Results from the artificial neural networks (ANN) regression models. Abbreviations: MSE: means square error.

Stage	Samples	Observations	R	Slope	Performance (MSE)
Training	168	1680	0.99	0.97	1.05
Testing	72	720	0.98	0.97	1.32
Overall	240	2400	0.98	0.97	-

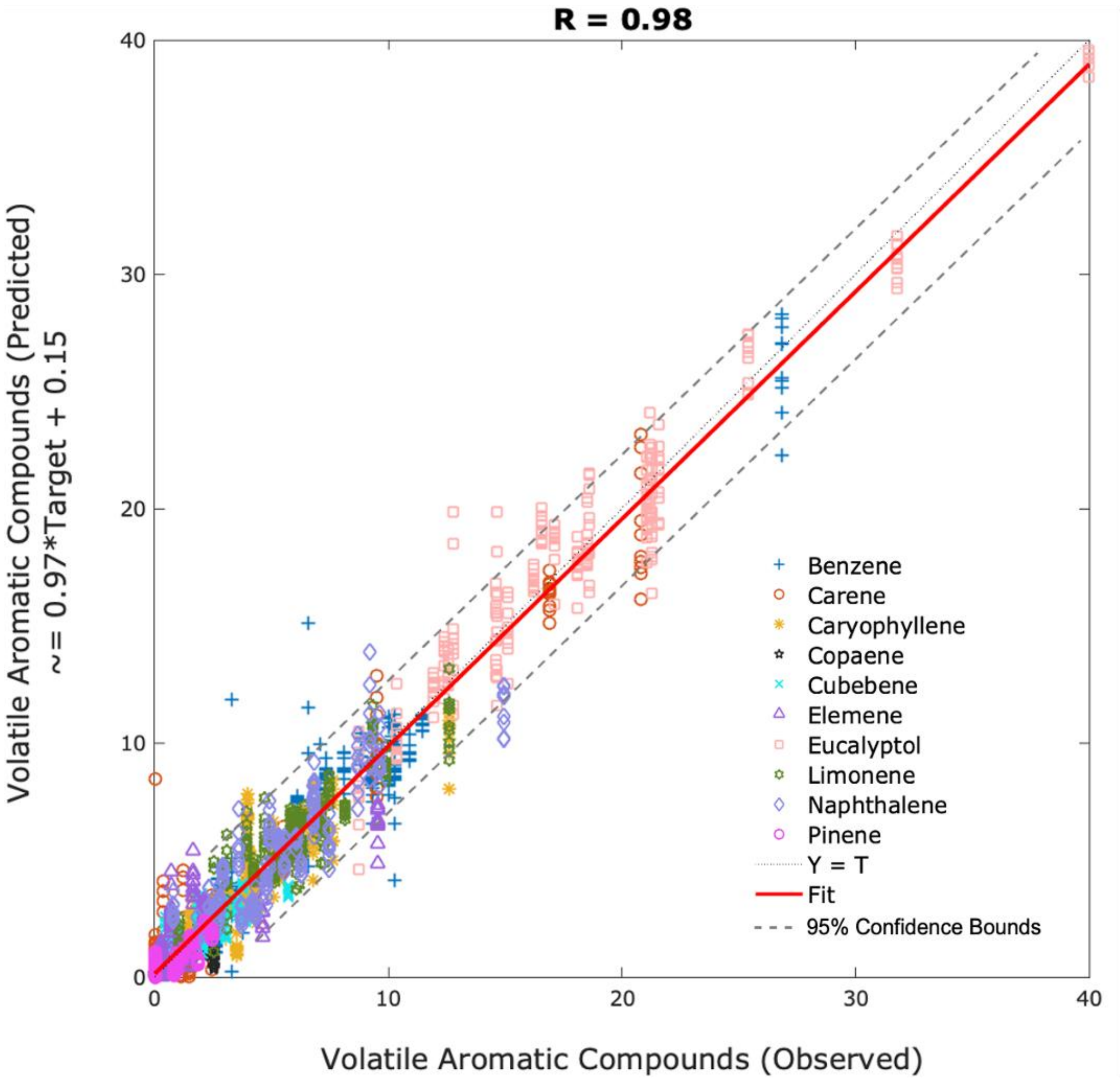


Figure 5. The overall ANN regression models using e-nose inputs for the prediction of volatile aromatic compound groups.

There have been minimal previous studies evaluating the use of e-noses to accurately identify and quantify multiple VOCs from FOGO. In this study, we showed that: (i) rapid, accurate digital technologies such as electronic nose (e-nose) and machine learning modelling (ML) for assessment of FOGO was feasible; (ii) ANN ML model developed was highly accurate (R=0.98) using e-nose values for the prediction of volatile aromatic compound groupings through high correlation values between GC-MS data (actual) and electronic nose readings (proxy). We note that more rigorous study is needed in future to further develop models with the addition of more compost data and treatments and replicated experiments.

The e-nose can be as sensitive as a human nose and in some cases more so. Because human noses suffer from aroma/odour fatigue (ie saturation of senses to become insensitive) while the e-nose can continue to detect the gases correlating/causing odours.

The finished compost, feedlot manure and FOGO were analysed for their individual chemistry and biology prior to any blending based on fungal: bacterial ratios and carbon: nitrogen ratios for soil and plant health. Full chemistry covering soluble, exchangeable and total pools were measured and nutrient analyses was carried out on the leaf material for pastures and vegetables. Biological analyses were carried out on the sample soil samples – active and total bacteria., active and total fungi, three pools of protozoa, five pools of nematodes, mycorrhizal fungal infestation of roots, F:B ratios measuring soil health. Environmental Analysis Laboratory at Southern Cross University was used for the chemistry analyses and AgPath Laboratory was used for the biology analyses.

For all fields trials, replicated and paddocks, the same analyses were carried out at regular intervals based largely on weather but as much as possible on grazing patterns for amount of dry matter present as an indicator of time to harvest.

Conclusions

We sought to develop recipes for the use of feedlot manure and FOGO waste streams (resource streams) that would result in fit-for-purpose products for animal and crop farming that fitted into the circular economy of Victoria and abroad.

The project plan has identified useful blends of two major waste streams for use in agriculture. This aspect has been successful. A two-year project does not give sufficient time to best interpret the impact of organic inputs compared with conventional inputs. However, it does show the trend that organic biological farming using the circular economy waste stream products is a viable option. A blend of 50% matured feedlot manure and 50% FOGO gave suitable C:N ratios for rapid thermal aerobic composting to a matured product fit-for-purpose for cropping and pasture.

Waste streams can be made into fit-for-purpose products to benefit the circular economy. Researching the benefits of these products to the soil and agriculture through mineralisation of nutrients.

The data collected has shown the advantages of non-synthetic chemical farming when compared with conventional synthetic input farming both for pasture and cropping. The huge variation in climatic conditions during the period of the trials made it difficult to be definite with these results.

A disappointment was the weather – very wet in 2022 and very dry in 2024-5 about which we could do nothing. Farmers face the same problems every year. What the results have shown, is that the treatments on the organic farm gave results useful to the farmer throughout the trial. The conventional farm at Labertouche, showed no real advantage from an agricultural perspective for the input of synthetic NPK with the organic amendments. This project has shown how weather patterns influence microbial activity in the soil, and therefore the mineralisation of any nutrients available to plants. From a farmer's perspective, the cost of production (conventional synthetic input VS organic input from the waste streams) will be an important parameter. We have shown clearly the consistency of production in an organic system compared with that in a conventional system, and the cost of production difference.

The major disappointment about which something must be done if the waste streams are to be used as fit-for-purpose products for farmers, is the serious contamination of FOGO. Agpath staff spent many hours removing mixed waste from the deliveries – more than 750kgs of waste was removed from 60 cubic metres of FOGO. This contamination is not totally removed at the waste receival stations making the final mulch/compost dangerous for animals and workers on cultivated agricultural land. Glass, plastics, rocks will contaminate pastures and can be ingested by stock injuring them if not killing them. On cultivated land, rocks, glass, plastic contaminated soil, become dangerous for workers and potentially can damage equipment. Although PFAS was not a part of this project, it must be considered in the future as a serious contaminant in the circular economy food chain.

Identified problems:

- Lack of information on the influence of FOGO on green organic matter recycling.

Data is available now to assess the role of FOGO nutrients on soil microbial activity and plant health.

- Lack of information on nutrient levels and mineralisation of organic products

Data is available now to assess the role of FOGO nutrients on soil microbial activity and plant health.

- Lack of information on biological status in organic products

Data is now available on nutrients levels on soil microbial activity under different management systems – conventional synthetic chemical input vs biological/organic inputs.

- Lack of information on nutrient levels and mineralisation of organic products on soil.

Data is now available.

- Lack of information on biological status of organic products in soil.

Data is now available

- Lack of product-specific information on the influence of recycled organics on plant health.

Data is now available

In systems where FOGO is part of the green organic recycling, there appears to be little or no information about the impact of this material on unacceptable levels of odour emission. There is a need for quantified data around mineralisation, nutrient levels and biological status of organic products and their influence in the soil. Also, there is a need for product-specific, soil-type-related information on plant health.

To determine if an e-nose can provide suitable information for odour management of FOGO for EPA regulation adherence

Data is now available on the elements/molecules released from FOGO/manure compost and the distances the odour is detectable.

Enhanced Markets

Farmers are looking for organic inputs that are fit-for-purpose. FOGO mulched at the receival stations is not fit-for-purpose because of contamination. If cleaner material can leave the receival stations and be mixed with the feedlot manure, then cropping and pasture applications can enhance soil nutrient fertility minimising the use of synthetic chemistry. This is what farmers are wanting. Distributors could blend the two waste streams to provide a very saleable product or products. Of all the blends, the 50% feedlot manure with 50% FOGO was a successful blend of the raw materials. This creates a market for the raw products to be delivered directly to a farm and spread in the windrow formation, If the FOGO could be cleaned of contamination to be fit-for-purpose, then it also could be delivered and mixed 50%:50% with the aged feedlot manure. Mixing could be done with a farm tractor and bucket attachment. This is possible but time will need to be allocated in the work programme. However, it comes back to the quality of the FOGO. Farmers cannot allow their cropping system or their vegetable system to be contaminated. If this aspect of FOGO can be addressed, then these two waste streams make a very valuable resource to the agricultural system at a minimal cost to farmers compared with the increasing costs of synthetic chemistry. Also, farming using organic inputs, allows the farm to be cropped continuously in a rotational system. Synthetic conventional farming without good rotational management does not allow for annual cropping. Farmers tend to rest paddocks every 3-4 years because of loss of fertility through loss of microbial activity.

Next Steps

The information in the final report will be made available on the Agpath website and, hopefully, on a Victorian government website. Articles will be written for appropriate farming magazines, and the data can be used in farming forums. The authors are using the data in their current and future presentations. Research papers can be written, and technical journal articles also will be written.

Farmers are looking for products that will maintain the productivity and profitability of their farming enterprise and increase resilience in the light of climate change. Cost of synthetic inputs continues to increase and return from those inputs appears not to yield the results comparable with cost. Therefore, by promoting the use of these waste stream products, farmers could be encouraged to change their farming practices to a more sustainable future.

What we have shown is farmers can reduce input costs and have a consistent response on their enterprise throughout seasonal variation. The results from this project align with the results shown in the Rodale 30-year report. That is, organic biological farming gives a consistent return on investment while conventional farming responds more greatly to environmental conditions and variations.

Stakeholder engagement

FIELD DAY. Wednesday October 11th 2023 approx. 60 people present. Speakers Dr Mary Cole (Agath & Univ Melb), Dr Alexis Pang Univ Melb), Mr. Eric Love (CORE), Andrew Dougall (SV). The participants were farmers and sellers of organic products.

Singapore Government Climate Action – Resilient Food future. 29th March 2025. Speakers: Dr Mary Cole – Soil Health & composting in the tropics.

Conference papers and/or journal articles

Cole, Pang, Love (2023) Field Day booklet. Quantifying minerialisation and biological status from organic amendments and soil. 27 pages.

Cole, M (2024) Using urban and farming waste streams to improve soil health in agricultural systems. 8th Global Conference on Plant Pathology & Biotechnology, Singapore 27-29th 2024.

Cole, M (2025) Mineralisation of Urban Waste through Composting in Agriculture in a Circular Economy. 9th Global Conference on Plant Pathology & Biotechnology, Singapore March 27-29th 2025.

To be presented: Cole, M (2026) Waste Streams become Resource Streams in the Circular Economy. 10th Global Conference on Plant Pathology & Biotechnology, Singapore March 25-27th 2026.

MASTERS THESIS. Chen, W (2023) Evaluation of electronic nose (e-nose) technology and machine learning for low-cost odour measurements for Food Organic Green Organic (FOGO) compost. University of Melbourne AGRI 90072, 1031488 supervisor Dr Alexis Pang.

Promotion/media

Populate table below, include consultations and workshops (See project update(s) for reference)

Communication platform	Summary of the communication	Link to communications webpage if applicable	Audience Reach (If known)
Agpath Website, Pakenham Gazette	Flyer promoting the field day.		Unknown.

Project Monitoring

Project monitoring Spreadsheet is attached with this document.

Project Evaluation

To what extent did the project deliver the planned outputs and outcomes.

The project has shown that the two waste streams can be blended into fit-for-purpose products both for pasture and for any agricultural production system. This statement is predicated on the condition that FOGO is cleaned to fit-for-purpose. The project results also show that organic biological farming enterprises can provide cost effective output compared with conventional agriculture with increasing input costs. As mentioned above, organic biological farming can be productive under all weather conditions because of the increased climate resilience defined by the microbial population, increased organic matter in the soil, and minimal disturbance of the topsoil and minimal impact from farm traffic.

To what extent did the project address the problem/s or need?

The project design allowed for flexibility in execution. For example, the vegetable component was able to be completed in raised garden beds at Agpath when it was obvious that working on commercial vegetable growing farms was not possible. The project has provided fit-for-purpose blends that can be used for cropping and for pasture. No organic material should need to go to landfill. It is a resource to be valued in the circular economic of the state. The project has exposed the degree of contamination in FOGO coming from the urban waste stream. Farmers cannot afford to use a product that will contaminate their enterprise nor cause physical damage to their livestock. This would lead to increasing costs on their part and seriously impact on their willingness to embrace organic biological farming or the use of highly nutritional waste stream products from the circular economy even if they choose to remain within the conventional agricultural system.

What were the unintended consequences (positive and negative?)

COVID had an impact on the project through problems with supply chain for product and equipment.

2022, the first year of the project was unseasonably wet and did not allow for the project field work to proceed in the time allowed. This put pressure on the remaining time to get sufficient harvests for meaningful data.

The electronic nose tool a very long time to get working and results to be obtained. This is again because of availability of the instruments and ground truthing the software.

The field day received very positive response from the 60+ farmers and agronomists who attended. Farmers are genuinely wanting to have fit-for-purpose organic products at affordable prices available to them.

To what extent did communications and engagement with community and/or stakeholders support the achievement of project objectives?

The research plots at Agpath had signage inviting farmers or interested parties to investigate the plots. The windrows were of interest and farmers came and asked questions about the quality and use of windrow composting.

Agpath received new clients interested in having their soils tested so that they could transition from conventional synthetic agricultural inputs to a more sustainable method of production.

To what extend did your program support self-determination and Traditional Owner decision-making in waste management and resource recovery?

It did not directly involve Traditional Owners. However, indirectly, methods of recycling waste streams that can contaminate ground water and surface water if sent to landfills, indirectly increases this project's aim of caring for country by eliminating waste streams and eliminating synthetic chemistry from agriculture thus improving the land and population health. More recently, the Bunurong Land Council, had their field officers attend a soil health workshop at Agpath where the discussion centred around use of compost in rewilding and recovery of damaged forested land.

To what extent was the project delivered within scope?

We believe the project has been delivered within scope despite the difficulties of finding suitable vegetable farms, inclement weather across the whole project period, and serious contamination of one of the raw materials. Fit-for-purpose products from two major waste streams can be offered to farmers, municipal parks and gardens and general householders. Data on mineralisation is presented.

To what extent was the project delivered within budget?

Budget was adequate except for time involved from the major participants. This was seriously underestimated, not because of the project design, but because of the unexpected contamination in the raw material delivered.

How appropriate were the chosen methods and activities in helping achieve the project outcomes?

Methods and activities were appropriate to the desired outcome. This project had the advantage of being carried out on a farm that was owned by the lead researcher. A change in the participation of vegetable growers was necessary because their time frame and the weather became impossible to control during the short period of the grant and the extremes of weather during those two years. The replicated research plots at Agpath were already established from a previous research project – Landcare and Catchment Authority.

If you were to deliver the project again, what would you do the same and what would you do differently?

The science around the project was sound and proven. The project design was effective in delivering the results required. Working with the calendar of cropping farmers is difficult so time would not be wasted in finding cooperative farmers. Rather the alternative of research plots on a manageable farm would be used from the start.

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Appendices

Appendix 1. NH_4 to NO_3 Ratio Comparison.

	Baseline		1st round of Soil tests		2nd Round of soil tests	
Treatment	AgPath	Labertouche	AgPath	Labertouche	AgPath	Labertouche
Untreated control	82.1%	38.4%	93%	4.17%	33.4%	20.90%
Feedlot manure	82.1%	38.4%	161%	4.53%	25.5%	21.07%
Dutson downs compost	82.1%	38.4%	124%	4.95%	24.9%	28.66%
FOGO Compost	82.1%	38.4%	109%	6.23%	45.9%	17.93%
50:50 Blend	82.1%	38.4%	126%	4.00%	27.1%	29.47%
Compost tea	82.1%	38.4%	102%	4.17%	24.7%	22.19%

Appendix 2. Rainfall and temperature data for the years of the trials. Temperature data was collected from Nilma North weather station and rainfall data was collected from Lang Lang weather station.

TEMPERATURE DATA FOR THE YEARS OF TRIALS

SCORSEBY IS THE WEATHER STATION FOR THE TRIAL SITES

Year Graph	Jan Graph January data	Feb Graph February data	Mar Graph March data	Apr Graph April data	May Graph May data	Jun Graph June data	Jul Graph July data	Aug Graph Aug data	Sep Graph Sept data	Oct Graph Oct data	Nov Graph Nov data	Dec Graph Dec data	Annual Graph Annual data
2022	27.6	25.8	24.4	20.3	15.7	13	12.6	14.3	15.7	18	19.2	23	**19.1**
2023	26.4	25.5	23	19.5	15.3	13.9	14.1	15.1	18.8	18.4	20.6	22.7	**19.4**
2024	24.8	26.6	25.8	18.1	16.6	13.1	12.6	17	16.6	19.5	23.4	26	**20**

WEATHER DATA FOR THE YEARS OF THE TRIALS

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	**Annual**
2022	87.6	2.6	62.2	63.2	43	105		121	54.6	131	129	75	**874.4**
2023	9.4	30.6	60.6	65.6	118	81.4	32.4	34.8	52.3	127	109	77.8	**799.5**
2024	89.6	20.2	4.2	113.4	28.2	37	112.6	19.4	69.2	25	50	27.2	**596**

Appendix 3. Comparing Agpath site with Labertouche site for pasture crude protein from the treatments during 2023 and 2023.

AgPath pasture crude protein (%)

	18-September-2022		14-March-2023	
	Mean	SD	Mean	SD
Untreated contro	19.7	0.87	18.8	0.88
Feedlot manure	20.7	1.16	19.2	1.49
Dutson Downs	20.9	0.89	18.4	1.19
FOGO	26.8	7.94	18.0	1.17
50:50 Blend	21.0	0.83	18.5	1.47
Compost tea	23.4	5.89	19.2	0.49

Labertouch pasture crude protein (%)

	18-May-2023		07-August-2023	
	Mean	SD	Mean	SD
Untreated contro	19.9	0.63	20.7	5.84
Feedlot manure	20.8	0.79	21.5	1.41
Dutson Downs	18.9	1.82	21.2	1.10
FOGO	18.9	1.22	23.9	1.73
50:50 Blend	18.5	0.58	21.3	1.10
Compost tea	18.9	0.80	20.9	2.10

Appendix 4. Comparing Agpath site with Labertouche site for pasture estimated metabolisable energy from the treatments during 2023 and 2023.

AgPath pasture estimated metabolisable energy (ME) (MJ/KJ)		
	14-March-2023	
	Mean	SD
Untreated control	9.7	0.15
Feedlot manure	9.7	0.30
Dutson Downs	9.9	0.28
FOGO	9.2	0.41
50:50 Blend	9.8	0.37
Compost tea	10.0	0.21

Labertouch pasture estimated metabolisable energy (ME) (MJ/KJ)		
	07-August-2023	
	Mean	SD
Untreated control	8.9	1.91
Feedlot manure	9.7	0.26
Dutson Downs	9.5	0.38
FOGO	9.5	0.34
50:50 Blend	9.6	0.30
Compost tea	9.3	0.82

Appendix 5. Comparing Agpath site with Labertouche site for pasture sugars from the treatments during 2023 and 2023.

AgPath pasture sugars (%)

	14-March-2023	
	Mean	SD
Untreated control	9.8	2.34
Feedlot manure	8.3	1.79
Dutson Downs	10.5	2.85
FOGO	7.4	1.75
50:50 Blend	9.7	3.01
Compost tea	10.0	0.89

Labertouche pasture sugars (%)

	07-August-2023	
	Mean	SD
Untreated control	20.3	17.60
Feedlot manure	12.6	0.64
Dutson Downs	13.5	1.36
FOGO	13.7	1.68
50:50 Blend	13.5	1.27
Compost tea	17.1	8.21

Appendix 6. Agpath and Labertouche pasture yield.

AgPath pasture yield (tonnes/ha)

	P=0.281 29-September-2022			P=0.748 11-May-2023		
	Mean	SD	Groups	Mean	SD	Groups
Untreated control	3.54	0.57	a	3.34	0.41	a
Feedlot manure	4.12	0.84	a	4.06	1.06	a
Dutson Downs Compost	3.00	0.96	a	3.55	0.83	a
FOGO Compost (CORE)	3.28	0.51	a	3.78	0.96	a
50:50 Blend	3.12	0.95	a	3.39	0.95	a
Compost tea	3.39	0.66	a	3.81	0.73	a

Labertouche pasture yield (tonnes/ha)

	P=0.869 17-May-2023			P=0.043 08-August-2023		
	Mean	SD	Groups	Mean	SD	Groups
Untreated control	13.00	5.00	a	2.00	0.89	abc
Feedlot manure	13.64	2.77	a	2.45	0.28	c
Dutson Downs Compost	13.83	4.94	a	1.74	0.39	ab
FOGO Compost (CORE)	11.64	2.79	a	1.47	0.29	a
50:50 Blend	11.23	4.16	a	2.14	0.23	bc
Compost tea	13.25	3.79	a	2.10	0.36	abc