Agriculture, Ecosystems and Environment 257 (2018) 12–19

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Can we maintain productivity on broad acre dairy farms during early transition from mineral to compost fertilization?

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ARTICLE INFO

Keywords:
Agriculture
Pasture
Compost
Dairy
Soil
Agricultural management

ABSTRACT

Composts are being increasingly used as an alternative to mineral fertilisers in production agriculture. However, some farmers are reluctant to utilise compost due to lack of consistent information regarding agricultural productivity and management. Here we explore the changes in soil chemistry, plant biomass production and nutrition during an 18 month transition period from mineral to compost fertiliser use. This was undertaken on plots excluding stock on two dairy farms in southeastern Australia. Biomass was not affected by compost application, demonstrating that productivity and nutrition were maintained during early stage transition. Soil chemical properties, including available nitrogen species, were influenced by compost, but changes fluctuated over the transition phase. Impacts of management practices, season and soil chemical influences on biomass production were explored using multivariate techniques. This analysis revealed that season and inherent soil chemical properties had the greatest influence on pasture biomass during early stage transition. Results are discussed in the context of a transition to compost-based nutrient management of grazed dairy pastures.

1. Introduction

There is increasing pressure to maintain and increase agricultural productivity, on less land, with fewer inputs. With rising costs of mineral fertilisers, and concerns about their environmental impacts, there has been resurgence in interest in the use of soil organic amendments to deliver nutrients on farms. The economic, environmental and social benefits of compost use are well documented (Smukler et al., 2008; Quilty and Cattle, 2011).

Composts and other organic amendments, when used alone or in concert with mineral fertilisers, can have wide-ranging benefits, including improvements in soil properties, and increased agricultural productivity (Quilty and Cattle, 2011; Richard, 2004; Thangarajan et al., 2013). Some of the benefits of compost application to soil include: increased soil organic carbon (OC); increased plant available nutrients (such as N, P, K and Zn); increased organic matter and slower release of nutrients; greater microbial biomass; promotion of microbial, earthworm and enzymatic activity; improved soil aggregation and reduced bulk density; enhanced cation exchange capacity; improved water holding capacity and porosity (Lal et al., 2007; Paulin, 2014; Quilty and Cattle, 2011; Richard, 2004; Thangarajan et al., 2013). Furthermore, the use of composts made using on-farm residues can reduce nutrient losses and reliance on external inputs, which often have a high embodied energy cost (Paulin, 2014; Quilty and Cattle, 2011).

The use of manure-based composts in agroecosystems has been ongoing for centuries (Chan et al., 2007; Quilty and Cattle, 2011). However, compost use in broad acre agriculture, including dairy farm production systems where nutrient-rich manure is a freely available resource that would otherwise go to waste, has been relatively limited (Beale, 2013; Chan et al., 2007; Poole, 2013). This limited uptake is due to a range of factors including, but not limited to, composition variability, a lack of scientific literature on compost production and broad acre application (Chan et al., 2007; Quilty and Cattle, 2011; Richard, 2004), and limited financial incentives to make the transition to compost (Paulin, 2014). These factors, along with concerns about N losses via leaching and as the potent greenhouse gas N_2O, have translated to a negative perception of amendments in many instances (Quilty and Cattle, 2011), which in turn has resulted in a reluctance to change practices (Chan et al., 2007; Paulin, 2014). Early failure, or poor successes, with the use of compost to deliver nutrients to pastures can also be a major roadblock to widespread adoption of their use.

Transition phases are a critically important period of time in which

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https://doi.org/10.1016/j.agee.2017.12.022
Received 13 April 2017; Received in revised form 19 December 2017; Accepted 20 December 2017

farmers can gradually learn new practices, change, monitor and adapt management strategies (Hauser et al., 2010; Lewis et al., 2011; Mutoko et al., 2014; Smukler et al., 2008). However, transition phases in agroecosystems are generally understudied (e.g. Lewis et al., 2011; Pant et al., 2014; Smukler et al., 2008). Although some work on transitions on dairy farms from the perspective of soil health, agricultural productivity and human ecology have been reported (Hansen, 1996; van Apeldoorn et al., 2011), there is a dearth of information on the transition to compost use on conventional broad acre dairy farms.

Here we present results of a field based study on two dairy farms over a 1.5 year period in which we monitored plant production and soil properties using an experimental transition to a compost-based nutrient supply system in southeastern Australia. Specifically we aimed to quantify the impacts of various levels of compost addition on pasture production and nutritional content, and soil physicochemical properties. Results are discussed in the context of managing dairy production systems during the early transition phase from a conventional to a compost-based nutrient supply system.

2. Materials and methods

2.1. Study location

Two dairy farms (Farm A and B) in the Colac dairy region, Victoria, in southern Australia, within 100 km of one another, were the focus of this study. Farm A was located close to the township of Birregurra (−38.34°S, 143.79°E), in low rolling hills and plains; the paddock used in this study (see below) was situated on the level plains. Farm B was located close to the township Camperdown (-38.24°S, 143.14°E), in rolling hills; the paddock used in this study (see below) was situated on the midslope of a hill. The region has a temperate climate with an average maximum 19 °C and minimum 7.4 °C, and an average rainfall of 721 mm year^{-1} calculated from 1898 to 2014 (Bureau of Meteorology, 2015a). Annual rainfall for the years studied in this trial were 595 mm in 2013, however the annual data for 2014 is incomplete for the most representative weather station (Bureau of Meteorology, 2015a). Mount Gellibrand station, which is approximately 50 km away was deemed to be a suitable substitute; the station recorded 568 mm for 2013 and 465 mm for 2014 (Bureau of Meteorology, 2015b). The soils at both sites are clay loams, classified as a Dermosol in the Australian Soils Classification (Isbell, 1996), which is a Terra Rossa Soil in the Great Soil Groups or Alfisol in US Soil Taxonomy. Key physicochemical of the soils are presented in Table 1. Pasture swards at both sites contained perennial rye grass, lucerne, clover, and perennial Australian native grasses.

The farms were managed differently. Farm A has an older and larger herd (approximately 1000 head) of mainly Holstein Friesian cows for milk production. Farm B, has a smaller (approximately 200 head) mixed herd of a younger age that includes Holstein Friesians, Brown Swiss and Jersey cows for cream production.

To assess the impact of compost addition on pasture production and soil properties, we established a field experiment on each farm where varying levels of compost were applied to the soil. The paddocks chosen for the study have not had previous compost application. The experiments were established as is now described.

Table 1
Average (N = 16) baseline soil analysis of Farm A and Farm B, ± 1 standard error, including bulk density (BD), pH, EC, NH_4^+-N, NO_3^--N, Colwell-P, TN and TC. NA is not applicable, as this was not measured on these samples.

Characteristic	Farm A	Farm B
BD (g cm^{-3})	1.29 ± 0.02	1.37 ± 0.03
$pH_{1:5\text{water}}$	5.39 ± 0.06	5.05 ± 0.06
$EC_{1:5\text{water}}$ (dS m^{-1})	0.14 ± 0.02	0.08 ± 0.01
NH_4^+-N (mg kg^{-1})	10.5 ± 1.7	11.7 ± 2.7
NO_3^--N (mg kg^{-1})	44.5 ± 12.1	22.8 ± 6.2
TN (%)	0.2 ± 0.02	0.2 ± 0.02
TC (%)	2.7 ± 0.2	2.4 ± 0.2

2.2. Compost

Two batches of compost were made and used in this trial over an 18 month period (February 2013–August 2014). All composting management, including C:N ratios, turning, oxygen, moisture content and temperature, followed formal compost production guidelines for the region (Department of Environment and Primary Industries, 2014).

The first batch of compost was applied at the beginning of the trial. This compost was made off-site using locally sourced materials over a five month period (Department of Environment and Primary Industries, 2014). The compost mix was composed of approximately 20 m^3 of high moisture and low moisture dairy manure, two round bales of hay (from Farm A), 22 m^3 of wood chips and 10 m^3 of poultry litter. The starting C:N of the mix was approximately 24:1. The materials were combined and composted in an open windrow system on a concrete pad, with regular turning (using a forklift) to ensure adequate oxygenation during the composting process. At the completion of the composting process, the compost was passed through a 10 mm screen to remove any coarse woody material and stones, prior to delivery to the farms.

The second batch of compost was made by the farmers on their own farms, as follows. Farm A used dewatered pond sludge (from the farm), spoiled silage and hay, greenwaste, and whole cow manure collected on farm. The materials were combined and were turned monthly and watered regularly for a period of five months, when the compost was assessed for maturity (see below). It was then stored for another seven months, prior to use in the experiment (see below). On Farm B, the compost was made using spoiled feed, poultry waste, hot mix compost from Camperdown Compost (Victoria, Australia), and calf bedding. The compost was turned and watered regularly for four months before being assessed for maturity (see below).

The compost was tested (by sesl.com.au, last accessed July 2017) against the Australian Standard for Compost, Soil Conditioners and Mulches (AS 4454), which includes measures of pH, EC, mineral N, P, organic C, moisture content, particle size and toxicity (germination assay). Final properties of the compost are presented in Table 2.

2.3. Experimental design

A 25 × 25 m plot was established on each farm and was fenced to

Table 2
Results of analysis of compost applied at the start of the experiment (0 Months when the same compost was applied at both sites, and the two different composts applied 15 and 14 months after the start of the experiment (Farm A and B respectively). Compost was analysed using the AS4454-2013 standard analysis of compost maturity (see text).

Characteristic	Compost Farms A and B At time of first spreading (i.e. 0 Months)	Farm A compost 15 Months	Farm B compost 14 Months
$pH_{1:5\text{water}}$	7.7	6.7	8.1
$EC_{1:5\text{water}}$ (dS m^{-1})	3.17	2.01	4.10
Phosphate-P (mg L^{-1})	12.1	11.3	11
Total P (%)	0.42	0.3	0.42
NH_4^+-N (mg L^{-1})	1.3	0.6	153.1
NO_3^--N (mg L^{-1})	3.42	111.52	1.93
Total N (%)	0.98	1.07	1.73
TOC (%)	24.1	15.9	23.5
C:N	24.59	14.83	13.62
Wettability > 16 mm	5.56	16.23	6.48
Moisture (%)	44.81	33.5	16
Plastics and glass (%)	0	0	0
Bioassay (toxicity) (mm root length)	44	75	< 5