Agricultural Water Management 181 (2017) 10–17

Contents lists available at ScienceDirect

Agricultural Water Management

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

Effects of summer turnip forage cropping and pasture renewal on nitrogen and phosphorus losses in dairy farm drainage waters: A three-year field study

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ARTICLE INFO

Article history:
Received 21 February 2016
Received in revised form
10 September 2016
Accepted 10 November 2016

Keywords:
Nitrate leaching
Cultivation
Pasture renewal
Drainage
Forage cropping
Nitrogen mineralisation

ABSTRACT

Spring cultivation of soil under long-term pasture to grow summer forage followed by autumn pasture renewal is a common practice on New Zealand dairy farms. Although this practice is widely used, there is limited research available on the impact that it has on nutrient losses to water. This three-year field study was conducted to quantify the effects of summer forage cropping and autumn re-grassing on nitrogen (N) and phosphorus (P) losses in mole and pipe drainage from a Pallic Soil in the Manawatu region of New Zealand. The two treatments compared were a continuation of long-term grazed pasture, and long-term pasture that was cultivated in spring, sown into turnips as a summer forage for dairy cows, followed by autumn re-grassing. Both treatments where located on artificially drained field plots.

Summer forage cropping and autumn re-grassing increased total nitrogen measured in drainage water by 21 kg N/ha in total over the three seasons monitored, which was a 84% increase compared to long-term pasture. Approximately three-quarters of this increase happened during the two months following spring cultivation, which was influenced by an atypically wet late spring/early summer period that extended the drainage season. It is estimated that if the spring cultivation had been conducted in a year with a more typical drainage season, then the additional total nitrogen losses are likely to have been about 6.9 kg N/ha. Overall losses of total phosphorus in drainage were low for both treatments during the study period, with the forage cropping and autumn re-grassing increasing total phosphorus losses in drainage by 0.36 kg P/ha over the duration of the study, which was 77% higher than the long-term pasture treatment.

1. Introduction

Mixed ryegrass-clover pastures, grazed in situ, provide the main source of livestock feed on most dairy farms in New Zealand. In the Manawatu region, it is common practice for dairy farmers to cultivate 5–10% of the farm's pasture area each year to grow summer forage crops (e.g. turnips or green feed maize). Summer forage crops are a valuable component of a farm's feed supply as they accumulate relatively large quantities of forage dry matter (DM) (Chakwizira et al., 2014) for use in summer when pasture growth and quality is often limited by inadequate soil moisture. After grazing, the area in forage is re-cultivated and planted with new, more productive ryegrass and white clover cultivars (Stevens et al., 2007).

Summer forage crops are also a useful strategy for reducing the excessive levels of potassium (K) that can accumulate in soils receiving K-rich farm dairy effluent (FDE) (Houlbrooke et al., 2004; Longhurst et al., 2000; Salazar et al., 2010). Excessive soil K levels are undesirable as they increase the risk of metabolic disorders in dairy cows, such as hypocalcaemia (milk fever) and hypomagnesaemia (grass staggers). Salazar (2006) found that turnips irrigated with FDE accumulated large quantities of K (e.g. >350 kg K/ha). Net removal of K from turnip areas can be achieved (Salazar et al., 2010) by grazing the turnips with dairy cows for short durations (i.e. 4 h) before moving the cows to other parts of the farm.

While there are the aforementioned benefits of growing summer forage crops, the cultivation of soil under long-term pasture also increases the risk of nutrient losses in drainage and runoff (Monaghan et al., 2002; Shepherd et al., 2001; Smith et al., 2008). Under long-term pastures, considerable quantities of soil organic N can accumulate (Haynes, 2000): cultivation results in net N mineralisation from pasture residues and soil organic matter (Davies et al., 2001; Eriksen et al., 2008; Eriksen and Jensen, 2001; Francis

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http://dx.doi.org/10.1016/j.agwat.2016.11.009
0378-3774/

et al., 1995). These increases in soil mineral N are beneficial to N nutrition of subsequent crops (Eriksen et al., 2008), however, they can also contribute to increased NO_3^- leaching if NO_3^- accumulates in the soil immediately prior to a period of drainage (Di and Cameron, 2002; Shepherd et al., 2001).

The timing of long-term pasture cultivation is known to have a significant influence on the potential for NO_3^- leaching from soils. In general, autumn cultivation is expected to result in higher NO_3^- leaching losses compared to spring cultivation, as there is a shorter duration after autumn cultivation for the crop to take up soil NO_3^- before the winter drainage season begins (Djurhuus and Olsen, 1997; Francis, 1995; Shepherd et al., 2001). The quantity of NO_3^- leached from autumn cultivation can also be influenced by the type of cover crop grown over winter and the timing of drainage in relation to crop development (Francis et al., 1998; McLenaghen et al., 1996). Winter cover crops are most effective when they are sown early in autumn and take up a large proportion of soil NO_3^- before the drainage season begins (Francis, 1995).

When soil under long-tem pasture is cultivated in spring for summer forage cropping and autumn re-grassing, there are a range of factors that can impact on subsequent NO_3^- leaching, which include; the proportion of soil mineral N taken up by the forage crop, the quantity of dairy cow excretal N returned during grazing (Christensen et al., 2011; Gourley et al., 2011; Ledgard, 2001; Lindsay et al., 2009; Silva et al., 1999), the timing of autumn cultivation and resowing of the new pasture and the proportion of soil mineral N taken up by the new pasture prior to the start of winter drainage (Francis, 1995).

Because NO_3^- leaching is influenced by the various interactions between crop, management, soil properties and climate, it is important to assess the combined impact of the aforementioned factors. Also, summer forage cropping and pasture renewal results in changes to soil properties and pasture botanical composition that may also influence NO_3^- leaching in subsequent seasons. However, there is limited information from field-scale studies about the influence of these practices over a number of years. In particular, information is required to determine the contribution that summer forage cropping makes to overall farm NO_3^- leaching on mole and pipe drained soils in New Zealand pastoral based dairy systems.

The aim of this study was to quantify the effects of cultivating long-term pasture, summer forage crop management and autumn regrassing on N and P losses in drainage water from a mole and pipe drained soil under dairy pasture in the Manawatu region of New Zealand.

2. Materials and methods

2.1. Description of study site

A 3-year (2006–2008) field trial was conducted on Massey University's No. 4 dairy farm near Palmerston North, Manawatu, New Zealand (NZMS 260, T24, 312867). The site is located in a flat to easy rolling landscape (c. 3% slope) on the Tokomaru silt loam soil, a Fragic Perch-gley Pallic Soil (Hewitt, 1998) or Typic Fragiaqualf (Soil Survey Staff, 1998). For the first two years (2006, 2007), the experiment consisted of four plots (40 × 40 m), each with an isolated mole and pipe drain system. In the third year (2008) of the trial, all the plots were divided in half to provide a total of eight drainage plots (20 × 40 m). In each plot, mole channels (40 m long) were installed at 2 m intervals at a depth of 0.45 m. Drainage from the mole channels was intercepted by perforated collecting pipe drains (0.11 m diameter) that were installed at a depth of 0.60 m at the edge of each plot. These collecting drains were perpendicular to the moles. Prior to commencement of this trial, all plots were under long-term pasture (i.e. > 10 years since previous grass renovation), which was grazed by dairy cows.

2.2. Treatments and site management

The trial design consisted of two treatments; the first treatment (hereafter, called *"LP"* treatment) was a continuation of long-term pasture, which was grazed as part of the farm's grazing rotation. The second treatment (hereafter, called *"CP"* treatment), involved cultivating long-term pasture in spring before sowing with turnips for use as a summer forage crop for dairy cows. In the subsequent autumn, the *CP* treatment plots were cultivated again and sown into new pasture. The limited availability of large drainage plots for this study meant that treatments were replicated twice.

In the Manawatu, cultivation of pastoral soils for summer forage cropping typically occurs as soon as the soil moisture reduces to allow conditions suitable for ploughing, which is usually in mid-late spring (i.e. corresponding to a soil water deficit of 15–20 mm). Following this common practice, the long-term pasture on the *CP* plots was sprayed with glyphosate, a non-selective herbicide, on 17 October 2006 and then cultivated with a mouldboard plough on 6 November 2006 (see crop calendar, Fig. 1). Due to heavy rain and very wet soil conditions during late spring, cultivation was not completed until 14 December 2006. At this time, the plots were prepared for sowing using power harrows and 'Dutch' harrows. Basal fertiliser (95 kg N/ha as urea; 31 kg P/ha and 34 kg S/ha as single superphosphate) was applied by hand to the *CP* plots and incorporated into the soil with chain harrows. On 15 December 2006, turnip seed (v. Barkant) was sown at a rate of c. 3 kg/ha using a Duncan vee-ring roller drill. Fertiliser N was not applied to the *LP* plots.

From 74 to 78 days after sowing (DAS; 28 February – 3 March 2007), the turnip crop on the *CP* treatment plots was strip grazed (c. 640 m^2/day) by 85 lactating dairy cows for two hours each day. The area allocated per day was based on offering a diet of c. 4 kg turnip DM/cow/day. For the entire duration of the trial, the *LP* treatment plots were grazed as part of the farm's normal grazing rotation.

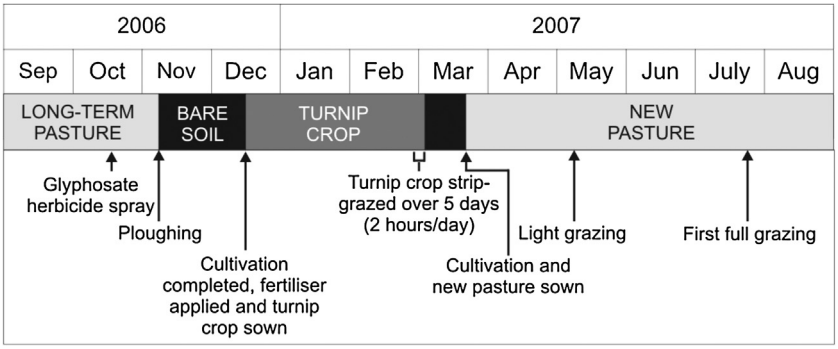

Fig. 1. Crop calendar for the *CP* treatment plots.