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Response of pastures to fertiliser nitrogen on two peat soils in the Waikato region

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Abstract

Fertiliser nitrogen (N) response trials were conducted on Waikato dairy pastures on two contrasting peat soils: a well-developed Kaipaki peat loam and a less-developed Rukuhia peat. On the well-developed site the most efficient N fertiliser rate in spring was 25 kg N/ha with a response of 22 DM/kg N applied. However, in autumn the most efficient rates of N fertiliser were 75 and 100 kg N/ha, with an average response rate of 11 kg DM/kg N. At the less-developed site, the most efficient rates in the spring were 25 to 75 kg N/ha with an average response of 18 DM/kg N applied. In autumn, the maximum response rate of 21 kg DM/kg N was reached through application of 50 and 75 kg N/ha. Results indicate that greater yields are expected from larger applications of N fertiliser on less-developed peat. However, the environmental consequences of increased N fertiliser applications have not yet been assessed.

Keywords: nitrogen fertiliser, pasture production, peat

Introduction

There are around 94 000 ha of peat (organic) soils in the Waikato with 80% of the area developed for agriculture (O'Connor *et al*. 2001). The properties of peat soils (e.g. carbon content, pH, and water holding capacity) change with development stage from raw to consolidated forms due to drainage and cultivation; developed peat has a higher bulk density, contains less organic matter and more mineral material (Holden *et al*. 2006), O'Connor *et al*. (2001) used the development state of organic soils to develop guidelines for fertiliser applications of phosphate, potassium and sulphur. However, there have been few studies in New Zealand on the response of pastures on peat soils to N fertiliser, and in particular how the stage of development might affect response (van der Elst 1980; Baars *et al*. 1989). Previous research has found that total soil N (% TN) values in mineral soils explain some of the variation in pasture response to N fertiliser (Shepherd *et al*. 2015), but it is unclear if this relationship holds for peat soils. Spring and autumn field studies on two peat soils of differing development status were commenced in August 2015. The objective was to determine which rates of N fertiliser produced the most efficient pasture response on peat soils.

Methods

Trial location

The two experimental sites in the Waikato region, north of Hamilton, were selected to represent contrasting peat soils used for dairy farming. The well-developed (WD) site was on a Kaipaki peat in an area that was developed for farming in the 1890s. The soil had a high anion storage capacity (ASC) and Olsen P status (Table 1). The less-developed (LD) site was on a Rukuhia peat, in an area developed for farming in the 1970s. It had a low ASC and a moderate P status (Table 1). Both sites were on well established, intensively grazed ryegrass/white clover pastures with low bulk density and high total carbon, compared with mineral soils. Before the start of the trial, soil measurements were taken to characterise the sites (Table 1).

Trial design and management

The experimental design at both sites and seasons consisted of: 5 treatments x 5 replicates arranged in a randomised block design. The treatments were: 0, 25, 50, 75 and 100 kg N/ha, applied as granular urea to 1.5 x 4 m plots. A single urea application was followed by 3 pasture harvests. The spring and autumn trials were in separate nearby areas.

Basal fertiliser was applied to both spring and autumn

Table 1 Soil properties of the 2 sites (0-15 cm depth). Samples were analysed for pH, Olsen phosphorus (P), potassium (K), sulphur (S), anion storage capacity (ASC), total nitrogen (TN), total carbon (TC) and bulk density (BD).

Site	pH	P	K	$S(SO_4)$	ASC	TN	TC	C:N	BD
		(μg/ml)	(QT)	(ppm)		(%)		ratio	g/cm^3
LD	5.4	24	5	6	19	1.67	37.1	22	0.37
WD	5.7	63	2	25	96	1.11	20.9	19	0.51

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trial sites before urea application to ensure that there were no nutrient deficiencies limiting pasture growth. Additional applications of potassium and sulphur fertiliser were applied during the trial to compensate for nutrient removal in pasture harvests. Pasture was cut to a 5 cm stubble with a motor mower, and all clippings were weighed; a subsample was taken for dry matter (% DM) determination. The clippings were removed from the site.

Statistical analysis

Analysis of variance (ANOVA) (GENSTAT v 17.1) was used to compare means of treatments.

Results and Discussion

Spring application pasture DM response to N fertiliser

In the spring, the average growth period was 21 days. The combined base DM harvest (nil fertiliser N applied) on the WD site was 3707 kg DM/ha for three harvests. Three base DM harvests from the LD site yielded 1469 kg DM/ha, or 40% of that of the WD soil, indicating a difference in the potential production between sites (Table 2). This underlying difference could not be removed completely by the addition of fertiliser N.

There was a significant increase ($P<0.005$) in pasture harvested from the WD site after the 25 kg N/ha application, but higher rates of fertiliser N did not result in significant increases in pasture growth. At the second harvest, only the two higher N rates (75 and 100 kg N) had significantly more growth than the control. By the third harvest, the effects of N fertiliser on pasture growth had disappeared (Table 2).

The first and second harvests from the LD site showed a near-linear response to increasing N fertiliser (Figure 1), with the effects of one application lasting for at least 45 days. By the third harvest the effects of fertiliser N were nil or negative.

Autumn application pasture DM response to N fertiliser

The average growth period during the autumn trial was 52 days. Base pasture growth during the late autumn to winter were low at both sites, with the lowest growth rates observed during the first measurement period. March and April were both dry months and it took time for pastures to recover from drought. The cumulative base DM harvest at the WD site for three harvests was 2400 kg DM/ha (Table 3). The base harvest at the LD site over three harvests was 832 kg DM/ha, or 35% of that at the WD site (Table 3).

At the WD site there was a significant ($P<0.05$) increase in DM production after applying 25 and 50 kg N/ha for the first harvest. Applications of 75 and 100 kg N/ha resulted in increased ($P<0.05$) DM yields for all three harvests.

At the LD site there was a significant increase ($P<0.05$) in DM production over the entire trial period where rates of 50, 75 and 100 kg N/ha were applied. Application of 25 kg N/ha fertiliser resulted in increased growth only at the first harvest (Table 3).

N fertiliser efficiency

In the spring trial on the WD site for the application rate of 25 kg N/ha an additional 22 kg DM/kg N was grown. Pasture responses to fertiliser N decreased with increasing rates of N applied above 25 kg N/ha (Figure 1). These results are similar to trial findings on mineral soils showing N response decreasing markedly above fertiliser application rates of 50 kg N/ha. (Ball

Table 2 Average harvested dry matter (kg DM/ha) from spring applications of nitrogen (N) fertiliser. Cumulative rainfall during the growth periods is also presented. The LSD is the least significant difference in harvested DM between treatments ($P<0.05$).

	Fertiliser treatment (kg N/ha)						
Site, harvest dates and number of days (d)	0	25	50	75	100	$LSD_{5\%}$	Rain (mm)
WD							
30/9 (21 d)	1068	1473	1612	1686	1738	168	75
21/10 (21 d)	1573	1723	1737	1843	1936	209	42
Total harvest 1 and 2	2641	3196	3349	3529	3674	319	117
19/11 (29 d)	1066	1068	872	790	898	186	58
LD							
14/10 (23 d)	674	970	1295	1571	1626	195	60
5/11 (22 d)	324	498	617	760	917	71	42
Total harvest 1 and 2	998	1468	1912	2331	2543	243	102
30/11 (25 d)	471	431	375	361	365	95	100

& Field 1982; Shepherd *et al.* 2015). In spring on the LD site, an additional 18 kg DM/kg N was grown where the application rate of 25 kg N/ha was used. Pasture responses to fertiliser N remained relatively high at the rates of N applied above 25 kg N/ha (Figure 1). This response would suggest a substantial N limitation at this site.

In the autumn trial on the WD site for the application rate of 25 kg N/ha an additional 2.7 kg DM/kg N was grown. Pasture responses to fertiliser N increased with increasing rates of N applied above 25 kg N/ha. Overall, response to N fertiliser was greater at the LD site, with an response of 21 kg DM/kg N measured for the 50 and 75 kg N treatments over three harvests.

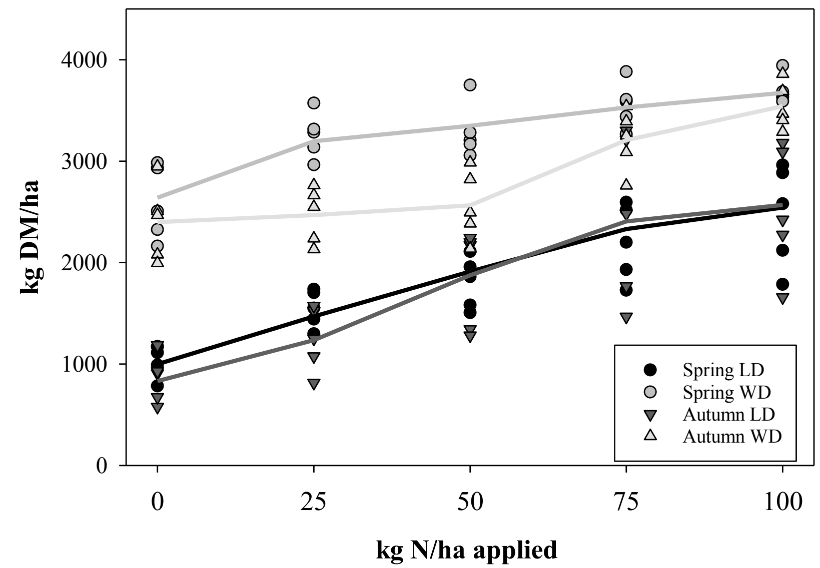

Figure 1 Effect of nitrogen (N) fertiliser on pasture dry matter (DM) accumulation for two sites: well developed (WD) and less developed (LD) for a single application of fertiliser in spring or autumn. The spring application is the total DM accumulation for two harvests and the autumn application is the total DM accumulation for three harvests.

These results highlight a difference in fertiliser N response rates between these two sites on peat soils. As there was only one example of each development stage, it is not possible to conclusively say that the development status is the only reason for differences between the sites. Small differences in weather between the sites, pasture age and composition, and paddock history would all have had an effect on pasture growth measured. However, previous research (van der Elst 1980; O'Connor *et al.* 2001; Simmonds *et al.* 2015) support the hypothesis that the development status of peat soils affects their properties and the cycling of nutrients.

Soil TN concentration has been shown to be a good predictor for base pasture growth (no N fertiliser) and N fertiliser response in mineral soils (Shepherd *et al.* 2015) with N response decreasing with increasing TN. This relationship does not appear to hold for these organic soils, and in fact appears to be the opposite. The C:N ratio of the mineral soils used by Shepherd *et al.* (2015) were around 9, while the soils used here averaged 21 (Table 1) suggesting a slower mineralisation and

Table 3 Pasture yields (kg DM/ha) in response to different rates of autumn-applied N fertiliser. Cumulative rainfall during the periods is also provided. The LSD is the least significant difference in harvested DM between treatments ($P<0.05$).

	Fertiliser treatment (kg N/ha)						
Site, harvest dates and number of days (d)	0	25	50	75	100	$LSD_{5\%}$	Rain (mm)
WD							
10/5 (35d)	246	330	349	394	416	66	30
4/7 (55d)	940	1001	1106	1356	1567	270	298
29/8 (57d)	1214	1137	1110	1457	1559	193	244
Total harvest 1, 2 and 3	2400	2468	2565	3207	3542	448	572
LD							
9/5 (36d)	147	247	425	486	523	89	32
11/7 (63d)	244	398	702	1022	1076	237	318
14/9 (66d)	441	590	748	899	970	182	253
Total harvest 1, 2 and 3	832	1235	1875	2407	2569	458	603

release of N from the organic soils. The C:N ratio was slightly higher in LD, and the low base growth and high response to N fertiliser is evidence of N limitation. However, it does not appear that the slight differences in C:N could fully explain the differences in N response between the two sites.

Conclusions

These findings indicate that farmers on less developed peat have lower base growth but can expect greater yield benefits from larger applications of N fertiliser. Farms with WD soils, similar to those here, can expect efficient pasture yield increases in the spring from rates of 25 kg N/ha. It should be noted that the environmental consequences of increased applications of N fertiliser have not been assessed in this study.

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Soil inorganic nitrogen in spatially distinct areas within a commercial dairy farm in Canterbury, New Zealand

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Abstract

For precision nitrogen (N) fertilisation of grazed dairy paddocks, soil N distribution needs to be quantified. It is expected that farm infrastructure will affect inorganic-N distribution due to its influence on cow grazing behaviour. Surface soil from four spatially distinct areas (main gate, water troughs, non-irrigated and the remaining pasture) was analysed for soil ammonium-N (NH_4^+-N) and nitrate-N (NO_3^--N) from three paddocks (180 soil samples) on an irrigated commercial dairy farm in Canterbury, New Zealand. Variation between paddocks was higher for NO_3^- (P<0.001) than for NH_4^+ (P=0.52). Differences between spatially distinct areas were detected for NH_4^+ (P<0.001) but not for NO_3^- (P=0.37), though there was variation in NO_3^- with distance from the gates and troughs. This study demonstrates methods for classifying spatially distinct areas of grazed pasture to quantify their influence on inorganic-N distribution. Further research is required to better understand variability.

Keywords: nitrogen, spatial nitrogen distribution, distinct areas

Introduction

Use of centre pivot irrigation and repetitive mineral N fertiliser applications on grazed paddocks have increased to support the intensification of dairy production in New Zealand (Foote *et al.* 2015). Precision fertilisation can exclude high N areas, reduce fertiliser amounts without sacrificing yields (Diacono *et al.* 2013), and reduce NO_3^- leaching (Foote *et al.* 2015). Strategies for precision fertilisation within cattle-grazed paddocks differ from cropped areas due to heterogeneous grazing behaviours of cattle (Sanderson *et al.* 2010).

Cattle grazing patterns are spatially uneven, as cows can spend ~50% of their time within 13% of the paddock (Hunt *et al.* 2007). Repeated grazing results in spatially random excreta distribution in the paddock (White *et al.* 2001), and rates of soil N accumulation are affected by stocking rate, grazing intensity and rotation (White *et al.* 2001; Hunt *et al.* 2007; Putfarken *et al.* 2008). However, cattle are known to frequent areas around farm infrastructure like water troughs, fences and shelter belts (White *et al.* 2001; Hunt *et al.* 2007; Putfarken *et al.* 2008), which may result in higher soil N in these areas. Identifying spatially distinct areas based on the orientation of farm infrastructures (i.e. water troughs, fences, shelter belts), may provide a way to characterise spatial N distribution around a grazed dairy pasture.

A strategy is needed to quantify the spatial distribution of N within intensively grazed pastures and to related farm infrastructure to develop precision fertiliser schemes. The objective of this paper was to test a methodology to delineate farm infrastructure related spatially distinct areas around a typical New Zealand dairy farm, and to quantify spatial distribution of NH_4^+-N and NO_3^--N.

Materials and methods

Experimental site

The site was an irrigated commercial dairy farm in Rolleston (43.56750°S, 172.32334°E), Canterbury, New Zealand. The soil was a stoneless, free-draining Lismore silt loam (Pallic Firm Brown Soil, Hewitt 2010). The farm stocking density was 3.6 cows/ha for a herd of 630 Friesians. Cows were rotationally grazed on perennial ryegrass (*Lolium perenne*)/ white clover (*Trifolium repens*) pastures. The grazing cycle varied from 26 to 40 days (26, 35 and 40 days for March, April and May, respectively, during 2017) with supplementary feed provided as required. Total broadcast N-fertiliser was 190 kg N/ha from September 2016 to April 2017, including 50 kg/ha of 'SustaiN 25K' (at 23% N) fertiliser after each grazing. Pasture irrigation averaged 3 mm/ha/day from October 2016 to March 2017.

Soil Sampling

Three paddocks (coded 17, 19 and 33), each 5.1-5.5 ha and located in the centre pivot irrigation area, were selected for soil sampling. Each paddock included a main gate, a water trough, and low producing (non-irrigated) area, that were spatially distinct.

Different sampling regimes were used for each distinct area of the paddock to obtain spatially

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