Use of optical sensor technology to reduce nitrogen fertiliser inputs on dairy farms

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ABSTRACT

Nitrogen (N) is one of the most widely applied nutrients to dairy pasture in Australia and New Zealand, with an average annual application of around 230 kg N/ha/year. Dairy cattle generally excrete 75 to 80% of the N they consume, with the N loading within a urine patch potentially reaching 1000 kg N/ha. The annual mean urine patch coverage is estimated to be approximately 20-25% of the area of an intensively managed dairy pasture. Urine deposition zones are often visible due to the more intense greenness and increased biomass of these zones. The grass colour and biomass differential provides an opportunity for optical sensors to detect these N rich zones. Smart-N technology, developed by Mackenzie Research Group in New Zealand, uses optical sensors (WeedSeeker®) to detect N rich zones in order to avoid application of liquid N to these areas. This study explored the use of the Smart-N technology on four commercial dairy farms in Tasmania. On each farm six plots of between 0.25 and 1.0 ha each were selected, giving three replicates of each treatment. Treatments included liquid urea-ammonium nitrate (UAN) fertilizer applied using the Smart-N technology (SN) and UAN applied without the Smart-N technology (control). Repeated applications (between 2 and 6) occurred at each site. Averaged across all sites and applications, the mean N application rate for the control treatment was 21.2 ± 0.6 kg N/ha which was significantly ($P < 0.05$) higher than the SN treatment, 12.9 ± 0.8 kg N/ha. Averaged across all sites the mean average pasture growth rate was 33.2 ± 2.4 kg DM/ha/day for the control treatment and 34.4 ± 2.5 kg DM/ha/day for the SN treatment, which did not significantly ($P > 0.05$) differ from each other. This study has indicated that significant N fertiliser savings are possible through the adoption of the Smart-N technology without compromising pasture growth rate, although further work is required to validate these findings. For the average Tasmanian farm, it is estimated that the Smart-N technology has the potential to save approximately 8 t of N per annum. This equates to a potential greenhouse gas abatement of approximately 50 t CO_2-e. Assuming that the adoption of the Smart-N technology satisfied the requirements as a Carbon Farming Initiative method and at a carbon price of $23 per t CO_2-e, the potential CFI income is $1,150.

Keywords: Nitrogen fertiliser, optical sensors, nitrous oxide, dairy pastures.

INTRODUCTION

Approximately 10% of all greenhouse gas emissions from Tasmanian pasture-based dairy farms are nitrous oxide (N_2O) emissions associated with urine and dung deposition (Christie *et al*. 2011). Fertilising pastures leads to even greater levels of N being present which increases the risk of N loss as N_2O (Lou *et al.* 2007), a potent greenhouse gas. Smart-N technology comprises an optical sensor technology that makes possible the measurement, in real time, of pasture's N levels. The technology adjusts the application rate of liquid N fertiliser to pasture to avoid N rich zones. Research in New Zealand has found up to 23% of the area of an intensively grazed dairy pasture is covered by urine deposition on an annual basis (Moir *et al*. 2011). The adoption of Smart-N technology has the potential to reduce N fertiliser usage by avoiding applications of N fertiliser to zones already high in available N. Potentially this would result in a lowering of direct and indirect N_2O emissions, and most likely have no adverse effect on pasture production. The Smart-N technology works by detecting differences in normalised difference vegetation index (NDVI) between high N (urine patches) and low N zones. When the NDVI reading is above the calibrated NDVI it switches off the corresponding spray nozzles to prevent the application of fertiliser N to these N rich zones.

MATERIALS AND METHODS

Four dairy farms were selected to trial the Smart-N technology in Tasmania (Table 1). On each farm N was applied with (SN) or without (control) the Smart-N technology. Each site consisted of an irrigated perennial ryegrass pasture. Six plots of between 0.25 and 1 ha were selected, giving 3 replicates of each treatment on each farm. To date there have been a total of 3, 6, 2 and 3 applications at the Ouse, Railton, Ringarooma and Yolla sites, respectively. Dates of application are shown in Table 1.

A spray unit was set up with a 6 m boom and 12 WeedSeeker® sensors spaced 0.5 m apart. The boom was adjusted to a height of 0.75 m from the ground. The spraying was done at a constant speed of approximately 16 km/hr. The spray nozzles were set back 0.25 m from the sensor. To calibrate the sensors, at each site and for each application, a hand-held GreenSeeker® (an active

Table 1: Sites selected for testing the Smart-N technology in Tasmania

Site	Location	Application Dates
Ouse	Southern Tasmania	03/06/13 (1), 10/01/14 (2), 17/02/14 (3),
Railton	North West Tasmania	13/03/13 (1), 04/04/13 (2), 19/06/13 (3), 14/01/14 (4), 03/02/14 (5), 24/03/14 (6),
Ringarooma	North East Tasmania	11/02/14 (1), 18/03/14 (2),
Yolla	North West Tasmania	10/12/13 (1), 30/02/14 (2), 25/03/14 (3),

optical sensor that provides an NDVI value based on the amount of red and near infa-red light emitted and reflected back to the sensor) was used to determine the NDVI reading of the background pasture and the urine patches in the paddock. The boom was then calibrated using a material with a known NDVI reading placed beneath the sensors and the calibration setting was adjusted to a reading close to the lowest detected urine patch NDVI reading.

The N source for the trial was urea ammonium nitrogen (UAN), containing 42.5% nitrogen w/v. The target application rate for the control treatment was 20 kg N/ha at each application for all sites except Ouse where the target rate was 30 kg N/ha. The N was applied at a volume rate of 100 L/ha. Typically N was applied shortly after grazing (this depended on the length of the grazing round but was typically about 10-15 days after grazing), with at least 10 days between N application and the next grazing event. For each N application, the quantity of N applied was determined with a flow meter linked to a Trimble® CFX 750 ™ GPS control unit using RangePoint™ RTX™ correction. The application speed was also determined using the Trimble® GPS unit. Pasture growth was measured at each site using a calibrated rising plate meter. Urine patches were included in the measurement of pasture growth. A minimum of 100 readings were collected for each treatment plot (6 treatment plots at each site) following a 'W' transect. An assessment occurred immediately after applying N to the pasture (post N) and again just prior to the pasture being grazed (pre grazing).

For each site the pasture growth rate and N application data was pooled and the study was analysed as a two way factorial ANOVA (treatment x site with replication) using IBM SPSS Statistics for Windows, Version 22.0.0 (Armonk, NY: IBM Corp).

RESULTS

Averaged across all sites and applications, the mean N application rate for the control treatment was 21.2 ± 0.6 kg N/ha which was higher ($P<0.05$) than the SN treatment, 12.9 ± 0.8 kg N/ha (Figure 1). Averaged across all sites the mean pasture growth rate was 33.2 ± 2.4 kg DM/ha.day for the control treatment and 34.4 ± 2.5 kg DM/ha.day for the SN treatment, which were not significantly different ($P>0.05$) to each other (Figure 1).

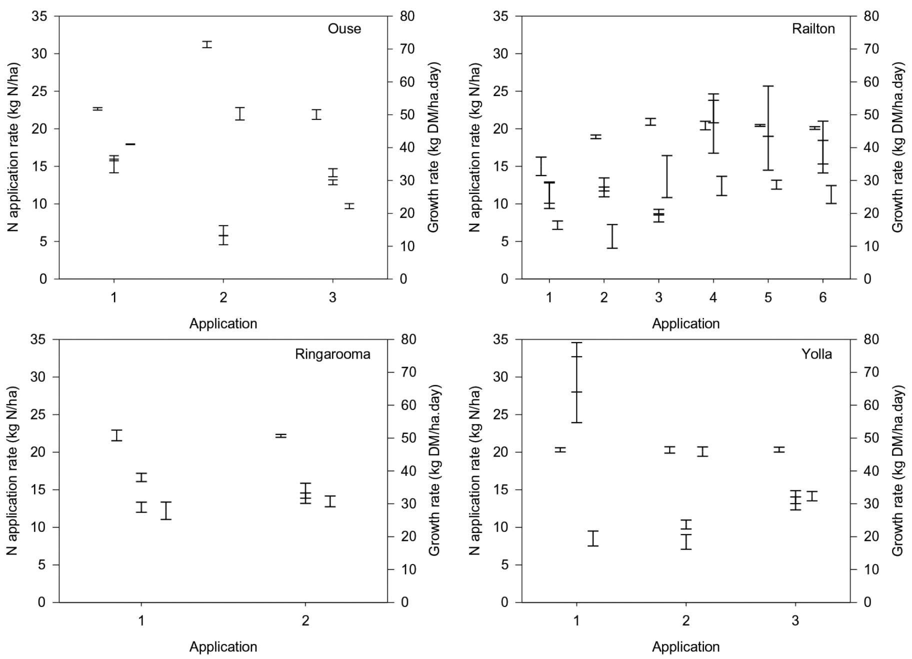

Figure 1: The mean N application rate (kg N/ha) with Smart-N (SN, open bars) and without SN (control, shaded bars) and the mean measured growth rate (kg DM/ha.day) for the control (open triangles) and SN (shaded triangles) treatments for each of the four sites for each application. Standard error of means shown as error bars.

DISCUSSION AND CONCLUSION

Correct calibration of the Smart-N boom is essential for optimising the application of N. The results from these trials indicate that when the calibrated NDVI reading is set close to the lowest NDVI reading from the urine patches, detection and avoidance of the patches is achieved without compromising pasture DM yields compared with blanket applications of N. Urine patches in intensively grazed dairy pastures can make up approximately 25% of the paddock on an annual basis (Moir *et al*. 2011) which is similar to the reduction in N being achieved with the Smart-N technology. One of the challenges however, is that the average NDVI readings of both the background and urine patches can vary within and between paddocks on some sites, necessitating the adjustment of the calibration setting during application. This is particularly the case where there are large differences in topography or soil types within and between paddocks. Using the Smart-N technology with wet pastures can also be a problem due to the moisture affecting the NDVI readings (Lamb, pers. Comm.). Further testing is required over extended periods of application and seasons to validate these results and determine the long term impact on soil fertility. Development of an automated calibration system that adjusts in real time would be useful for commercial application of this technology for highly variable sites.

According to 2012/13 Tasmanian Dairy Business of the Year figures the average Tasmanian dairy farm uses 26.4 t of N per farm per annum. The results to date have indicated that Smart-N technology has the potential to reduce the N fertiliser application rate by 30 to 40%. Assuming a 30% reduction, with no negative influence on pasture productivity, this would equate to an average saving of approximately 8t of N per annum. This has an approximate value of $10,000. In addition, the N_2O emissions associated with 1t of N fertiliser is 4.2t CO_2-e (DCCEE, 2011), which is made up of both the direct (direct N_2O emission associated with N fertiliser application) and the indirect (N_2O emissions associated with leaching, runoff and volatilisation) emissions (DCCEE, 2011). There are also the embedded emissions associated with production of the N fertiliser product and its transportation. Although this can vary, reported embedded emissions factors for UAN range between 2.0 (Kongshaug, 1998) and 3.7 t CO_2-e per t N (Kuesters and Jenssen, 1998). For the average Tasmanian farm, where it is estimated that the Smart-N technology has the potential to save 8 t of N per annum, then the potential abatement is approximately 50 t CO_2-e. Assuming that the adoption of the Smart-N technology satisfied the requirements as a Carbon Farming Initiative method and with a carbon price of $23 per t CO_2-e, the potential CFI income is $1,150.

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