Potential for DMPP to increase pasture yields following repeated application

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Abstract
Up to 40% of fertiliser nitrogen (N) can be lost in subtropical pasture, and while some enhanced efficiency fertilisers such as 3,4-Dimethylpyrazole phosphate (DMPP) coated urea have been tested, previous findings have been mixed. A longitudinal experiment was conducted on ryegrass/kikuyu pastures on a heavy clay soil at Casino, NSW to determine if and under what conditions DMPP may be effective in increasing yields and agronomic efficiency of N fertiliser at both reduced and comparable application rates to conventional urea. An average increase in ryegrass yields of 15% was observed in the first two years, and over 70% in year 3 compared to the equivalent N rate as urea only.

Keywords
Dairy, ryegrass, enhanced efficiency fertilisers, Nitrogen-use efficiency.

Introduction
Previous research has highlighted the high potential for nitrogen (N) losses from northern dairy soils, and the difficulties faced by farmers in deriving practical, on-farm options for the management of this very leaky element. Up to 40% of N applied as fertiliser is known to be lost in subtropical pastures (Rowlings et al., 2016), and while mitigation options such as enhanced efficiency fertilisers have been tested, previous findings have been mixed (Dougherty et al., 2016, Koci and Nelson., 2016, Rowlings et al., 2016). As such, this study aimed to assess the agronomic, economic and the nitrogen use efficiency (NUE) benefits of using DMPP under both irrigated and dryland conditions in the Northern dairy region.

Methods
A long-term trial was conducted at Casino, North Coast NSW to assess DMPP on pasture biomass. The field site (28.8 °E, 152.9 °S) was a commercial dairy farm, which had been intensively managed for more than thirty years, stocking an average of six head of cattle per hectare and currently milking around 300 cows. The farm has year-round irrigation and annual N fertiliser inputs reach around 340 kg N ha^{-1}. Mean annual rainfall at the site is 1037 mm, with summer (December – February) dominant rainfall. The soil is a black Vertosol with a clay content of 44% Following the usual practice in the region, the summer dominant kikuyu (*Pennisetum clandestinum*) pasture is mulched in autumn and oversown with annual ryegrass (*Lolium perenne*).

Treatments were applied to the same plots over three years to account for any long-term changes in mineralisation and immobilisation associated with using DMPP (as seen in Friedl *et al.,* 2017) and were conducted on grazed paddock plots to replicate "real" farm conditions. In year 1 of the trial, DMPP was compared at a 22% reduction (1.5 kg N ha^{-1} day^{-1}) against standard farmer practice (2 kg N ha^{-1} day^{-1}) urea rate. In years 2 and 3, DMPP was compared against an equivalent urea rate, 25% reduced from the "optimum" N rate to ensure any reduction in N losses was determinable in the biomass response. A second, optimal urea rate was also used to quantify the optimal urea rate and check if the pasture was responsive to additional N. Fertiliser was applied following grazing at the 3-leaf stage (approximately every 3 weeks), equating to 14 fertilisations per year. The exact treatments were; **Low-Urea**: 26 kg N ha^{-1} per application –364 kg N ha^{-1} yr^{-1}, **High-Urea**: 35 kg N ha^{-1} per application – 490 kg N ha^{-1} yr^{-1}, **Low-DMPP**: 26 kg N ha^{-1} per application – 364 kg N ha^{-1} yr^{-1} and **Zero** N.

The agronomic efficiency of N (AE_N) was calculated as the marginal biomass response to increasing N fertiliser rate. Harvest return was estimated by multiplying produced biomass by an assumed dry matter replacement value of \$2.50 kg^{-1}. Profit was the difference between cost of fertiliser inputs and harvest return assuming a premium of 15% and 30% for DMPP.

Results

The trial demonstrated the effectiveness of using the nitrification inhibitor DMPP to increase yields and agronomic efficiency of N fertiliser (AE_N) at both reduced and comparable application rates to urea. Direct comparison of DMPP and urea at the reduced rate showed a clear production advantage of the inhibitor, with an average increase of 15% per grazing of ryegrass in 2017 and 2018, or an additional 71 kg DM ha^{-1} grazing^{-1}. This effect was further enhanced in the third year of application (2018) when 156 kg ha^{-1} of N applied over the 14-week ryegrass season in the LOW-DMPP treatment produced an additional 856 kg DM ha^{-1}, an increase of over 70% compared to the equivalent N rate as urea only.

This variation in the effectiveness of the inhibitor to increase yields, and the variation between grazing cycles in DM production to N fertiliser rate in general can largely be explained by the amount of precipitation (rainfall + irrigation) received over the interval. Figure 1 shows the influence of grazing interval and precipitation on pasture response to N, also accounting for temperature and grazing interval length. The strongest responses to applied urea N occurred during wet (>120 mm) periods, particularly in kikuyu when adequate soil moisture allowed applied N to be fully utilised by the plants. DMPP also had the strongest effect during these wet periods at the highest N rates, though potentially limited the conversion of NH_4^+ mineralised from the soil organic matter to the more plant available NO_3^- at the lower application rates.

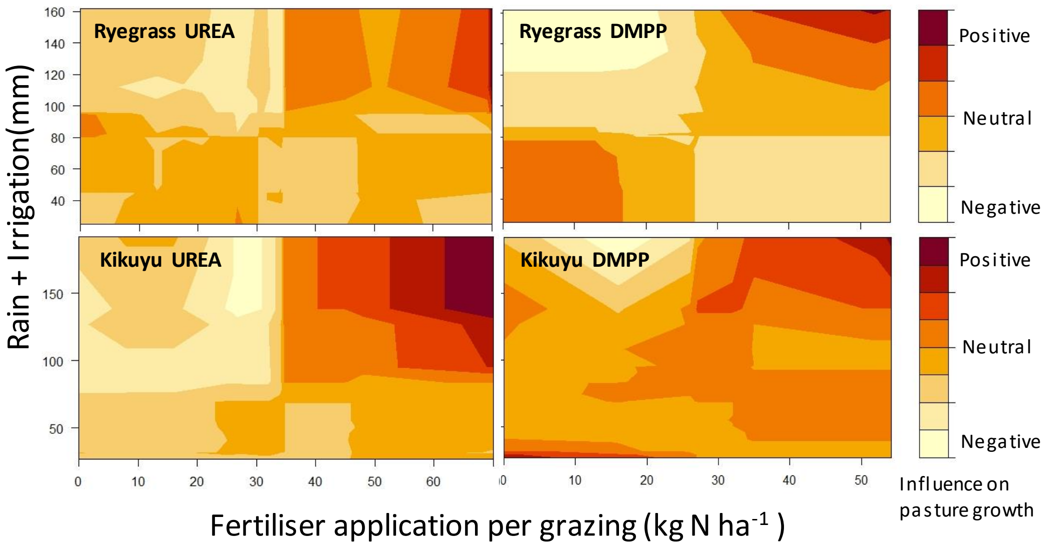

Figure 1. Influence of rainfall and irrigation on biomass productivity response to fertiliser N application rate for both standard UREA and DMPP coated urea in winter/spring ryegrass and summer kikuyu at Casino as determined by a Generalised Additive Model (GAM).

Overall, in ryegrass, DMPP had the greatest effectiveness at the application rate of 20-30 kg N ha^{-1} application^{-1}, with limited benefit observed at the higher rates where the retention of N in the soil-plant system has less impact on yield (Figure 2). The inhibitor also increased DM yield to a lesser extent in the kikuyu, though the response was less consistent and did not vary with N rate. This is most likely due to the importance non-fertiliser derived N from mineralisation has during this season, with DMPP having been shown to also inhibit N losses of organic matter derived N (Friedl et al., 2017).

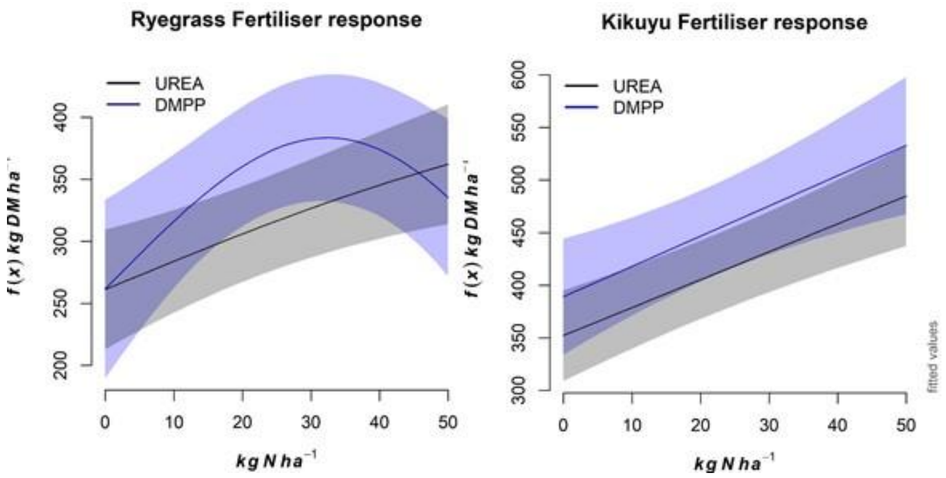

Figure 2. Pasture biomass response (kg DM ha^{-1}) for standard UREA and DMPP coated urea to increasing N fertiliser application rates (kg N ha^{-1} grazing^{-1}) in winter/spring ryegrass and summer kikuyu at Casino modelled using GAM. Shaded areas represent the 95% model confidence interval.

Even at the higher price premium for the DMPP fertiliser, the increase in harvest return from additional pasture growth far outweighed the additional cost (Figure 3). However, due to the plateauing nature of pasture growth to N inputs as other factors such as moisture, sunlight, temperature, other nutrients, grazing interval and genetic potential become growth limiting factors, the additional expense of the product meant profit and marginal profit declined rapidly once application rate surpassed the optimal. The additional price of the inhibitor product increased the breakeven point for increasing AE_N from 5 kg DM kg^{-1} N to 6 and 7 for the 15% and 30% price premiums respectively, which AE_N fell below at

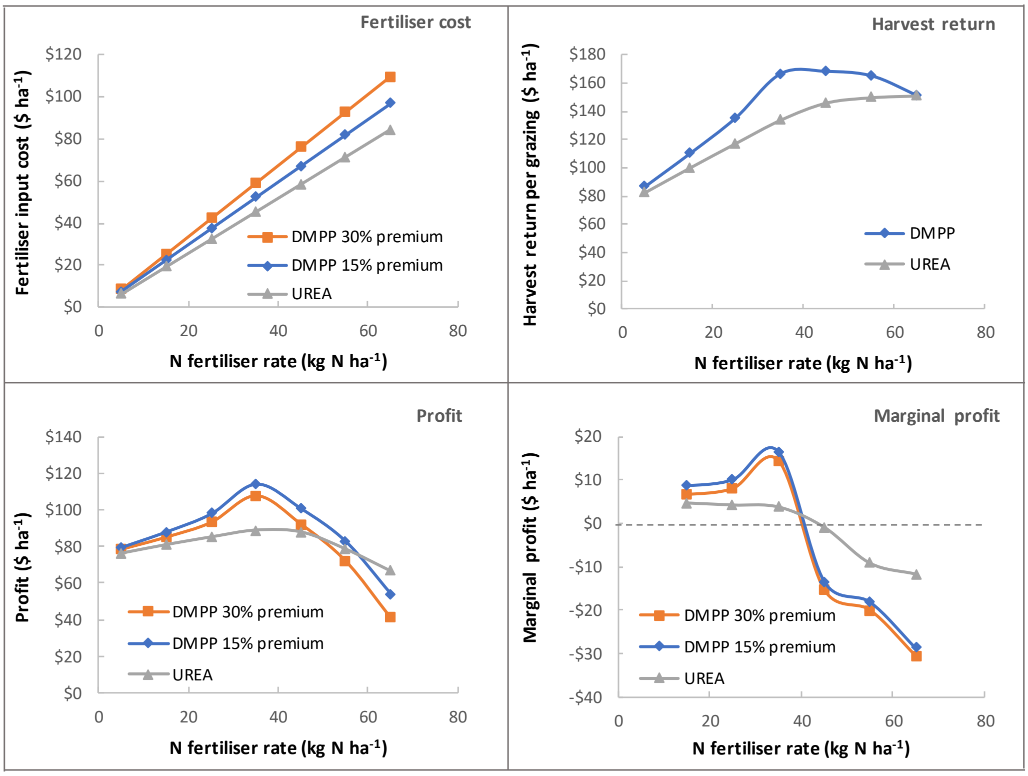

Figure 3. Economic indicators of applying DMPP versus Urea fertiliser in annual ryegrass at Casino. DMPP 15% and 30% premium represents a price of $1.50 and $1.70/ kg N respectively compared to $1.30 for urea. Harvest return was calculated assuming a fodder dry matter value of $2.50 kg^{-1}.

37 kg N ha^{-1}. Subsequently, increasing the N rate from 35 to 45 kg N ha^{-1} (1.7 to 2.1 kg N day^{-1}), decreased the marginal profit from +$14.4 kg of additional N to -$16.9. As such it is recommended as a rule of thumb that DMPP application always be applied at a 15-30% reduction in N rate, effectively maintaining fertiliser expenditure but increasing yields and reducing environmental losses.

Previous studies have shown a mixed response to the nitrification inhibitor DMPP (ENTEC™) in subtropical dairy pastures, ranging from no effect on biomass yield and N losses at Camden (Dougherty *et al*., 2016), to decreasing denitrification losses at Casino by 70% (Friedl et al., 2017), and increasing yields by 30% at Gympie (Rowlings et al., 2016). There are a number of possible reasons for these discrepancies, including climatic conditions, length of study and inappropriate experimental design (i.e. not applying at a suboptimal rate (Rose et al., 2018), although it's likely that soil type is a also major contributing factor. As a substantial proportion of the effectiveness of DMPP appears to be the inhibition of mineralised N from the soil organic matter, soils with higher carbon contents and subsequently higher mineralizable N supply should benefit the most (Friedl et al., 2017). However, more research is needed conducting long-term N rate by inhibitor trials across a range of dairy soils to fully evaluate the effectiveness of DMPP as a means to increase farm profitability.

Conclusion

Due to the high potential of N losses in subtropical dairy production systems, profitability from N fertiliser should be focussed on trying to match plant demand within the short-medium term (1-3 grazing cycles) as opposed to broad seasonal rules of thumb. Heavier, higher carbon clay soils immobilise a significant proportion of applied N particularly under high-growth conditions, which is then released (mineralised) under warm and wet conditions when it can be prone to loss. The success of enhanced efficiency fertilisers appears directly tied to this fertiliser N interaction with the organic matter, and have greater potential in the clayeyer soils. As such their use should be used in conjunction with more strategic N management during the different growing seasons, and ensuring adequate soil moisture is available to optimise plant N utilisation.

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