An assessment of the agronomic effectiveness of N-(n-butyl) thiophosphoric triamide (nBTPT) - treated urea on dry matter yields of clover-based pastures, grasses and arable crops

Doug C. EDMEADES, Robert G. McBRIDE

agKnowledge Ltd, PO Box 9174, Hamilton 3240, New Zealand
Corresponding author: doug.edmeades@agknowledge.co.nz

Abstract

Approximately 50% of the world's population depends on nitrogen (N) fertiliser to secure a sustainable food supply. Improving the efficiency of nitrogen fertiliser – the nitrogen use efficiency (NUE) - is a major goal both nationally and internationally, driven by the need to reduce the environmental footprint of farming. One of the technologies developed for this purpose is the addition of the urease inhibitor, N-(n-butyl) thiophosphoric triamide (nBTPT), to urea, to reduce the volatilisation of ammonia from the soil.

In this paper we report the results from field trials, recorded in the national and international literature, comparing the effects of nBTPT treated urea, relative to untreated urea, on plant dry matter (DM) yields (clover-based pasture, grasses and arable crops) from 45 studies summarizing the results on a site × year × crop basis. For the aggregated data (n = 348) the marginal yield results were normally distributed around a mean of about 3% (95% confidence interval 0.9), with a range from -23% to +32%. The results for the various subsets (based on different crop types) of data were very similar. The size of the effect of nBTPT was related to the rate of N application.

Keywords: agrotainÒ, ammonia volatilization, plant responses.

Introduction

Approximately 50% of the world's population depends on nitrogen (N) fertiliser to secure a sustainable food supply (Goklany 2012). Improving the efficiency of nitrogen fertiliser use (Nitrogen Use Efficiency, NUE) is a major goal both internationally (UNEP 2013) and nationally (Ministry for Primary Industries 2013). This is motivated primarily by the need to reduce the environmental footprint when N fertilisers are used.

One approach to this problem has been to add a urease inhibitor to urea - one of the major N fertilisers - to slow the conversion of the urea to ammonium in the soil and thus reduce the potential for ammonia volatilisation and hence improve NUE by either a) increasing plant yield per kg N applied or b) reducing the amount of N required to achieve a given plant yield

One urease inhibitor N-(n-butyl) thiophosphoric triamide (nBTPT) is marketed as agrotain$^{\text{Ò}}$ by Koch Agronomic Services USA and is sold in New Zealand under the trade names SustaiN$^{\text{Ò}}$ (Ballance agriNutrients Ltd) and N Protect$^{\text{Ò}}$ (Ravensdown Co-operative Ltd).

Several authors (Saggar et al. 2013; Silva et al. 2017; Cantarella et al. 2018), have concluded, based on recent reviews of the literature, that nBTPT-treated urea can reduce ammonia emissions (volatilization) by up to 50%, when measure directly in the field. If a reduction in ammonia volatilisation results in an increase in available soil N, then increases in plant yield from nBTPT-treated urea, relative to urea alone, are to be expected. However, such large effects of nBTPT-treated urea, relative to urea alone, are not necessarily captured in terms of their relative effects on plant dry matter (DM) yields (Hendrickson 1992; Edmeades and McBride 2011; Silva et al 2017; Cantarella et al. 2018).

The aim of this paper is to compare the relative effects of nBTPT-treated urea, and urea alone, on plant DM yields, by undertaking a meta-analysis of all the available literature, using a technique based on the cumulative distribution functions.

Material and Methods

A complete description of the methodology, and the interpretation of cumulative distribution functions, used throughout this paper is given elsewhere (Edmeades 2002). Briefly, for any given product the results from field trials are recorded on a site × year × crop type basis. (Note that in this context crop includes clover-based pasture, grasses, and arable crops) and the measured DM yield differences between the control and the nBTPT treatments are calculated as a percentage of the control yield, either positive or negative. Only results from replicated and randomised field trials, with statistical analysis and available in open access publications have been included. The rank and distribution, and hence the cumulative frequency distribution, of the observed product responses are then determined, together with the descriptive statistics of the distributions.

A database available on request consisting of 348 individual records of site × year × crop type measurements was assembled. The crop types were primarily clover-based pastures and grasses (68%) with the balance being an assortment of arable crops, predominantly cereals and corn (32%). The trials were

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Table 1 Summary of the descriptive statistics of the aggregated data and subsets of the data

Crop type	Number of observations	Mean DM yield response (%)	Range of DM yield response (%)	95% confidence interval (%)
All crop types	348	3.1	-23 to +32	0.9
Arable crops	114	2.8	-23 to +26	1.8
Grasses	234	3.2	-18 to +32	1.0
Clover based pastures	153	2.9	-13 to +32	1.1

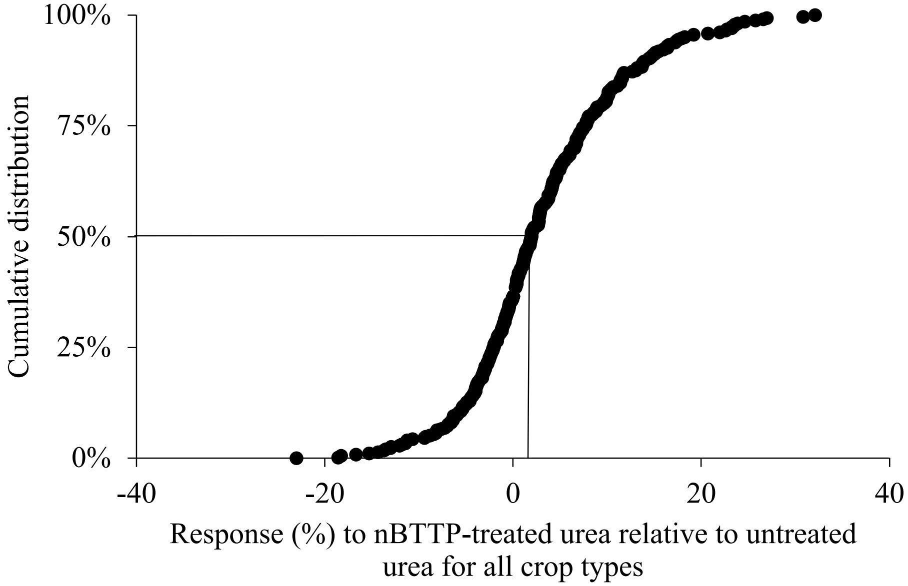

Figure 1 Cumulative frequency distribution of plant dry matter (DM) responses to nBTPT-treated urea, relative to urea (%), for all crop types.

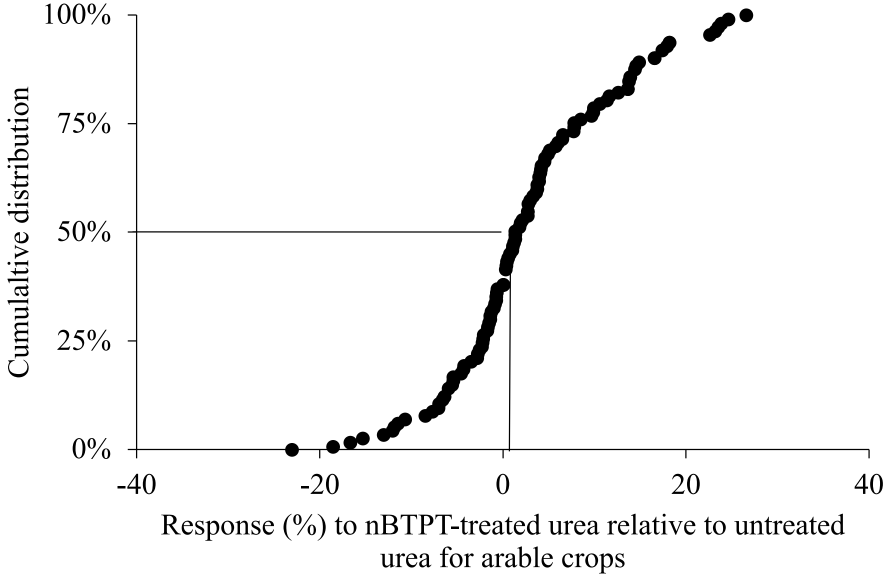

Figure 2 Cumulative frequency distribution of plant dry matter (DM) responses to nBTPT-treated urea, relative to untreated urea (%), for arable crops.

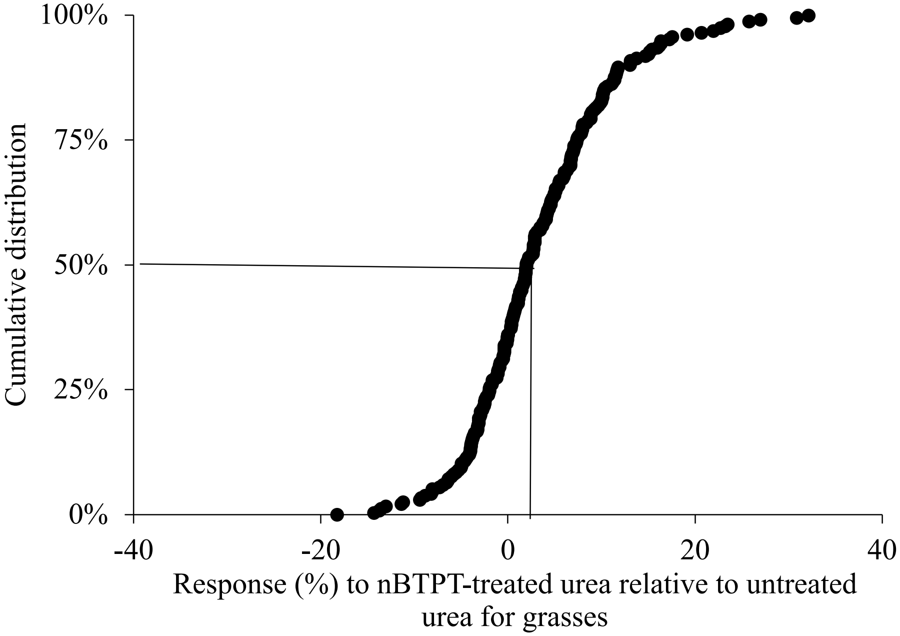

Figure 3 Cumulative frequency distribution of plant dry matter (DM) responses to nBTPT-treated urea, relative to urea (%) for grasses.

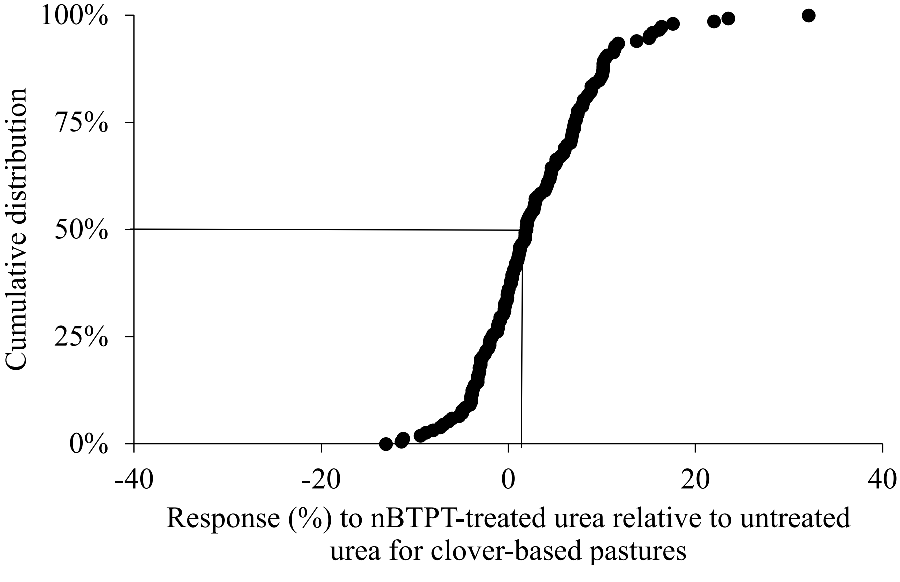

Figure 4 Cumulative frequency distribution of plant dry matter (DM) responses to nBTPT-treated urea, relative to urea (%) for clover-based pastures.

Table 2 Effect of the rate of fertiliser nitrogen (N) application on the plant dry matter (DM) yield responses (%) to nBPTP-treated urea relative to urea alone.

Rate of N fertiliser application (kg/ha)	Number of measurements	Mean DM yield response (%)	Range in DM yield response (%)	95% confidence interval (%)
0-50	104	1.4	-18 to +23	1.4
51-100	126	2.6	-18 to +30	1.6
101-200	53	4.9	-23 to +26	2.6
+200	34	7.5	-13 to +32	3.1

from North America, Europe, Australia, New Zealand, South America, Asia and Africa.

Results

The descriptive statistics of the cumulative distribution functions for the aggregated data, and for subsets of the data based on crop type, are summarised in Table 1.

The results are also shown graphically in Figures 1, 2, 3 and 4 and demonstrate that the distributions are similar and normally distributed.

For this set of data, the mean DM yield responses to nBPTP-treated urea, relative to urea alone, increased with increasing rate of fertiliser N applied (Table 2).

Discussion

The distribution of plant dry-matter (DM) responses to nBTPT-treated urea, relative to untreated urea, for the aggregated data and for the subsets of data based on crop type, are similar and they are all normally distributed around a mean of about 3% with a range between -13% to +32% (Table 1 and Figures 1, 2, 3, 4). Silva et al. (2017) reviewed data from 12 countries and reported that the typical mean DM yield responses to nBPTP were about +5% with a range from -2% to +10%. In their review, Cantarella et al. (2018) reported mean responses of about 6% with a range from -10% to +10% and Hendrickson (1992) reported negative DM yield responses to nBPTP-treated urea on corn in 33% of 78 trials. The frequency of negative responses in the current set of data is, on average across crop types, approximately 35% (Figure 1, 2, 3 and 4). It is unlikely that adding nBPTP to urea has a detrimental effect per se on plant growth and hence there must be other reasons why negative responses occur, and are apparent, especially in large data sets such as in the current study.

The likely explanation for the observed range in negative "responses" is that they reflect the inherent uncontrolled variability – 'the background noise' - that occurs in all field trials (Edmeades 2002). If this is accepted, then logically the range in the "positive" responses will also reflect this variability, and should not necessarily be attributed to real treatment effects. The average response in the current dataset is about +3% (Table 1), which indicates that the normal distribution is moved slightly to the right, suggesting that nBPTP has a small positive effect on plant DM growth, which lies within the limits of error in field trial work (Edmeades 2002). This phenomenon is seen in other large sets of data where the observed effects of products are small in relation to the background variability (Edmeades 2002, Edmeades and McBride 2011)

It is tempting to suggest that the range in the positive DM yield responses (+1% to +30%) are real and that the range is an expression of the many factors which are said to affect the volatilization of ammonia following urea application viz: soil factors (pH, organic matter, temperature, texture and moisture), plant factors (crop type), climatic factors (amount and timing of rainfall events) and the rate of N application (see Silva et al. 2017; Cantarella et al. 2018). Unfortunately, many of these possible soil and climatic factors were not measured or reported for most of the trials in this database and hence the possible factors affecting volatilisation, and thus DM yield responses, cannot be investigated further with this set of data. This is an inherent problem when analysing large datasets contributed by many researchers operating with a range of trial protocols.

Furthermore, there is no consistent explanation in the literature for the range in the positive effects of nBPTP-treated urea on plant yields. For example, Silva et al. (2017) reported that yield responses were not related to soil pH, contrary to the results of Black et al. (1985). Similarly, Hendrickson (1992) reported that there was no relationship between corn responses to nBTPT and the amount of fertiliser N applied, noting that large effects were found at both low and high rates of N applied, but not the intermediate N rates. The current analysis (Table 2) suggests that the effect of nBPTP-treated urea on plant yield increases with the rate of N application. In addition, Cantarella et al. (2018) suggested that plant type may affect ammonia volatilisation and hence the effect nBPTP-treated urea. This effect is not apparent in the current analysis (Table 1).

It is likely that the mean response of +3%, on plant DM yields found in this review, is an overestimate. Many studies have reported beneficial effects of nBPTP on ammonia volatilisation from soil, when measured directly, but the associated effects on plant yields have not been reported because they were not statistically significant. The non-reporting of negative results can introduce bias into the literature, as discussed elsewhere (Edmeades 2002).

Thus, the overall conclusion from this review is that nBTPT-treated urea has only a small mean effect on plant DM yield, and hence NUE, relative to untreated urea. Considering all the data in Table 1, the average, across all crop types is typically 3% and the range of apparent DM 'responses', both positive and negative, is likely an artifact arising from the inherent variability in field trials. This suggests that either a) the amount of N volatilized from urea applied to the soil is typically small or b) that the conserved N is not taken up by the plant or c) the conserved N is incorporated into the soil N pool and is not accessible to the plant. These later two suggestions are unlikely given that the yield from clover-based pastures, grasses and crops are always limited by N and will respond to applied fertiliser N up to very high rates of N.

The small effect of nBPTP-urea has on plant DM growth is in contrast to the large reported effects that nBPTP (up to 50%) has on reducing ammonia volatilisation when measured directly in the field (Saggar et al. 2013, Silva et al. 2017 and Cantarella et al. 2018). This raises a question; are the techniques currently used to measure ammonia volatilisation directly in the field over estimating N volatilisation losses?

Conclusions

At a practical level, it is noted that most of the urea used in New Zealand is applied to clover-based pastures. Typically it is applied at 20-30 kg N/ha per application in the spring and autumn. The data in Table 2 indicate that nBPTP has little effect on plant DM yields at this rate of N application, because the confidence interval of 1.4% includes the mean of 1.4%, and hence the yield effect of nBPTP, at these low rates of applied N, is not statistically significant. In these circumstances the use of nBPTP-treated urea would not be recommended as a means of increasing plant DM yields and hence improving NUE.

However, there are other reasons for considering the use of nBPTP treated urea, especially when N is applied at higher rates. Ammonia volatilised from the soil is returned via rainfall to the soil and hence can increase nitrous oxide emissions – a significant greenhouse gases. In this context nBPTP can be regarded as a risk management tool for greenhouse gas emissions.

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