agKnowledge
"The Independent Fertiliser Experts"

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This is the 50th edition of the **Fertiliser Review**. With two editions per year, this means that it is now 25 years old. It is appropriate to reflect.

The origins of the Fertiliser Review go back to the early 2000s. I had recently left institutional science – I was at the time the National Science Leader (NSL), Soils and Fertiliser, in the CRI, AgResearch, based at the Ruakura Research Centre, Hamilton - and I was wondering what I might do for the second half of my science career. My thinking was encouraged by farmers, whose advice I valued, who expressed the view that now I was free from bureaucratic ties, I might be more useful to the farming sector! As things have turned out, they were probably right, after all, I did receive a gong (ONZM) for services to agriculture in 2013.

I have always had a keen interest in fertilisers and fertiliser issues. In my time at Ruakura, I had seen the subsidies on fertiliser removed, the Fertiliser Act repealed and the fertiliser industry go through a period of major reforms. The consequences of all these changes were that by 1990, fertiliser was the major item of discretionary expenditure on most farms, there was no legal protection for farmers against unscrupulous salesmen and advertisers, and the fertiliser industry was shifting its focus and becoming more sales-orientated. The net result was that the fertiliser market became a "free for all" and farmers were left confused and vulnerable when it came to making informed decisions.

Against this backdrop I thought I could make a difference and so I began writing technical articles about fertiliser and soil fertility for the various farming newspapers, intending to help farmers make sense of the advertising and advertorial claims being made.

I was quickly disabused of this approach. Editors were not keen on publishing articles critical of products and services that they were promoting either via advertorial comment or, more importantly, by advertising. They feared two possibilities – loss of advertising revenue and/or defamation action. This conclusion, albeit self-serving, did not help the farmers. I decided to do something about it and hence began the **Fertiliser Review**, an independent, science-based, product and service guide, written particularly for farmers and farm consultants, focussing on soil fertility and fertilisers. I did not see the spector of defamation as a major risk, given my layman's understanding of New Zealand's defamation law (see box "Lessons from the Maxicrop Case").

In addition to avoiding legal hassles, I was advised by otherwise well-meaning science colleagues, familiar with the technology transfer world, that my idea to write the **Fertiliser Review** would peter out before long because of the lack of new information to keep it going. That, I am pleased to say, has never occurred. In the fluid, ever-changing world of farmers, fertilisers and soil fertility, there are always matters that need addressing.

All back issues of the Fertiliser Review are available on our website, www.agknowledge.co.nz.

LESSONS FROM THE MAXICROP CASE

Recall that in 1986 the then Ministry of Agriculture and Fisheries (MAF) was sued for about $11m, by the Bell-Booth Group, for allegedly defaming their product, a liquid seaweed fertiliser product called Maxicrop. The action arose because of comments I made on a nationwide television program called “FairGo”, to the effect that the product did not work. The legal case ran for 12 months in the High Court in Wellington, becoming the longest civil case in New Zealand at that time. I was retained by MAF as the science advisor to the legal team representing MAF. I had a ‘ring-side’ seat and I learnt a lot in the process - it was a very formative experience in my career.

In particular, I learnt about NZ’s defamation law. Put briefly, there are two primary defences against defamation. Firstly, “truth” is a total defence. If what was said is true then it cannot be defamatory. Secondly, there is a defence based on “fair comment “. Some comments may not be 100% accurate but if they are offered without malice on a matter of public importance, they would not necessarily be deemed defamatory. I have tried to follow this recipe.

Thus, in terms of preparing articles for publication in the **Fertiliser Review**, I needed to be absolutely certain that they were factually correct (i.e., based on sound science) and also, on matters of public importance, meaning in my case, important to the farming sector.

Sure, in a couple of instances, I was threatened with legal action. I argued with the enraged proprietors that, should the matter go to court, the first questions that the Judge would ask are: what does the science say and is it in the farmer’s interest? I sometimes added that should these defences fail, and as a result, I lost the legal argument, I had no money should they wish to seek compensation! This approach has served me well.

SUSTAIN AND N-PROTECT

SustaiN (from Ballance) and N-Protect (from Ravensdown) are modified urea products. A small amount of the chemical agrotain is added to the urea which slows the conversion of plant unavailable urea to plant available ammonium and nitrate in the soil (Figure 1). In theory, this reduces the amount of N volatilised to the gas ammonia (Figure 1). It is claimed that it can reduce ammonia volatilisation by up to 50%.

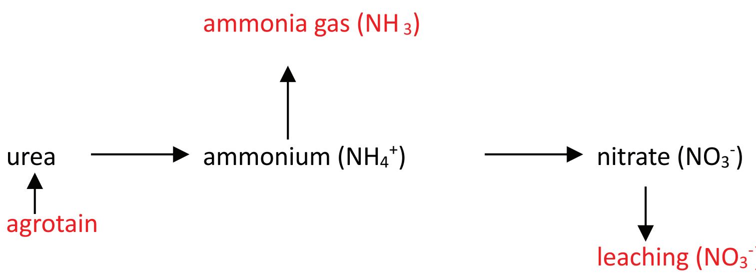

Figure 1 Adding agrotain to urea slows the conversion of urea to ammonium in the soil and hence the amount of N that can be volatilised as ammonia gas.

Assuming that the N conserved from the reduction in ammonia volatilisation, results in an increase in available soil N then increases in plant yield from agrotain-treated urea, relative to urea alone, are to be expected – plants are mostly N deficient and will readily take up any available N in the soil.

In Fertiliser Review 32, we estimated that the pasture response to agrotain-treated urea was 4% +/- 4%, relative to untreated urea, with a range of responses from -25% to +53%. These estimates were based on a small set of trials (16) on pastures.

Subsequently, we updated these estimates based on the results from 105 field trials. With this expanded set of data, the average response of agrotain-treated urea, relative to untreated urea, was: 2.3% +/- 1.1%, with a range of -11% to +24% (Fertiliser Review 34).

Curious, we decided to cast the net a little wider to include all the trials we could find in the international literature. We were careful to include only those trials which were replicated and for which the statistical information was available.

We ended up with a database of 348 individual records of site × year × crop-type measurements. The crop types were primarily clover-based pastures and grasses (68%), with the balance being an assortment of arable crops, predominantly corn and other cereals (32%). The trials were from North America, Europe, Australia, New Zealand, South America, Asia and Africa. The results are summarised in Table 1.

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

The results (Table 1) are similar for all the crop types tested and they suggest that agrotain-treated urea has a small effect on plant yield (2%-3%). This is consistent with a considerable body of international research and with the results obtained from the smaller database (105 trials) discussed earlier.

In theory, the effect of agrotain should increase as the rate of N application increases. We were able to explore this possibility and the results were consistent with the theory (Table 2).

These results have some important practical implications for the use of agrotain-treated urea, at least in New Zealand. There are situations where high rates of N (> 100 kg N/ha) are applied 'upfront' at sowing time for crops such as maize and many vegetable crops. At these rates of application, the mean responses are larger (5%-7%) and statistically and economically significant responses can likely occur.

The situation is different for pastures. Typical applications of N are in the range 20-30 kg N/ha per application. The results in Table 2 suggest that the effect of agrotain-treatment of urea is not statistically significant at these rates (i.e. the mean response lies within the confidence interval).

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

Rate of N fertiliser application (kg/ha)	Number of measurements	Mean response (%)	Range (%)	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

In all the data presented above there is a wide range in the measured responses, typically in the range -20% to +30%. While it is tempting to attribute the positive effects as real responses to agrotain, how are the negative effects to be interpreted? It is unlikely that agrotain has a negative effect on plant yield. To make sense of this we need to dig deeper and look at the distribution of the responses around the mean. To do that we need to understand and interpret cumulative distribution functions.

Edmeades and McBride 2023. An assessment of the agronomic effectiveness of N-(n-butyl) thiophosphoric triamide (nBTPT) - treated urea on the production of clover-based pastures, pastures, grasses and crops. Journal of New Zealand Grasslands 85: 147-151

UNDERSTANDING CUMULATIVE DISTRIBUTION FUNCTIONS

Some theory

The power of an experiment to detect treatment differences depends on (a) the size of the difference measured (b) the variability in the quantities that are measured, and (c) the number of replicates of each treatment. Typically, the variability (coefficient of variability, CV) of pasture and crop yields is between 5 to 10% and it is estimated that 9-28 treatment replications would be required to detect a 10% difference in yield at a 95% level of probability.

Most field experiments do not meet this standard and the reported effects of some products, on plant yields, are generally small (10%, as in this case for agrotain-treated urea (see later). It is not surprising therefore that the effects of such products, as measured in individual field experiments, are frequently not statistically significant. The interpretation of such results is problematic - is the product having an effect but the experiment is not sufficiently accurate to detect it, or, is the product having no effect and the observed 'treatment effect' is due to the background biological variation? The converse situation also arises when an individual result is statistically significant – is the effect due to the treatment or is it due to the small but finite probability that the product is having no effect and the observed effect is due to the background variability? These possibilities give rise to the classic Type I and II errors associated with statistical testing.

There is a pragmatic solution to this problem. It arises when a given product has been tested many times. This enables the frequency distribution of the measured treatment effects to be examined and compared with a normal distribution with a mean of zero. For convenience, this is achieved by converting the distribution frequency and plotting the **cumulative**

distribution function. Any displacement of the distribution, either positive or negative, relative to zero, can be taken to indicate a real treatment effect.

For example, the data in Figure 2 are from a set of experiments in which the effect of a small application of water (225 L/ha) on crop yields was measured, relative to a nil treatment (no water). Such a small input of water would not be expected to have a sustained or substantial effect on crop yield. This is indicated by the fact that the observed 'effects' of water are distributed normally around a mean of zero (In this case the mean is – 0.6%, which lies within the confidence interval of 2.3%). The range in the observations is – 30% to +30%, with about 50% positive and 50% negative. These results are consistent with the product (a small amount of water) having no effect on plant yield and the range reflecting the variability normally associated with experiments of this nature.

This then, is a 'picture' of the 'background noise', which occurs in all field trials and against which we attempt to estimate the efficacy of products.

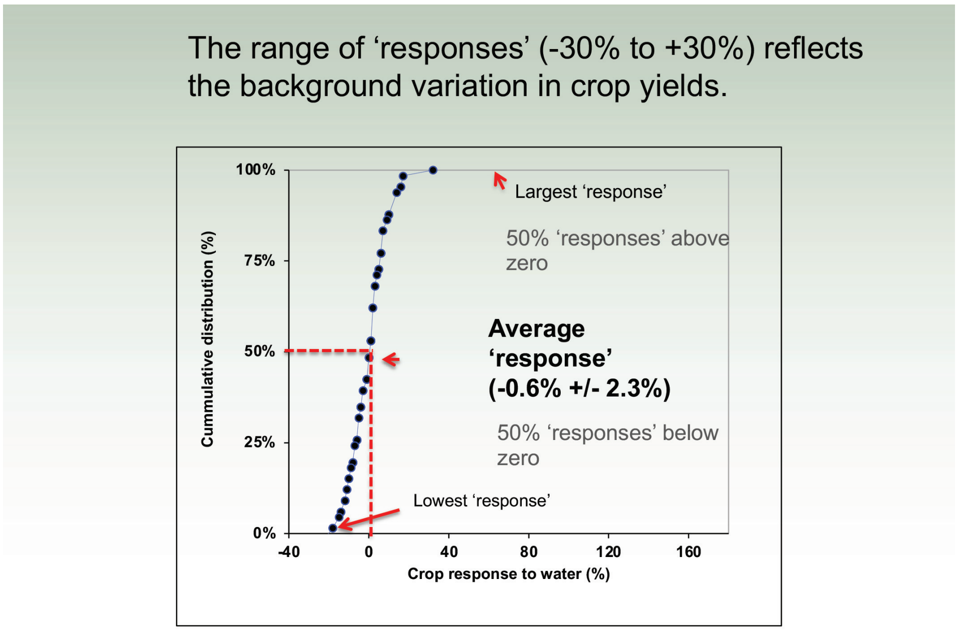

Figure 2 The cumulative distribution of apparent crop 'responses' to a small application of water relative to control (no water).

If a product has a real, and sufficiently large, effect the distribution of responses, relative to the control, will move to the right. This is observed in Figure 3, for a set of data derived from field experiments on pasture, in which the effects of applying either phosphate or nitrogen fertiliser, on nutrient-deficient soils, were measured. Although the population of results was not large enough to clearly define the expected S-shaped cumulative distribution, the positive shift in the population of results on the x-axis, relative to the background noise, is apparent.

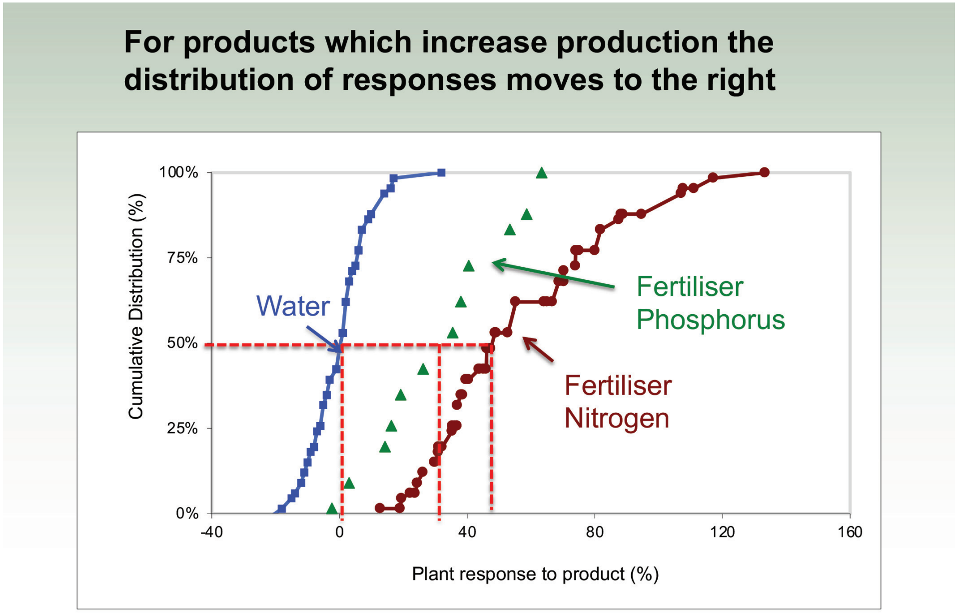

Figure 3 The cumulative distribution of plant responses (%) to fertiliser N or P, on nutrient-deficient soils, compared with the background noise (refer to text).

This method of meta-analysis has some advantages. There is a strong visual impact – it is easy to visualise all the data simultaneously and to see the results from individual trials in the context of the total set of data. Further, it is not necessary to know whether the results for any given trial are statistically significant or otherwise, thus avoiding the Type I and II conundrum discussed earlier. The biometrical test becomes the movement of the distribution on the x-axis relative to zero.

[For further reading go to Edmeades DC. 2002. The effects of liquid fertilisers derived from natural products on crop, pasture and animal production: A review. Australian Journal of Agricultural Research 53: 965-976.

Agrotain-treated urea

Figure 4 shows the cumulative distribution of plant responses to agrotain-treated urea relative to untreated urea, for all the crop types examined (Note that the distributions of the responses (Table 1) from specific crops-types are very similar and hence it is unnecessary to show the crop-type distributions). The responses are normally distributed around a mean of 3.1% (confidence interval 0.9%) and a range of -23% to +32%. About 60% of the apparent 'responses' are positive and the balance are negative.

It is tempting to suggest that the reason for the range in the estimated positive effects of agrotain is due to the many factors which affect the volatilisation of N, which include: soil organic matter and moisture content, rate of N application and rainfall post-application. This may be true, but how can the negative effects (30% of the trials gave negative 'responses') be explained? Since there is no reason to suggest that adding agrotain to urea actually makes urea less effective, the only rational reason for the negative effects is the background noise. And, if this is accepted, then it must be accepted that a large proportion of the positive 'responses' are also a reflection of the background noise.

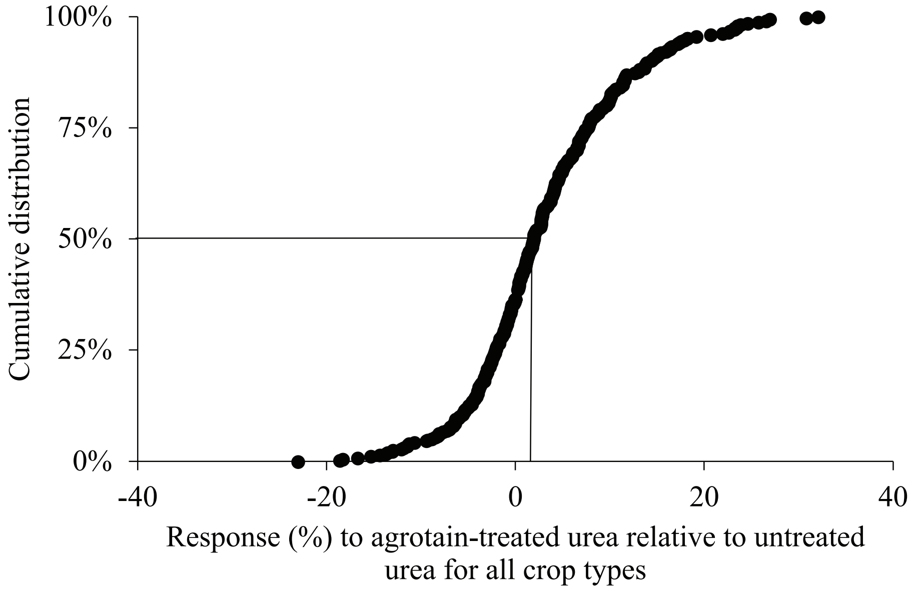

Figure 4 The cumulative distribution of responses (%) to agrotain-treated urea relative to untreated urea for all crop types.

The overall conclusion is that agrotain-treated urea has only a small effect on plant growth, relative to urea, of about 3%. This suggests that either a) the amount of N volatilized from urea 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 most pastures, grasses and crops are always N deficient and will respond to applied fertiliser N up to very high rates of N.

Simple calculation reinforces the conclusion that the amount of N volatilized from urea is typically small especially when the rate of application is < 50 kg N/ha per application. For example, assume that urea was applied to a pasture and that the pasture yield over the duration of the fertiliser N effect (say 2 months) was 2000 kg DM/ha. If agrotain-treated urea was used instead of straight urea, the increase in pasture production would be on average 3% i.e. 60 kg DM/ha. Assuming a pasture N concentration of say 4% DM, this would represent about 2-3 kg N/ha.

It is ironic that long-before agrotain-treated products came on the market, the general view among soil scientists was that losses of N from urea via volatilisation, when it was applied to pastures at normal rates (20-30 kg N/ha per application) in the spring and autumn, were small – in the range of 0-5% of the amount of N applied (i.e. <5 kg N/ha per application). The implication is that N volatilisation, as a mechanism for N losses from urea, has been ‘overplayed’ by the industry to create a market for these products.

The small effect of agrotain-treated urea on plant growth stands in contrast to the large reported effects (up to 50%) that agrotain-treated urea has on reducing ammonia volatilisation, as measured directly in gas chambers. Is it possible that these techniques used to measure ammonia volatilisation directly, are overestimating the size of this loss?

Finally, it is noted that ammonia gas per se is not a greenhouse gas. However some of the volatilised ammonia could be returned to the soil dissolved in the rainfall, which could increase the amount of available N, and hence the amount of nitrate N, in the soil (Figure1). If this additional N was not intercepted by the plant, it could result in an increase in the emissions of the greenhouse gas nitrous oxide (N_2O) from the soil. Given the amounts of N involved, and the somewhat remote mechanisms of loss, my personal view is, that the amount of N (as N_2O) lost in this manner will be of little practical consequence, in most pastoral situations, when urea is applied at normal rates (20-30 kg N/ha per application.