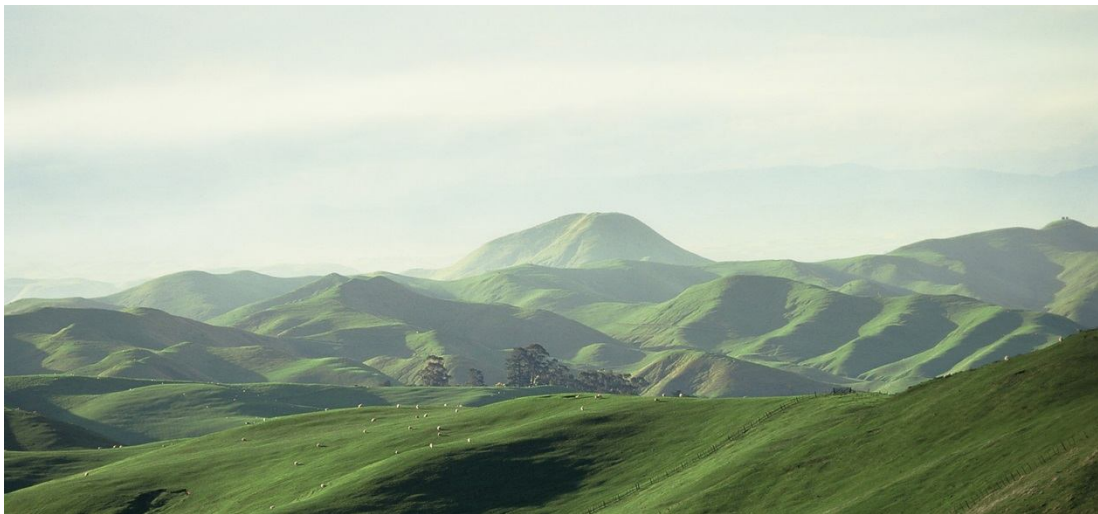


Critique of the literature review of fine particle fertilisers and application methods

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1. Executive Summary

A literature review was undertaken (Crossley, 2017) to collate and assess the evidence for improved nitrogen (N) fertiliser efficacy for pasture production by adoption of the Fine Particle Application (FPA) method. The aim here is to critique the literature review to determine if it was impartial and credible.

There was not a large body of evidence for the review to assess. The lack of documented experimental work on FPA has also been noted by others. The review focused on six documents: one refereed journal paper, three conference papers and two internal reports. There were five other various reports that were justifiably rejected mainly due to experiment design. Six reports is not a large dataset to develop robust conclusions, especially given the wide ranging quality of those source documents.

The review would have benefitted from a more critical assessment of the papers, reports or data. For example: not all documents included statistical analysis, which should be acknowledged; each document appeared to be treated with equal weight whereas the single peer-reviewed journal paper should have been acknowledged as the most robust source of information; and there seemed to be some anomalies between data reported in the conference papers and some of the associated trial datasheets provided separately. The review could also have considered the ONE-system® approach that uses micro-prills of urea sprayed with water, with the aim of encouraging foliar uptake. A couple of conference papers report similar findings to those in the review (albeit with urease inhibitor included, but still would have added information).

However, in general, I agree with the overall conclusions, that there is some evidence that FPA has advantages in terms of fertiliser use efficiency over conventionally applied N. In general, I agree with the recommendations for future work, particularly around the need to understand mechanisms for observed effects. This would also help identify when FPA might and might not convey a benefit (e.g. under what environmental conditions).

There is definitely a need for follow up experiments given the indication of large responses to the applied N in some circumstances. As well as science questions about mechanism of action, it would be interesting to understand why the fertiliser industry in general is not exploring FPA as an option for increasing fertiliser N efficiency; this would provide an interesting insight and might unearth more research results.

2. Background

Various reports, generally in the grey literature (non-refereed reports), have suggested an increased nitrogen (N) use efficiency (NUE) and dry matter production if fertiliser N is applied as a Fine Particle Application (FPA), compared with the standard granular formulation. This has generally been observed when applying urea or urea plus urease inhibitor (for example in products such as Sustain). If these results are reproducible in practice, this could potentially result in farm systems being able to achieve the same levels of production with smaller N inputs. However, to date the technology has not been widely adopted.

Living Water is a partnership between the Department of Conservation and Fonterra with the focus of finding game-changing solutions that will enable farming, freshwater and healthy ecosystems to thrive side-by-side. Therefore, as part of this focus, the Living Water Partnership commissioned a review of the scientific literature to collate and assess the evidence for improved agronomic and environmental performance of FPA of N fertilisers. The review was completed in 2017 (Crossley, 2017) as a first stage in developing a research programme for further evaluation of FPA.

In February 2018, Dr Mark Shepherd was asked to provide a critique of the literature review, with the following objectives:

2.1 Purpose of the peer review:

To determine if the literature review is impartial and credible and in particular;

- Assess if all relevant trials and information were included in the review – or, have any important or significant pieces of information been left out
- Assess if the review summarised the conclusions of the trials accurately in terms of FPA efficacy vs other application methods
- Assess if the review made any claims about FPA that are not supported by the data
- Include any thoughts on the next steps presented in the review

This report summarises the findings from the assessment of the literature review.

3. Assessment of the report

3.1 Approach to critiquing the report

I read the review and then read and assessed the supporting source documents where they were provided. I cross-checked the source documents and my understanding of them with the review (both accepted and rejected documents). I also undertook a literature search using Google Scholar to identify other potential information sources and supplemented this search with papers I already had in my possession.

Based on my experience as a Journal editor and an author of reviews, successful reviews address the following points:

- Is the review a synthesis of the papers, providing some critique, rather than just cataloguing reports and papers?
- Is the interpretation in the review correctly supported by statements and statistical evidence cited in the source documents?
- What is the quality of the source documents? This will determine the robustness of the conclusions in the review.
- Does the review take the state of knowledge forward and does it identify where next?

I assessed the review against these criteria.

3.2 Overview

The literature review was undertaken to collate and assess the evidence for improved fertiliser N efficacy for pasture production by adoption of the FPA method.

It identified a range of source documents and summarised the key points, including a summary of the results from each experiment. The review then included conclusions and recommendations for future direction based on an assessment of the source documents.

The review focused on six documents (one refereed journal paper, three conference papers and two internal reports), and rejected five other documents with a justification of why these were rejected. Six datasets is not a large body of evidence to develop robust conclusions, especially given the wide ranging quality of those source documents. The lack of experimental work on FPA has been noted by others:

“Applying fertilizers and inhibitors in a fine particle suspension has been proposed as a measure to further reduce N losses and increase crop yields and NUE (Di and Cameron, 2005). However... [there is a] low number of studies providing data for this category. More studies using this and other innovative application techniques are therefore required.” Abalos et al. (2014)

My overall assessment of the review is as follows:

- At the start, there was a clear explanation of what is considered as FPA fertiliser and how it differentiates from other fertiliser types, e.g. suspension fertiliser. This was very useful and set the boundaries of the review.
- The review would have benefitted from a more critical assessment of the reports:

- There are three types of reports included in the assessment: peer-reviewed journal paper(s); non-peer reviewed conference proceedings; and internal experiment summaries. Consequently, the reports varied in the detail and the clarity they provided, including statistical analysis. Some weighting of importance should therefore have been placed on the different types of reports. For example, clearly the most comprehensive and authoritative paper was that of Dawar et al. (2011) as this was published in a reputable peer-reviewed journal and the authors undertook detailed measurements to understand underpinning mechanisms, yet this is treated with equal weight compared with the other reports. I recommend that this paper is reported first, and the remaining papers used to supplement findings from this paper.
- The review tends to be a collation of verbatim statements from those reports and does not always differentiate between what is speculation about some of the possible mechanisms and what has been proven in the paper.
- A more critical assessment might have picked up some of the inconsistencies in the data. For example, the paper by Zaman & Blennerhassett (2009) reports three trials from Canterbury but as far as I can see, this does not correspond to the trials summarised in the review (only one of the three corresponds to the paper).
- I also wonder if there would have been a benefit from undertaking a meta-analysis of the reported benefits, for example collating results from all of the reports and undertaking some statistical analysis.
- It would have been good to weigh the evidence to explain the number of proposed mechanisms that convey the efficiency of FPA, i.e. what evidence was provided to support the list of proposed causes of the benefit. This would then provide more guidance and justification for the direction of future research.
- However, in general, I agree with the conclusions, that there is some evidence that FPA has advantages in terms of fertiliser use efficiency over conventionally applied N. However, the evidence would be more compelling and transparent if more of it was published in peer-reviewed journals as opposed to non-refereed conference papers or internal experiment reports.
- In general, I also agree with the recommendations for future research, particularly around the need to understand mechanisms for observed effects. I would add also the following points need to be addressed in that future research:
 - Identify when FPA might and might not convey a benefit (e.g. under what environmental conditions)
 - If there are potentially large agronomic benefits, what are the barriers to its uptake by the industry and promotion by the fertiliser cooperatives? It is important to understand these barriers to adoption when designing a future research programme.
- The aim of the review was granular urea vs FPA urea. Several of the experiments also included NBPT. It is important to clearly differentiate the two when reporting the results. This wasn't always the case; this was more of an editorial point, rather

than mis-interpretation of data. I just felt that the two comparisons needed to be clearly separated in the review.

- Other papers could have been considered:
 - Dawar K, Zaman M, Rowarth JS, Turnbull MH (2012). I believe this is a critical paper to add weight to explaining why there are benefits from FPA. I would consider this as a useful follow-on from Dawar et al (2011) that is reported in the review.
 - POSSIBLY, also include the reports of Bert Quin's One-System®, which uses micro-prilled urea sprayed (0.8-2.8 mm) with water (includes NBPT) and is based on the same principles of enhancing foliar uptake. Papers include:
 - Quin, B., Gillingham, A., Spilsbury, S., Baird, D. & Gray, M. (2015a) – includes a non-NBPT treatment: Table 4.
 - Quin B, Gillingham A, Baird D, Spilsbury S, Gray M (2015b) – comparison is compromised by inclusion of NBPT in the FPA.

Both are conference papers. I can understand the author excluding these because of the inclusion of NBPT in the FPA, but some of the information in these papers would probably have added some additional insight for the overall review.

In summary, the correct conclusions have been reached but the review could be more critical, and therefore more robust, in its appraisal to support those conclusions and to direct future experiments.

3.3 Detailed comments

Below, I summarise my assessment of the papers and highlight where I would have interpreted differently.

3.3.1 AgConsult (1993)

This is an internal experiment report.

If I have understood this report correctly, they applied a single application of DAP, equivalent to 9 or 18 kg N/ha, yet they monitored for almost 12 months. This is unusual for monitoring a fertiliser N effect because this effect generally lasts 1 or two harvests. Unfortunately, it looks like the Control did not have any base fertiliser, which complicates the interpretation of the results.

- I would have questioned why such a long monitoring period for a small amount of N. I suspect they were also interested in the longer-term effects of the applied P.
- I would have also questioned why an apparent large relative response in May, many months after application? There did not appear to be a credible reason given for this.
- I would have also commented on the unusually high fertiliser response from the FPA (1700 kg DM from 18 kg N/ha!) and I would have suggested that some of this

is probably due to the lack of base fertiliser in the control; there was a response to superphosphate alone, which suggests some nutrient deficiency.

- There is evidence that FPA urea was more effective than granular urea but the design of the experiment places some uncertainty around the robustness of the conclusions.

3.3.2 Zaman & Blennerhassett (2009)

This is a conference paper, supplemented with some internal experiment reports.

I picked up a few apparent anomalies in this paper.

- The methods stated trials were done in 2007 and 2008. However, it looks like the three trials were all done in 2007 only.
- **Experiment 1** compared like with like (i.e. urea, SustaiN or 'Rapid N' applied as either granular or FPA) and states there was a statistically significant difference between granular and FPA N. Note also that I think the data summarised in the review for this site does not correspond to the graphical data in the paper.
- The data for **Experiment 2** reported in the paper are not comparing like with like; it is comparing granular urea with FPA urea plus a urease inhibitor. It also does not say whether the treatment effects are significant and I have taken this omission as a suggestion there was no significant effect. If there was no statistically significant effect then the authors should not be quoting differences in fertiliser N response. The data included in the review includes a wider range of treatments and, although there appears to be a numerical DM production advantage from FPA on this graph, there are no supporting statistics. The authors of the paper allude to poor growing conditions at this site.
- In **Experiment 3**, there was no effect; again poor growing conditions were alluded to by the authors. Note also that I think the data summarised in the review for this site does not correspond to the graphical data in the paper.
- I therefore disagree with the statement in the paper and re-iterated in the review that 'applying urea with Agrotain in FPA form showed significantly better pasture growth, N response and response efficiency than urea alone' without more detail included in the paper. There is conclusive evidence presented of response at 1 out of 3 sites.

3.3.3 Dawar et al. (2011)

This is a peer-reviewed journal paper.

This is the best paper, but beware of over-interpreting the results. This is an example of where I think the review confuses for the reader reporting comparisons of urea with urea FPA and with urea FPA plus urease inhibitor; the two comparisons need to be separated out, especially if the report is about comparing granular urea and FPA urea.

- When we compare granular urea with FPA urea, my interpretation differs with that of the review:
 - NH₃ volatilisation: no significant effect (this is stated as a significant effect in the first bullet points, page 16 but is contradicted (correctly) under the 'results section).

- N₂O: no significant effect
- NO₃ leaching; significant effects, but probably I would comment that the absolute amounts are small. Nevertheless, this is an indication of foliar applied N potentially bypassing the soil and reducing leaching risk.
- Good evidence of a FPA effect on DM production and N use efficiency, with enough detailed measurements to explain some of the potential reasons for improved efficiency.

3.3.4 Mahoney (2010)

This is an internal experiment report.

The document reports a small plot experiment undertaken in Australia over almost a year with repeated applications of N fertiliser, including a comparison of urea (42 and 84 kg N/ha per application) in either granular form or FPA. Based on the report, this was a well-executed experiment supported with statistical analysis. The experiment demonstrated a benefit from the FPA of c. 10% more total pasture over the duration of the experiment, or an 18% increase in pasture from the applied N fertiliser alone.

This report appeared to provide compelling evidence; pity this was not reported more widely.

3.3.5 Zaman et al. (2014)

This is a short conference paper.

It provides evidence of the mechanism for improved NUE of FPA being foliar uptake.

Perhaps correctly cite the paper in the review as: Zaman M, Barbour M, Turnbull M, Kurepin L Influence of fine particle suspension of urea and urease inhibitor on nitrogen and water use efficiency in grassland using nuclear techniques. In: International Symposium on Managing Soils for Food Security and Climate Change Adaption and Mitigation, ed. by Heng LK, Sakadeva K, Dercon G and Nguyen ML. Food and Agriculture Organization of the United Nation, Rome, 2014. pp 29-32

3.3.6 Quin et al. (2005)

This is a short conference paper.

This was a wide ranging paper but included results from a field experiment in the Taranaki (one harvest) comparing 30 kg N/ha as urea or SustaiN applied in granular form or FPA. Frustratingly, in both the paper and the supporting trails information sheet there was no mention of statistical analysis. However, the treatment means looked sufficiently different to suggest a real effect of FPA both on urea and SustaiN.

Perhaps cite the correct reference in the review: Quin B, Blennerhassett J, Zaman M (2005). The use of urease inhibitor-based products to reduce nitrogen losses from pasture. In: Proceedings of the Workshop on Developments in Fertilizer Application Technologies and Nutrient Management” (LD Currie and JA Hanly, Eds.), Occasional Report, vol 18.

Note: another trial report was included in the bundled literature for the review (Whangarei), but this was not cited in any paper, nor the review. Again, there were no supporting

statistics on the trial sheet but the treatment means were sufficiently different to suggest an effect of FPA.

3.3.7 Comments on omitted papers

I have thoroughly examined the experiment reports for the omitted trials and I agree that either the treatments used are not appropriate to the review or there is sufficient doubt about how the experiments were conducted; therefore, their exclusion is justified.

Note that the Suter paper reported in the review (Suter et al. 2013) correctly notes that a comparison between FPA and granular urea is not possible because a urease inhibitor was used in the FPA. A second paper (Suter et al. 2016) also makes the same comparison, but is not mentioned in the review.

3.3.8 Comments on concluding remarks

Paragraph 1: 'The trials reviewed above have shown benefits being derived ...' - I agree there is some evidence that FPA can show large benefits (up to an unprecedented 40 kg DM/kg N!). The author is also right to point out that some sites did not show such large effects and this was attributed to 'sub-optimal conditions'. This points to the need to further understand where responses are and aren't likely and I think this should be a key focus of future research.

Paragraph 2: 'It is apparent that FPA technology provides wider benefits ...' - Although this sounds right, there is little evidence in the report (or outside the report) to support this statement. In the absence of NBPT there was no difference in ammonia volatilisation or nitrous oxide emissions between granular and FPA urea, as reported by Dawar et al. (2011). No other papers reported on these losses, with the other papers being agronomic trials and although they speculated on cause of results, there were no supporting measurements of mechanisms. There was a reduction in N leaching from the same Dawar et al. experiment. However, in grazing systems the main source of N leaching is not from fertiliser N *per se* but via its effects on protein eaten by the animals and discharged via the urine patch. Interestingly, not one of the papers/reports discussed implications for protein levels and hence implications for amount of N eaten and excreted. Some of the data suggested to me that the combination of greater N uptake because of higher use efficiency and the increased DM production resulted in pasture with a similar protein content to that produced by granular urea. If so, there may be no reduction (or even an increase) in N leaching risk from urine, but this needs to be investigated.

Paragraph 3: 'There was also evidence of FPA improving soil N' - I don't think it confirmed the theory of increased biological activity; to do this would have involved measurements and some direct evidence.

Paragraph 4: 'The Winton trial also noted an appreciable shift in pasture composition' - why focus on this one trial; was there evidence from others? I suggest too much emphasis is placed on one experiment. This was also a trial potentially with low fertility so ca

Paragraph 5: 'There were environmental benefits' - I disagree: see comments above.

3.3.9 Comments on recommendations

Paragraph 1: 'One of the benefits of fine particle ...' - there wasn't much cited evidence in the report of the effect on tillering, so it is interesting that it is seen as a major priority. I agree it is interesting but where does it fit in the list of priorities?

Paragraph 2: 'There is a need to investigate and confirm the biological pathways ...' - I agree this is a major priority and might help clarify how likely a response is given a certain set of environmental conditions.

Paragraph 3: '... a more comprehensive understanding of the role of grinding and spreading ...' - again, there was not much discussion in the review, or indication from the papers, that this was a concern; however, I agree that understanding this is important.

As described under Section 3.1. I believe we need to understand the barriers to the uptake of FPA by the industry and promotion by the fertiliser cooperatives. It is important to understand these barriers to adoption when designing a future research programme. This might also unearth further experiments, including nil improvement with FPA.

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