RADIATA MANAGEMENT TECHNICAL NOTE

Site Productivity

Number: RSPTN-019
Date: July 2011

Nitrogen Leaching Response to Fertiliser (3)

Summary

There is an opportunity to improve plantation forest productivity through use of nitrogen (N) fertiliser, but the environmental consequences of N application to forests are not well known. Nitrogen fertilisation could lead to increased N leaching to drainage waters, but the amount and duration of such leaching is unknown. Environment Waikato has set limits to N fertiliser application to forests in the Lake Taupo catchment, possibly foreshadowing intervention by councils in other regions. This study was initiated to improve our understanding of both the growth response and the environmental consequences of applying N fertiliser to forests.

This Technote presents results of the effect of N fertiliser application on potentially leachable soil water N concentrations, collected from lysimeters placed below the majority of roots, for the first 15 months following fertilisation. Nitrogen fertiliser (urea at 200 kgN/ha) rapidly increased nitrate-N concentrations in soil water at two South Island sites, but the increase has been short-lived (8 months) and concentrations have since declined to those in non-fertilised plots. At two North Island sites, N fertiliser application caused a delayed but sustained increase in soil water nitrate-N concentrations. At five sites there has been no effect of N fertiliser application on soil water nitrate-N concentrations, while at one site dry conditions have so far precluded determination of the fertiliser effect. Preliminary estimates indicate that leaching of nitrate-N after fertilisation, in locations where it occurs, is likely to be limited in comparison with pastoral environments. Nitrogen fertiliser application has had little or no affect on soil water ammonium-N or organic-N concentrations, probably because they are less mobile than nitrate-N. Sampling will continue at six-weekly intervals until mid-winter 2011 at all sites, and will then be discontinued except at sites where nitrate-N concentrations in treated plots remain above concentrations in control plots. After a soil water model has been parameterised and calibrated we can determine N leaching rates. The nitrogen leaching data generated in this study will be used to develop and test the robustness of the leaching component of a nutrient balance model. This model may be used as a decision support tool, helping forest managers to reduce some of the negative ecological effects associated with forest operations.

A subsequent tech note will report N fertiliser effects on tree growth.

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Background

As described in the previous Technical Notes (RTN-009 and RSPTN 018), a study is being undertaken to improve our understanding of both the growth response and the environmental consequences of applying nitrogen fertiliser to forests. This research is focusing on:

- Measuring the tree growth response to N fertiliser (urea at 200 kg/ha of N fertiliser application) across New Zealand forest sites.
- Determination of relationships between foliar and soil indices of N availability, climate and growth responses to enable improved prediction of N response.
- Determination of nitrate-N leaching losses in response to N fertiliser application, and how this varies with soil, rainfall and stand characteristics.

The study uses 17 existing Long Term Site Productivity Series 2 trial sites. The series was selected because soil and climatic parameters for the sites were already well characterised. The forest stands at the sites were 6-9 years old at the time of N application. Existing 20 x 20 m permanent sampling plots at these sites form unfertilised controls. An additional plot was established to match the existing plot in terms of soil, slope and aspect at each site. Nitrogen was applied to these additional plots in November 2009 to determine the tree growth response to N application. To determine the N leaching response to N addition, at ten of the 17 sites four lysimeters were installed in each plot (with and without N) for extraction of soil water at approximately six-weekly intervals. The lysimeters were placed between 0.6 and 1 m below ground, below most roots, to allow estimation of the amount of nitrogen that is potentially leachable below the root zone.

Previous Technical Notes have described the study and presented results of urea effects on soil water nitrate-N concentrations up to four months after application. In this Technical Note, data on the effects of urea on soil water nitrate-N concentrations for the

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first 15 months after application are presented. Results from periodic analyses of samples for ammonium-N and organic-N are also presented. Results reported are unweighted for soil water volume. To date the lysimeters have been sampled on twelve occasions, but low soil moisture levels precluded collection of samples on a number of occasions at most sites.

Results

Nitrate-N

Average soil water nitrate-N concentrations in control plots ranged from 0.04 mg/L (Waimarino, Karioi) to 1.98 (Bulls) mg/L (Fig. 1). The higher average value observed at Bulls may be associated with a pasture history, while gorse, which fixes N, may have contributed to the higher values at Eyrewell and Ashley. At all other sites average values remain at 0.5 mg/L or below. These concentrations are similar to those found in other studies in radiata pine forests in New Zealand (Knight and Will 1977, Dyck *et al.* 1981, 1983) and are consistent with values from land not influenced by pastoral agriculture.

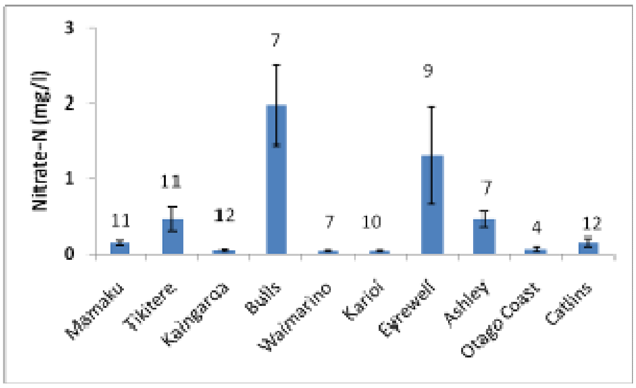

Figure 1. Average soil water nitrate-N concentrations in control plots. Values above histograms show the number of days samples were collected, and bars show standard errors.

Nitrogen fertiliser application had no effect on average soil water nitrate-N concentrations at five sites, but increased concentrations at four sites (Fig. 2). The increases were statistically significant at Mamaku ($p < 0.05$) and Ashley ($p < 0.01$) and non-significant at Tikitere and Catlins (Fig. 2). The Bulls site is not shown in Figure 2 because an extended dry period beginning in February 2010 resulted in only one sample being collected from the fertilised plot since that time.

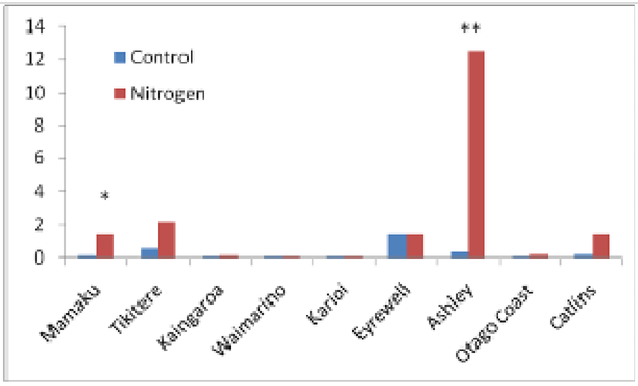

Figure 2. Effect of urea application on soil water nitrate-N concentrations.

At the four sites where fertiliser has increased nitrate-N concentrations, the pattern of increase has either been immediate and relatively short-lived (as at Ashley, Fig. 3), or somewhat delayed (six months) but sustained (as at Mamaku, Fig. 4). Because of this delay, the response at the two sites where it occurred (Mamaku and Tikitere) had not been noted in the earlier report.

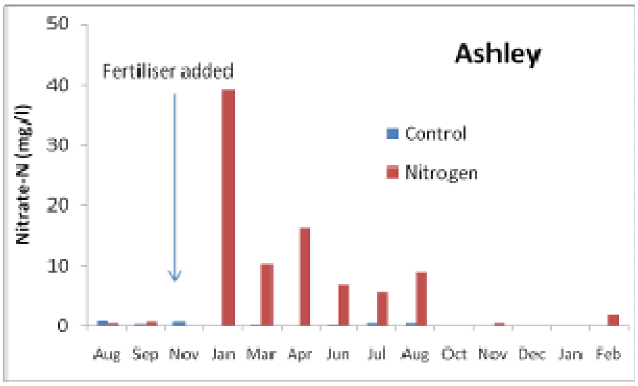

Figure 3. Effect of urea application on soil water nitrate-N concentrations at Ashley.

The nitrate-N response at Ashley has been substantially greater than at other sites (Fig. 2), and this may be associated with the site having a history of gorse. Apart from this, the reasons for the differences between sites and patterns of response are not obvious at this stage.

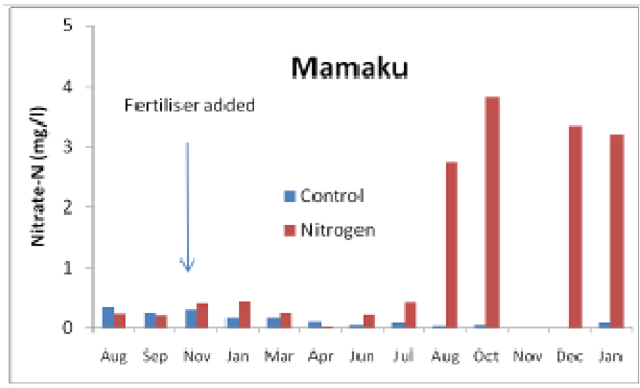

Figure 4. Effect of urea application on soil water nitrate-N concentrations at Mamaku.

Ammonium-N and Organic-N

Periodic analysis of samples for ammonium-N and organic-N indicate fertiliser has had, with the possible exception of ammonium-N at Ashley, little effect on concentrations of these components (Figs. 5 & 6), probably because they are less mobile than nitrate-N. Although very little ammonium-N is normally lost by leaching, organic-N may be leached and makes up the dominant form of N lost by leaching in indigenous forests. Note that data for the Bulls site are not included in Figures 5 and 6 because drought since February 2010 resulted in insufficient samples being collected

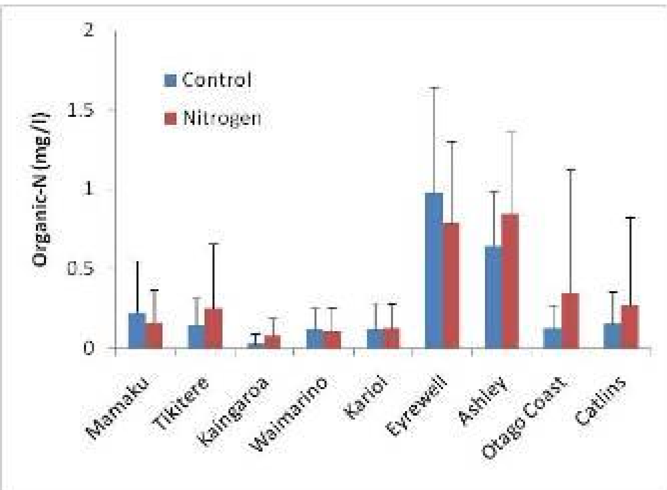

Figure 5. Effect of urea application on soil water ammonium-N concentrations. Bars show standard deviations

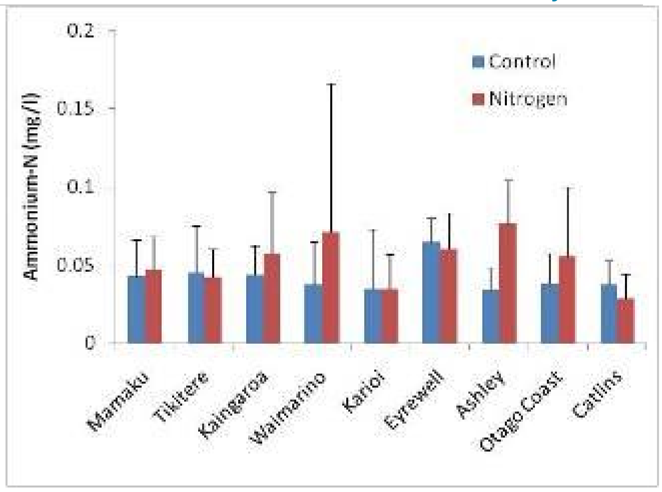

Figure 6. Effect of urea application on soil water organic-N concentrations. Bars show standard deviations.

Mean ammonium-N concentrations were very low, ranging between 0.03 and 0.08 mg/L at all sites. Organic-N concentrations were a little more variable, and ranged from 0.03 (Kaingaroa) to 0.97 (Eyrewell) mg/L.

Discussion

Sampling to date has indicated that fertilisation with urea at an application rate of 200 kgN/ha has not affected nitrate-N concentrations in potentially leachable soil water at five sites, but has increased concentrations significantly at two sites and non-significantly at two further sites. Our finding of a lack of effect of nitrogen fertilisation at five sites is consistent with the results of Worsnop and Will (1980) who found no leaching of nitrate for three years after application of urea (at 200 kgN/ha) to 14-year-old radiata pine in Kaingaroa Forest. International studies, however, have shown that N fertilisation frequently increases nitrate-N concentrations in soil drainage water (Binkley *et al*. 1999), so the nitrate response at four sites in the present study is not surprising. New Zealand studies in very young plantings on coastal sands have also found increased soil water nitrate concentrations after N fertilisation (Smith *et al*. 1984; Thomas and Mead 1992). Drought has so far precluded determination of the fertiliser effect at our site on a coastal sand site (Bulls).

The greatest increase in nitrate-N concentrations recorded so far in our study has been at Ashley (Fig. 2), where concentrations on one occasion

immediately after fertiliser application reached 40 mg/l. However on other sampling occasions concentrations in fertilised plots ranged between 0.5 and 16 mg/l. The mean concentration since fertiliser application at Ashley was 12.5 mg/l compared to 0.3 mg/l in unfertilsed plots. Soil water drainage under young radiata pine stands with annual rainfall up to about 1000 mm generally does not exceed 100 mm (Watt *et al*. 2008). From the mean nitrate-N concentration value and assuming 100 mm drainage, it can be crudely estimated that nitrate-N leaching in the year following fertiliser application at Ashley (rainfall about 850 mm) may have amounted to 12.5 kg/h, compared to 0.3 kg/ha in unfertilised plots. As most leaching occurs in winter, and the highest nitrate concentrations at Ashley occurred in summer and autumn, the value of 12.5 kg/ha is likely to be an over-estimate. While more accurate estimation of the amount of nitrate leaching must await estimation of soil water drainage from water balance modelling, this preliminary estimate indicates that nitrate losses following forest fertilisation, where they occur, are likely to be minimal. By comparison, losses from pastoral farming are approximately 20 kgN/ha/yr for sheep and beef systems, and 40 kgN/ha/year for dairy systems (Menneer *et al*. 2004). It should be noted these are annual losses, while the data from this study suggest that losses from fertiliser application to forestry, if they occur at all, may be relatively short lived.

Why fertiliser has caused a nitrogen leaching response at some sites but not others is not clear at this stage. As noted above, the presence of the N-fixer gorse may have contributed to the response at Ashley, but gorse was also present at Eyrewell (though in smaller amounts) and there was no response to urea application there. Site information on soil chemistry and texture, tree foliar chemistry, understory vegetation composition, crop and weed leaf area index and rainfall has been collected and will be examined to determine if these factors may explain differences in the nitrate leaching response between sites.

Further work

Sampling will continue at six-weekly intervals until mid-winter 2011 at all sites, and then be discontinued except at sites where nitrate-N concentrations in fertilised plots remain above concentrations in control plots. Sampling will continue at the latter sites until concentrations decline to control plot concentrations. After a soil water model has been parameterised and calibrated with soil moisture data collected during the study, drainage data estimated from the model will allow determination of nitrate-N leaching rates in kg/ha on an annual basis.

As noted in Technote RSPTN 018, nitrogen leaching data generated in this study will be used to develop and test the robustness of the leaching component of a nutrient balance model that could be used as a decision support tool to help forest managers reduce the negative ecological effects associated with forest operations.

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