Growing confidence in forestry's future Research Programme

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Technical Note

Examining the potential uses for biuret in New Zealand forestry

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Summary: The activity of the soil microbial community is fundamental to nutrient cycling processes. Enhancing the rate at which soil microbes release nutrients from complex organic matter is therefore seen as potential pathway to increase the productivity of New Zealand forests. The chemical biuret is a known stimulant of microbial activity, but has the potential to damage plants through phytotoxic interactions. Through various glasshouse and nursery trials with pine, it has been found that biuret is an efficient nitrogen source for this species, and also that it promotes beneficial physiological responses rather than acting as a toxin. Additional trials are underway to confirm the extent to which soil microbes respond to biuret, as, to date, it has been difficult to isolate the indirect benefits to pine from soil microbes from the unexpected direct benefits of biuret. Opportunities to utilise the phytotoxic effects of biuret as a weed control option are also being explored in nursery and forest settings.

Introduction

Meeting the forestry sector target of sustainably increasing New Zealand's forest exports to $12 billion by 2022[1] is linked with growing more biomass in forests. This, in turn, is reliant on the ability of forest soils to supply the resources required to support increased growth demands. The activity of soil microbes is essential to nutrient cycling, so enhancing the rate at which this community processes complex organic matter into simpler forms that are accessible to plants is an important step towards this ambitious goal.

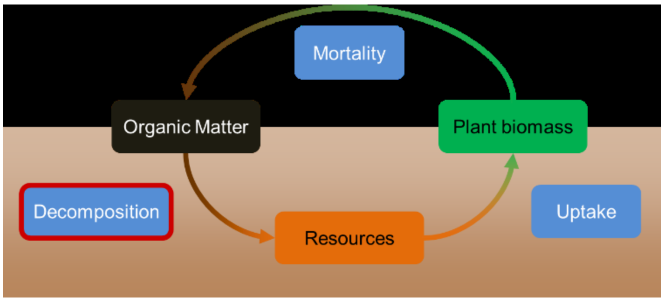

Figure 1 A conceptual model of the nutrient cycling process. Through the decomposition process, soil microbes convert organic matter into resources that can be utilised again by plant biomass.

In most forest soils, a considerable pool of nutrients is locked up in organic matter. Getting a greater proportion of these resources into play is an effective option to help sites reach their biological potential for forest growth. Past research has also shown that the soil microbial communities in New Zealand pine plantations are relatively responsive – alterations to management practices can drive changes in the activity of the soil microbes, with meaningful effects on rates of nitrogen mineralisation, for example[2].

To drive the development of new forest management techniques that can get more from soil microbes, a set of projects have been launched as part of the "Growing Confidence in Forestry's Future" (GCFF) research programme[3]. The goal of these projects is to determine how the soil microbial community at a given site can be induced to increase the frequency and extent of the beneficial activities they perform, and how long any enhancement of beneficial activity lasts. The issue of longevity is a critical one, as it may be that only small improvements in microbial activity can be achieved, but if these persist for the life span of the rotation, then significant productivity gains can still be accumulated.

Opportunities to modify a wide range of beneficial plant – microbe interactions are currently being investigated. These include production of plant

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hormones by soil microbes, the influence of mycorrhizal fungi on the ability of plants to acquire resources, and the factors that regulate the activity of the soil bacteria that can alleviate plant stress. However, given the role of nutrients as the building blocks of plant productivity, significant effort has also gone into the development of viable techniques to enhance the microbial process that drive nutrient availability in forest soils.

In this technical note the outcomes from a series of trials using biuret will be presented. Biuret is a relatively simple chemical capable of stimulating forest soil microbial activity in some conditions[4,5]. Given that a number of unexpected positive results have been observed from this work, the research undertaken with this chemical has rapidly evolved beyond the original bounds, crossing over into areas such as fertiliser application and weed control, and is also being conducted at a much greater scale than initially planned for at this stage. Therefore, in the interest of proving a comprehensive assessment of progress, the range of topics discussed will extend beyond the intended use of biuret as a stimulant of beneficial microbial activity.

Biuret – production and properties

Biuret is produced through a process very similar to that used to make urea, and is almost always found in some concentration in urea-based nitrogen fertilisers. When urea is heated to or above 132°C a number of different chemicals begin to form, including biuret. Pressure and other factors in the manufacturing process can also affect this, causing more of less of the urea to convert to biuret[6,7].

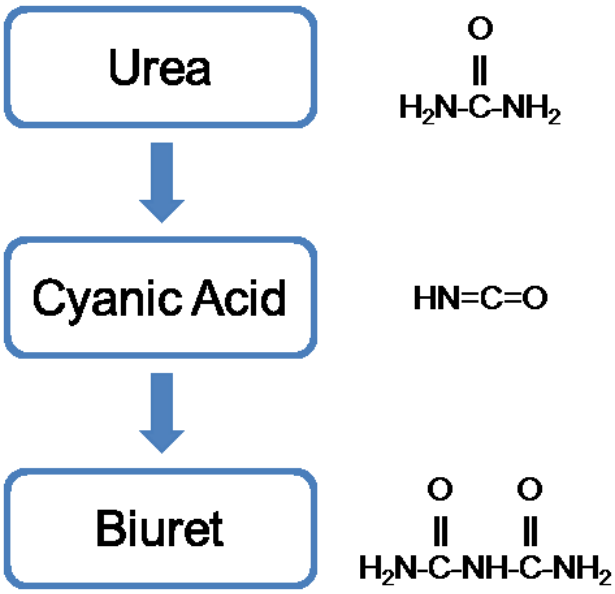

Figure 2 Formation of urea from biuret. Note that urea will form molecules other than cyanic acid, and the cyanic acid will form molecules other than biuret. Opportunities exist to increase current conversion efficiencies.

Despite containing ~40% nitrogen, various studies have found that biuret is toxic to plants either through soil or when directly applied to the plant foliage[8]. This toxicity can manifest in various ways, but is commonly associated with moderate to significant loses in growth. Toxic effects been observed in some plant species at application rates as low as 3 – 4 kg per ha to the soil [8]. As a consequence of these effects, there has been considerable research performed to limit the extent of biuret contamination during urea production.

Initial biuret trials

Based on past research carried out with some coniferous species (Douglas-fir in particular), it was indicated that a “sweet spot” could be found where the toxic effects of biuret may be outweighed by the beneficial effects on microbial activity and the potential use of biuret as a nitrogen source[9,10]. In addition, some of the earlier work also suggested that biuret may have some beneficial stimulatory effect on the tree itself, although this was not able to be confirmed at the time[9].

To investigate this possibility, a two-part trial was developed to test the compare the effects of biuret and urea application on the growth of newly germinated radiata and maritime pine seedlings, and also identify the levels at which biuret induced toxic effects on the young plants. To help observe any stimulatory effect of the biuret on the decomposition, the seedlings were raised in a sand / organic matter mix in which the nutrients were largely unavailable unless that organic matter was broken down.

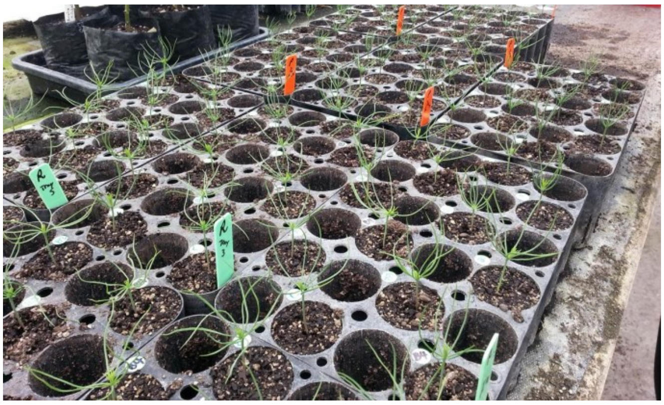

Figure 3 Layout of a section of the biuret and urea fertilisation trial, containing both radiata and maritime pine seedlings.

In the fertiliser trial, the application of biuret did not cause any death nor other significant toxic effects at any application rate for either species, with only minor impacts at highest rates. Conversely, the highest rate of urea application killed every seedling it was applied to within 48 hours. In terms of growth, the response to biuret improved with increasing application rates, and surpassed that achieved with urea addition. The most significant result was a substantial increase in nitrogen uptake efficiency with biuret, which demonstrated that the more biuret the seedlings were exposed to, the more nitrogen they could capture per unit of root mass. This effect was observed for both radiata and maritime pine.

The toxicity trial produced very simple results, as no toxic effect was found at the rates of biuret being tested. These ranged up to 1200% of the dose rate being used in the fertiliser trial, and the main effect observed was increased growth. Some physiological effects in terms of growth characteristics were observed, but these abated rapidly and the only long term effect (measured in weeks) was greater biomass.

These results were not anticipated, and prompted the development of further trials utilising biuret in the nursery environment, focussing on the potential to maintain or nitrogen nutrition while still adding less elemental nitrogen to this soil.

Figure 4 Radiata seedlings treated with the highest dose of biuret in the toxicity trial. Only beneficial effects were observed from this, and these seedlings outperformed those treated with lower rates of biuret in the toxicity trial.

Operational scale nursery biuret trials

With the assistance of ArborGen, an operational scale trial was established at Tokoroa ArborGen nursery over 1.2 km of seedbed in 2015. The trial compared the effects of biuret application at 50% and 25% nitrogen application rates of the standard urea treatment during the growth of a cohort of radiata pine seedlings. During the life of the trial, no toxic effects related to biuret application were observed. At harvest, based on comparisons of average root collar diameters, the seedlings that had received less nitrogen in the form of biuret had grown more. Several thousand seedlings from this trial have been used in out-planting trials that will enable the longer term effects of this nursery treatment on field performance to be known.

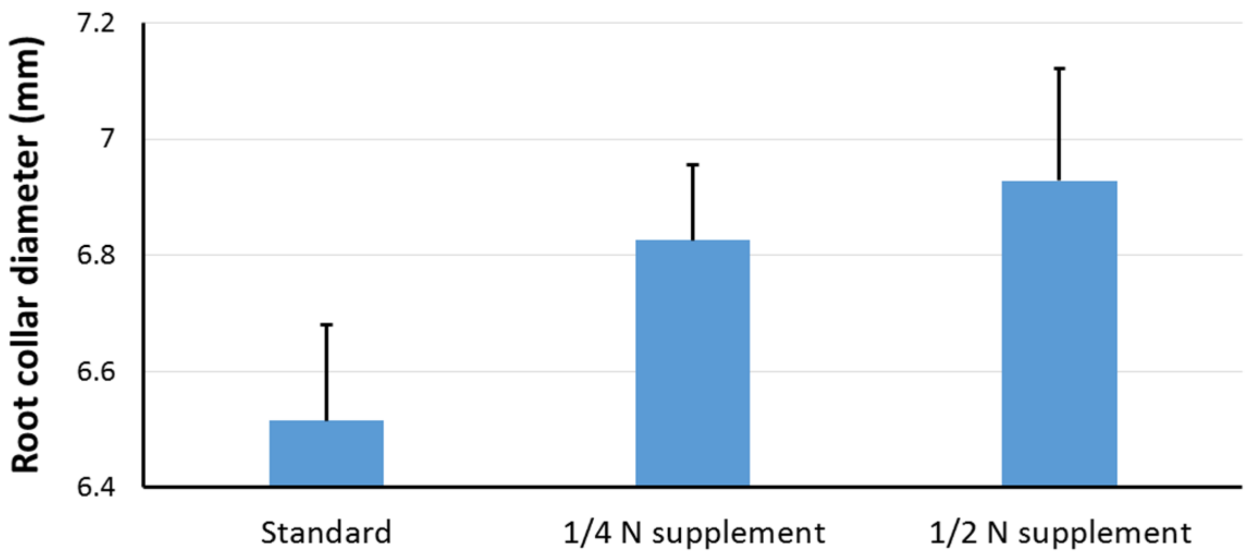

Figure 5 Comparison of radiata seedlings root collar diameter growth following nine months growth under different treatment regimes.

In 2016 another operational scale nursery trial utilising biuret application to radiata pine seedlings was established at the Tokoroa ArborGen nursery, this time over 6.3 km of seedbed. Interim results from this trial again showed no toxic effects related to the application of the biuret, and negative effects on growth rate despite the seedlings receiving only 40% of the nitrogen dose they would normally receive through urea applications. More data on this trial will be available shortly.

Additional biuret toxicity trials

To address final concerns around the application of biuret at rates appropriate for field use, a second series of toxicity trial were established in the Scion Research Nursery, utilising seedlings that had germinated approximately one year earlier. This trial series was also considered an as opportunity to identify that point at which toxicity from biuret would actually occur for radiata pine. Seedlings in the first trial were treated with between 0 – 10.2 g of nitrogen in the form of urea in the initial trial, with growth and health monitored for two months.

As demonstrated in Figure 6, the only negative impact for health manifested as needle burn caused by overexposure to nitrogen; no evidence of phytotoxicity due to the presence of biuret itself was noted. In terms of growth, biuret application resulted in larger root collar diameters, generally increasing more with higher biuret doses.

Figure 6 Impact of biuret applications on needle colouration and health. The left panel shows an example of the minimal needle burn observed with the low rate of biuret application (0.41 g nitrogen per seedling). The right panel shows an example of the greater needle burn associated with the highest rate (10.2 g of nitrogen per seedling).

A second high rate toxicity was trial was then launched with the year old radiata seedlings, this time including urea at equivalent nitrogen dose rates to determine how this affected seedling health. Biuret was added at 20.4 g nitrogen as both a powder and a slurry, equal to about 20 tons per ha of nitrogen. Urea was added at 10.2 and 20.4 g per seedling as a powder. At both rates urea application killed substantial number of seedlings almost immediately, and after a month nearly all seedlings treated with the higher urea dose were dead. All surviving urea treated seedlings showed substantially reduced growth rates, with some actually shrinking. Biuret application was again associated with needle burn, but no mortality occurred, and growth rates were not reduced relative to untreated controls. This lead to a conclusion that for radiata pine, nitrogen toxicity was the greatest threat from biuret, and this threat was greatly reduced compared to other potential nitrogen sources.

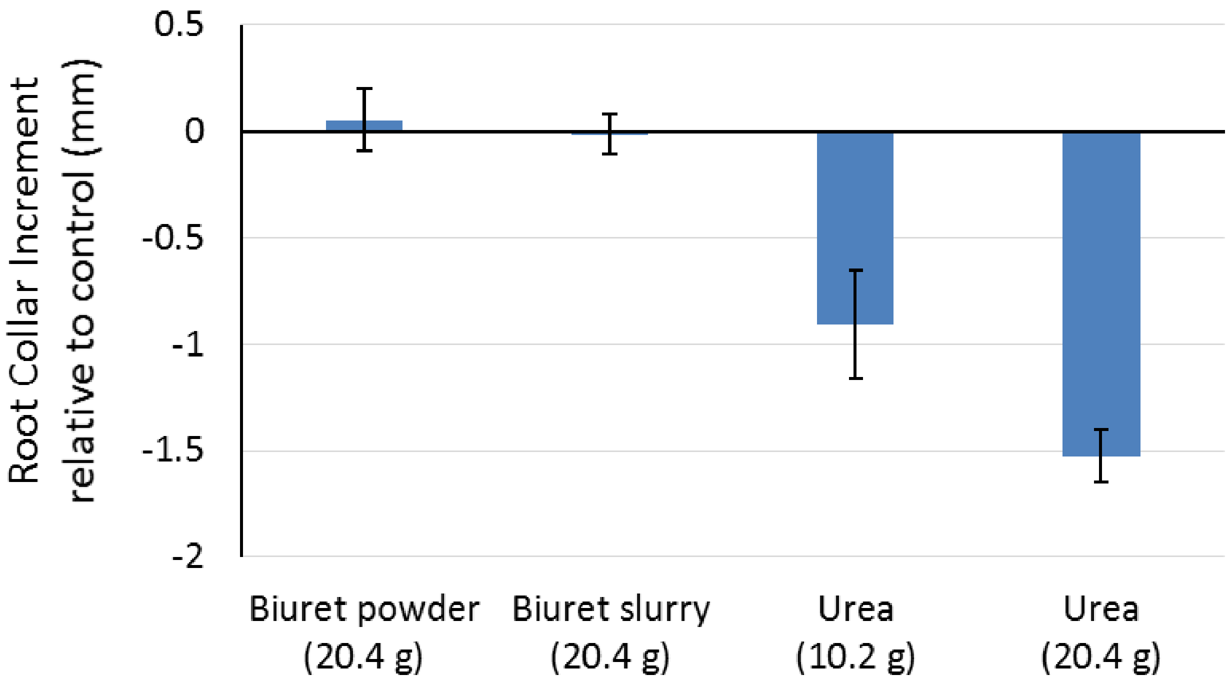

Figure 7 Impact of biuret and urea applications on root collar growth

Field trials

Biuret is currently being added to the five site modification trials established to evaluated opportunities to enhance beneficial soil microbial activities. These trial area located in Northland, Wairarapa, Marlborough, Canterbury and Otago. The effect of biuret will be studied in the presence of boron, which is also a known modifier of microbial activity. Given the demonstrated direct benefits of biuret for the growth of radiata pine, it is acknowledged that isolating any benefits for radiata health and growth through an indirect effect on the soil microbial community will be difficult. This issue is being resolved through the use community level assessment of microbial activity using DNA tools. This will pinpoint changes in particular microbial functions that have impacts on forest performance. These trial sites will be studied over several years to determine the outcomes of the treatments on forest performance.

In addition to this, two forestry companies are currently consulting with Scion over the establishment of operational scale biuret trials in their forests. This process is well advanced, and the treatment will be deployed in Spring 2017. These trials also provide opportunities to assess the environmental impact of biuret against urea. All measurement to date suggest it should outperform urea in this area as well.

Further research

A new trial that attempts to put the phytotoxic effect of biuret to use is also in development. This trial will test the efficacy of biuret as a weed control option in nursery settings, based on both inhibition of seed germination and the health effect on already germinated weeds. This work will be conducted with a number of common weed species at the Scion nursery, and will commence in Spring 2017. The impact of biuret on weed growth will also be assessed in one of the planned operational scale field trials.

Acknowledgements

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