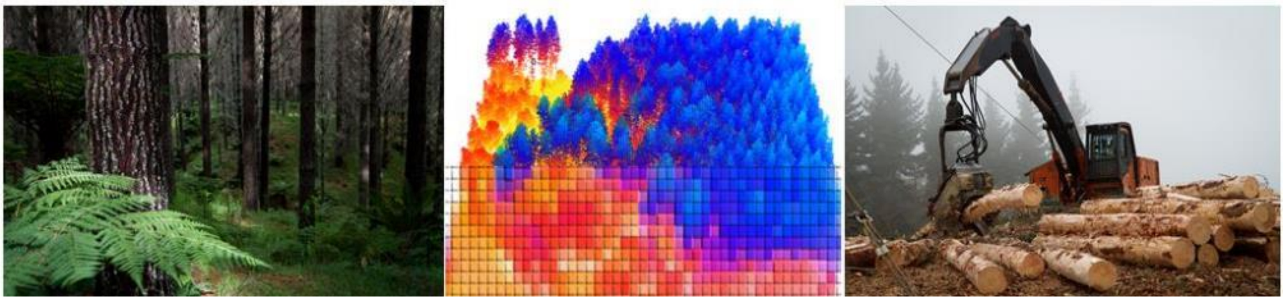
Precision Silviculture Programme

# Extended planting season trial using hydrogels: Rayonier Matariki Maramarua Forest


**Rob Schoonderwoerd[1], Katie Yallop[1], Kane Fleet[2], Eli Vili[2] and Carol Rolando[2]**

[1] Rayonier Matariki Forests
[2] Scion, New Zealand Forest Research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# EXECUTIVE SUMMARY


## Problem

Hydrogels have been used internationally to aid plant establishment and growth in a range of soil conditions. The potential of hydrogels to extend the planting window for plantation forestry in New Zealand has not yet been extensively evaluated. The need to extend the planting window in New Zealand is closely aligned to potential wider adoption of mechanised tree planting systems, the cost-efficiency of which increases with increased machine utilisation.

## Aim

The objective of this trial was to quantify the effects of two hydrogels and a water application treatment, all applied at 500 ml/seedling, on radiata pine survival and growth rate following planting with the M-Planter on a clay soil in early summer. A nanocellulose hydrogel produced by Scion (natural product) and a super absorbant synthetic polymer Aquasorb™ were used in the trial. All treatments (water and two hydrogels planted with M-Planter) were compared to manual planting with no water or hydrogel.

## Methods

The trial was planted between 13th and 15th December 2022 on a cutover site of reasonably flat terrain, with medium slash levels and clay soils in Rayonier Matariki's Maramarua Forest in the Waikato region. The trial was designed as a randomised complete block design of four treatments and six replications, with five replications planted in December, and the final replication in late January 2023. All treatments used containerised *Pinus radiata* seedlings planted into spots that had been ripped and mounded by the M-Planter as part of the same operation. All treatments were planted at approximately the same time except the manual planting, which occurred shortly after ripping and mounding.

## Results

Extreme wet weather conditions experienced before, during and after planting, severely compromised the outcomes of this trial. A key learning was the limitation of the M-Planter to plant in clay soils in wet weather with problems experienced in both the movement of the seedlings down the planting tube that was being clogged by wet soil as well as adequate closing of the planting holes by the mechanical planting 'foot' after planting the seedlings.

At five months after planting there was no effect of the treatments on tree survival which was over 90% across the trial with trees in the manually planted treatment significantly larger than those that were planted with the M-Planter (water and two hydrogel treatments). This was not a surprising outcome given the challenges experienced with mechanical planting.

## Recommendations

The study is part of a larger evaluation within the Precision Silviculture Programme of the potential to broaden the planting season window using mechanised planting coupled with the application of hydrogels, fertilisers and growth stimulants. This trial has demonstrated the limitations of the M-Planter in its current configuration when planting in wet conditions and in clay soils. However, learnings from this outcome point at M-Planter design improvements that could overcome challenges of these conditions e.g. improve the movement of the seedling down the planting tube in wet weather as well as provide better compaction around the planting hole when operating in clay soils.

Assuming there is ongoing interest in evaluating hydrogels, we recommend that further controlled studies, not reliant on the vagaries of weather conditions, are carried out. The aim would be to understand the water retention characteristics of hydrogels and their effect on plant available water when used at different concentrations and volumes across typical forestry soils. An expanded operational trial series is also needed to increase experience in using hydrogels as well as examine factors such as placement, quantity and timing of application.

# INTRODUCTION

## Background

Hydrogels, developed to increase the water holding capacity of amended media, have been used to aid plant establishment and growth in dry soils (Agaba et al., 2010, Crous, 2017). They have the potential to absorb water many times their weight, retain it and supply it to plant roots during water stress, thereby enhancing early plant survival and growth. The addition of hydrogels to soils have been shown to not only improve its water holder capacity but also to increase the supply of plant available water (Abedi-Koupai et al., 2008). For example, an increase in plant available water of up to 100% in sandy loam and loam soils was reported by Agaba et al. (2010). The use of hydrogels to improve success of forest establishment and/or extend the tree planting season into drier seasons has been investigated in South Africa, Europe, Canada and the USA (Crous, 2017). While many studies have shown improved survival in response to the use of a hydrogel at planting, a number of studies have also shown either no and/or negative impact (Crous, 2017). Inconsistencies in survival and/or growth responses to the use of a hydrogel have been attributed to differences in weather, soil properties, the specific conditions of the application of the hydrogel, type of hydrogel, particle size of the hydrogel crystals, quantity of hydrogel used, water quality, species planting and method of application. Many potentially interacting factors therefore underpin whether the application of a hydrogel will be beneficial or not!

The potential of hydrogels to extend the planting window in New Zealand plantation forestry has not yet been extensively evaluated (Ford et al., 2023a). The need to extend the planting window in New Zealand and adapt to seasonal climate risk when planting *Pinus radiata* is closely aligned with a wider adoption of mechanised tree planting systems, the cost-efficiency of which improves with increased machine utilisation (Ersson et al., 2018). There is a growing interest in New Zealand in the application of mechanised tree planting systems for forest establishment and re-establishment to overcome potential labour shortages and, as such, there is a need to evaluate potential additives, including hydrogels, that could be used to improve the success of out-of-season mechanised planting operations. Further, hydrogels could improve planting success during climate-change driven unseasonable droughts, likely to be increasing in probability.

In collaboration with forest companies, a series of operational trials are being established within the Precision Silviculture Programme aimed at increasing our understanding of the potential for hydrogels to extend the planting season window when planting with a mechanised planting system. The first trial was implemented in Kaingaroa Forest in April 2022 in collaboration with Timberlands Ltd and M-Planter NZ (Ford et al., 2023a 2023b). This trial tested the potential of a nano-cellulose hydrogel produced by Scion to improve the performance of trees planted in late summer with an M-Planter, a mechanised planting head. The results at one year indicated marginal benefits in survival and growth of the container grown *P. radiata* in response to the application of a hydrogel at the time of planting with an M-Planter. However, there were multiple learnings from the trial including increased knowledge around the use of the M-Planter and mechanical application of hydrogels applied at the time of planting.

The purpose of the study reported here was to expand the operational trial series investigating the potential of hydrogels to extend the planting season window using the M-Planter. The study was implemented in collaboration with Rayonier Matariki Forests who are interested in extending the planting season into early summer in parts of their estate. Typically, planting in early summer leads to crop failure in the ensuing dry season in mid-to-late summer, particularly on the dry, compacted soils on parts of the Rayonier estate.

## Objectives

The objective of this trial was to test the feasibility of planting with the M-Planter on a clay soil in early summer using two different hydrogels: a nanocellulose hydrogel produced by Scion (natural product) and a super absorbant synthetic polymer Aquasorb™.

The outcomes of the trial will be used to inform the potential for different hydrogels (synthetic vs natural) to provide a moisture benefit at the time of planting and also evaluate the logistics and practicalities of planting with the M-Planter.

The purpose of this report is to capture the details of the trial at the time of planting and document early results.

# METHODS

## Description of the site

The trial was planted on a 5.2 ha cutover site of reasonably flat terrain, with medium slash levels and clay soils in Maramarua Forest (Figure 1 and Figure 2). Maramarua Forest was selected for this trial as traditionally it has been a forest where cultivation at establishment is difficult, particularly in dry summers and where compaction of the clay soils has occurred. Soils at the site are described as Ultic Yellow, consisting largely of poorly drained clays.

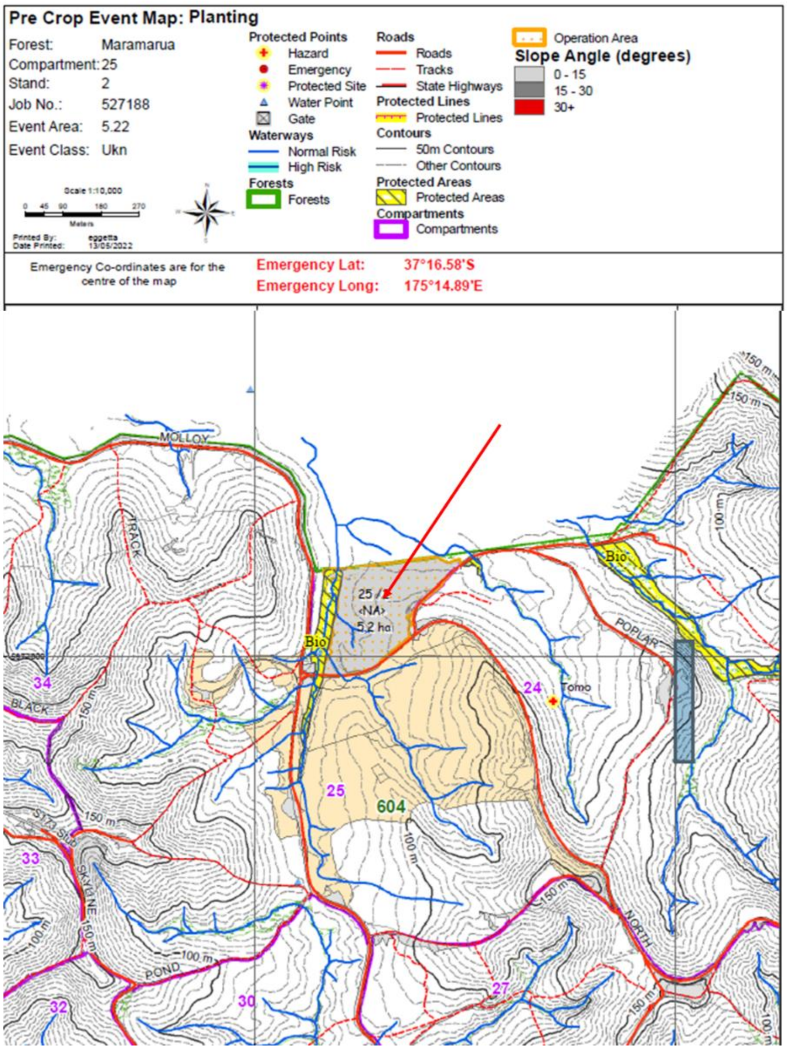


Figure 1. Location of trial in Maramarua Forest

Figure 2. Area planted to the hydrogel trial in Maramarua Forest.

## Treatments

The trial was designed as a randomized complete block design of four treatments and six replications. The four treatments consisted of a manually planted treatment, a water planted treatment and two hydrogel treatments consisting of either a synthetic product (Aquasorb®) or a naturally extracted seaweed-based nano-cellulose product (Table 1). The hydrogel treatments were designed to be applied to the root zone, placed into the planting hole by the M-Planter before planting the tree. Based on previous trials (Ford et al., 2023a), this product was diluted in-field at a rate of 1:5 (hydrogel solution:water) to provide a gel that was suitable to be applied with the mechanised M-Planter planting head. The Aquasorb® product was used as per manufacturer recommendations and diluted at 8 g/L of water.

Table 1: Description of treatments applied to each tree

| Treatment | Cultivation | Method | Dosage |
|---|---|---|---|
| Control | Rip/Mound + clear slash | Manual Plant | N/A |
| Water | Rip/Mound + clear slash | M-Planter | 500 mL applied to rootzone |
| Nanocellulose hydrogel | Rip/Mound + clear slash | M-Planter | 500 mL applied to rootzone |
| Aquasorb™ | Rip/Mound + clear slash | M-Planter | 500 mL applied to rootzone |

Site preparation for all treatments consisted of ripping (depth 1 m), mounding and clearing of slash carried out by the M-Planter. Manual treatments were planted manually following site-preparation whereas all other treatments were mechanically planted with the M-Planter at the same time as site preparation was carried out.

The treatments were designed to be implemented in a practical way to complement the mode of operation typical for the M-Planter. The M-Planter carousel accommodates up to 120 trees and the platform typically plants three rows at a time. For each block, the M-planter carousel was refilled approximately 4x to cover each of the treatments, originally planned to include ~100 trees per treatment. However, during trial implementation practicalities meant that each treatment comprised at least 60 trees, with 30 measurable trees per treatment (the excess trees being used as buffer trees, so to minimise outer treatment effects on the measurable trees). In total each replicated block has approximately 250 trees within it. A layout of the trial, as implemented is shown in Figure 3.

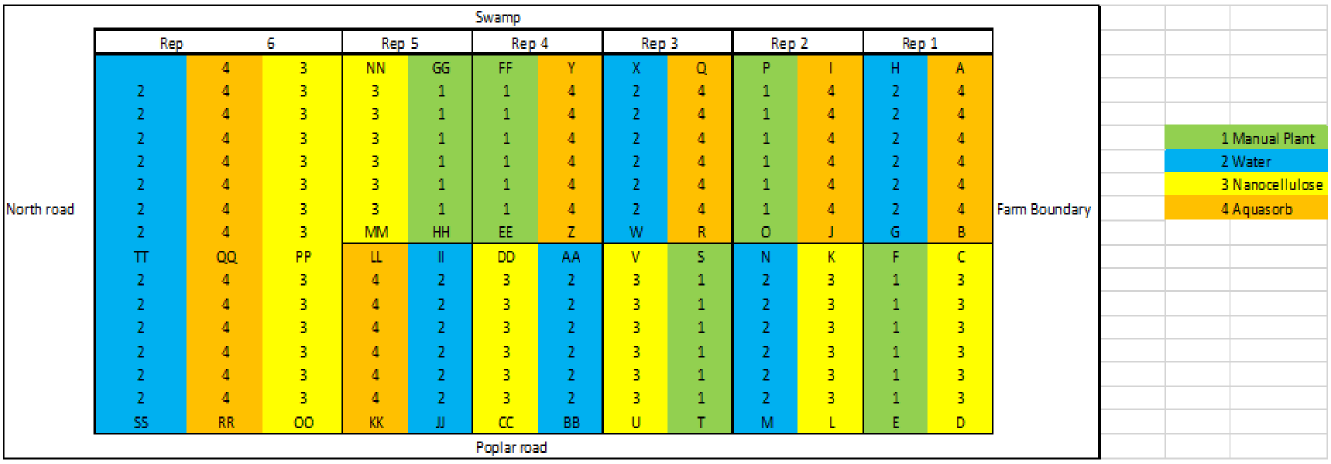


Figure 3. Final trial layout. Replications 1-5 were planted 13-15th December 2022, with the final replication planted in late January 2023. Delays in planting were as a result of extreme weather over the period December 2022 to February 2023.

Containerised tree stocks for the trial were sourced from the Arborgen Nursery at Te Teko. The bulk of the trial was planted between 13th and 15th December 2022, however, severe weather and difficult planting conditions meant that the final block (Block 6) was planted 26th January 2023.

## Assessments and analysis

The height (ht), groundline diameter (gld) and health of trees were measured shortly after planting and again at five months. A biomass index was calculated for each tree (Biomass index=$gld^2$ x ht).

Basic analyses of the data were carried out in RStudio to determine early treatment effects. Assumptions of normality and homogeneity of variance were checked and where appropriate data were transformed to meet these assumptions. A least significant difference test was used to test for significant differences between means where an overall F-test was found to be significant ($p<0.05$). Rainfall data were obtained from the nearest weather station using New Zealand's National Climate Database, CliFlo (https://cliflo.niwa.co.nz).

# RESULTS

## Trial implementation

Planting of the trial was planned for mid-December 2022, when conditions are normally warm and dry. However, contrary to expectations, at the time of planting, and after, the weather was extremely wet and atypical for that time of year (Table 2). Due to nature of the clay soil and the unexpected wetness, problems were encountered during planting with the M-Planter which meant that planting was much slower, and less effective, than expected.

Table 2. Estimated rainfall around the time of trial planting in December (Replication 1-5) and late January (Replication 6).

| Date | Period | Rainfall (mm)* |
|---|---|---|
| 12-16th December 2022 | Week before planting | 16.4 |
| | Week of planting | 70.6 |
| | Month after planting | 79.8 |
| 26 January 2023 | Week before planting | 0.4 |
| | Week of planting | 189.4 |
| | Month after planting | 149.4 |

* Rainfall data were obtained from the nearest weather station (21 km) using New Zealands' National Climate Database, CliFlo (https://cliflo.niwa.co.nz).

Our initial plan (Table 1) was to apply the hydrogel treatments, and water, to the root zone, an obvious placement to maximise the soil water retention properties of the gels. As such, when we started planting, the hydrogel was applied at the bottom of the hole to the root zone with the M-Planter. However, because the soil was already so wet application of the gels resulted in the trees being forced up and out the top of the hole (see Figure 4)! Hence, at the beginning of planting block two, the hose configuration of the M-Planter was changed. This method change meant that the hydrogels were applied around the top of the hole, after planting the trees, to ensure the tree stayed in the ground! Applying the hydrogels around/over the top of the trees resulted in some of the taller trees "bending" with the weight of the hydrogel. However, even with this change, planting was compromised. We noted that the wet clay soil was causing problems for the M-Planter in that it was not re-filling/compacting the soil around the hole once the tree was inserted (Figure 4). This essentially meant that many of the trees had to be manually "firmed-down" after planting to ensure the tree was stable and the hole filled with soil, so as not to leave the roots exposed (Figure 4). Notwithstanding the challenges experienced with the application of hydrogels and planting there were also issues with the M-Planter planting tube in the very wet weather. Firstly, there were problems getting the planting stock through the planting tube. This could have been partly the result of the size of the stock but was also because, secondly, the planting tube was getting clogged with the wet soil which meant that the operator had to periodically flush out the tube.

As a result of the challenges experienced with the wet weather and time constraints (the machine was only available for four days), the team reduced the overall trial size. While Block/Rep 1 included up to 100 trees in each treatment (as planned), the rest of the trial only had 60 trees per treatment. in order to maximize the number of replications planted. The final replication (Block/Rep 6) was planted in late January 2023, as there was not enough time to do so in December. It should be noted that the tree stock planted in Block 6 had more handling than is considered optimal since first being deployed in December, so lack of tree quality/vigor can be expected. This block also has only three treatments and is laid out slightly differently, see Figure 3. Further, the site varied slightly in slope, with blocks closer to the farm boundary and wetland sitting slightly lower. During planting the team found these areas were much wetter than others which may affect the results, if not adequately accounted for through the blocking.

Figure 4. Examples of open planting holes that needed to be firmed up after planting with the M-Planter, as well as a picture showing the amount of water on the site during the planting week.

## Early tree survival and growth

This trial was intended to test tree survival with the aid of hydrogels in dry clay soils, however, an unprecedented wet summer (Table 2) meant that the conditions were different to that expected. It is likely the trial will not meet the intended objectives and results may be skewed by a number of factors that include wet soil, tree stock conditioning/handling and challenges experienced with the planting with the M-Planter. Nevertheless, there are multiple learning from the trial. Results presented here refer only to blocks 1-5 planted 13th-15th December 2022.

At five months after planting there were no significant differences in survival across the trial, with average survival >90% (Control=98%, Water=92%, Nanocellulose=93%, Aquasorb™=94%). This result largely reflects the wet conditions surrounding the time of planting, ideal weather for good survival regardless of any potential benefits from hydrogel in dry conditions. There is clearly a trend for slightly lower survival where trees were planted with the M-Planter, however, given the overall good survival (>90%), the complexities of planting the trial, including that many of these trees were 'firmed in' after mechanised planting, these data have not been analysed further.

There were significant differences in tree size detected in measurements taken shortly after planting, particularly for tree groundline diameter, where manually planted seedlings and seedlings planted mechanically with water were significantly larger than those planted with either of the hydrogels (Figure 5, Appendix 1). The biomass index at planting indicated that overall, the manually planted and water planted seedlings were "larger" than the seedlings where a hydrogel was used. This outcome is possibly a reflection of the planting method and challenges experienced with using the gels, applying them over the top of the seedlings, and needing to firm-up the planting holes after planting. It is likely the 'firming-up' resulted in these seedlings being planted deeper than those manually planted or where only water was used.

At five months after planting, the manually planted seedlings were significantly larger than all seedlings planted with the M-Planter (Figure 5, Appendix 1). This outcome no doubt reflects the difficulties experienced when planting in the wet clay soil with the M-Planter, and the application of the gels over the top of the seedlings rather than in the planting hole. It will be useful to quantify the longer-term impact of the planting method (manual versus mechanical) on tree performance with follow-up measurements at 12 and 24 months.

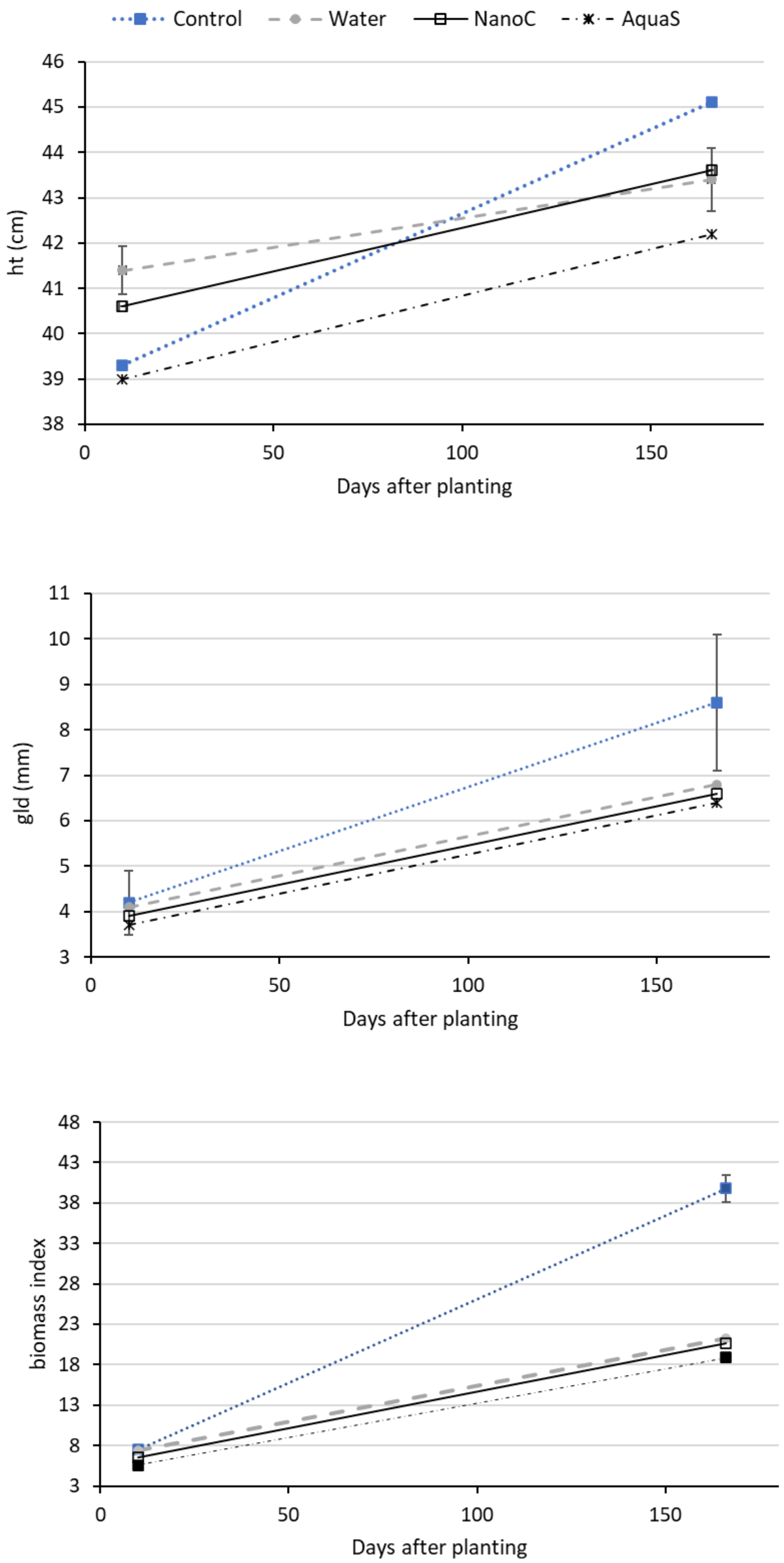


Figure 5. Change in tree size for the four treatments: height (top panel), groundline diameter (middle panel) and biomass index (bottom panel). Error bars show standard error.

It is notable that others have documented similar issues when planting with the M-Planter in wet soils. Rantala and Laine (2010) investigated factors affecting the efficiency of the M-Planter through evaluation of several operators working across five areas in Finland where machines were already in operational use. Their study found that on average 67% and 12.5 % of total machine working time was spent on primary planting work and filling the seedling cassettes, respectively, with mean productivities for the units across the five areas over two years (2008/2009) estimated at 158 seedlings $hr^{-1}$. Post-planting assessments indicated that an average of 31.2% (range 23.8% to 39.3%) of seedlings planted expressed some kind of defect such as insufficient compaction of soil around the seedling or shallow planting. However, almost all seedlings were planted in the mounds, and almost all mounds were placed such that stones, slash or water did not adversely affect the growing conditions of the seedling. Operators cited rain as a factor that caused planting defects for two reasons, firstly due to impacts on the seedlings with cassette rotation where disintegration of wet root plugs resulted in poor movement of the plug through the planting tube and secondly because in some soils, notably soft peat lands or fine soil types, compaction after placement of the seedling did not work well and where the planting tube was easily blocked with soil.

# CONCLUSION

The objective of this trial was to test the effect of hydrogels to extend the planting season when using an M-Planter. However, achieving this objective was severely affected by extreme rainfall over the summer of 22/23. Unfortunately, this is a similar outcome to the trial conducted by Ford et al. (2023 a,b) where rainfall affected the evaluation of the nanocelluose hydrogel to improve early tree survival and performance when planting over an extended dry period. The outcome of the trial at Maramarua Forest was further exacerbated by complications with application of the hydrogel in wet weather resulting in application of the products over the top of seedlings rather than to the root zone. Nevertheless, the trial was valuable in that it has demonstrated the limitations of the M-Planter when planting in wet conditions and in clay soils, an outcome that can be used to improve the performance of the M-Planter in future operations conducted under similar conditions. Already, M-Planter NZ is evaluating designs for the M-Planter that could potentially improve the movement of the seedling down the planting tube in wet weather as well as providing better compaction around the planting hole when operating in clay soils. Similar issues associated with 'open planting holes' have not been experienced when the machine has planted in sandy soils or clay loams.

Outcomes from this trial should be used to guide the next steps in understanding the potential of hydrogels to:

- extend the planting season outside of the current window (May to October) or provide a moisture buffering capacity in the case of unseasonable droughts;
- provide a medium for inoculating the newly planted stock with nutrients and/or beneficial microbes to increase capacity to withstand stress at the time of planting.
- provide on-going benefits to the tree crop as they degrade *in-situ*.

If further work with the hydrogels is a high priority for forest growers, we recommend that fundamental work is undertaken to understand the water retention characteristics of hydrogels and their effect on plant available water when used at different concentrations and volumes across a range of forestry soils. Such an approach would underpin a more structured understanding of the optimum hydration for the product(s) and the amount to apply at planting (0.25 mL or 1 L), plus enable an estimation of the period over which the hydrogel(s) is likely to provide a buffer against extreme dry weather conditions, if at all. Without this information it will be challenging to provide foresters with the decision-making tools required to estimate when to use the hydrogel, how much to use, how to apply it and the period over which the hydrogel is likely to provide a buffer to extremely dry conditions. Ultimately, the decision will be driven by the cost:benefit which can only be determined when we have an estimate of: 1) the probability of improved survival/tree performance, 2) the amount of hydrogel and water required at the time of planting and 3) the cost of the product to be used.

# ACKNOWLEDGEMENTS

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# APPENDICES

## Appendix 1: Summary of analyses

Table A1. Summary of the analyses used in this report. Means followed by different letters are significantly different.

| Variate | F-value (df) | Mean | | | | SE |
|---|---|---|---|---|---|---|
| | | Control | Water | Nanocellulose | Aquasorb™ | |
| gld at planting (mm) | 10.5 (3/600) | 4.2a | 4.1ab | 3.9b | 3.7c | 0.07 |
| gld 5 months (mm) | 47.3 (3/566) | 8.6a | 6.8b | 6.6b | 6.4b | 0.15 |
| ht at planting (cm) | 4.4 (3/600) | 39.3b | 41.4a | 40.6ab | 39.0b | 0.53 |
| ht at five months (cm) | 6.7 (3/566) | 46.1a | 43.3b | 43.6b | 42.2b | 0.65 |
| Biomass index at planting | 8.9 (3/600) | 7.5a | 7.4a | 6.6ab | 5.6b | 0.29 |
| Biomass index at five months | 42.4 (3/566) | 40.9a | 21.2b | 20.7b | 18.9b | 1.63 |