FOREST GROWERS RESEARCH

Precision Silviculture Partnership

TECHNICAL NOTE

PSP-TN 001 FGR334 _CN12407
Basic Hydrogel Trials PSP 2.4.2 Date: February 2024

Nanocellulose hydrogels & soil water retention

Summary

The utility of nanocellulose hydrogels as a soil amendment to help increase soil water retention is unknown. We conducted pilot experiments in jars with forest soil and sand to understand the hydrogel's impact on soil water content. The results showed different soil types exhibited varying rates of water loss when amended with nanocellulose hydrogels. We also found the nanocellulose hydrogels will quickly lose water to the atmosphere if they are not covered, but that adding nanocellulose hydrogels to soils slows rates of water loss relative to just water. The next steps are to complete water retention curves for Brown and Pumice soil amended with different amounts of nanocellulose and synthetic hydrogels.

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Introduction

For mechanical planters to be economically feasible, the planting season must be extended outside of standard planting windows. This presents logistical challenges as outside of the typical planting season, soil environmental conditions are potentially warmer and drier than is optimal for tree establishment. Adding hydrogels to the rootzone during planting may help mitigate these negative impacts by extending the time water is available to the newly planted tree. Hydrogels generally retain water and slowly release it, extending the water supply for the seedling to establish their roots into surrounding soil.

Together with Scion, AgriSeaNZ Ltd have used a seaweed derivative to develop a nanocellulose hydrogel. This organic hydrogel is easily biodegradable and therefore will not accumulate and become toxic in soils as occurs with some synthetic hydrogels. However, it's utility as a soil amendment is unknown. A previous field trial aimed to test if nanocellulose hydrogels benefited seedling growth during dry conditions outside of the typical seasonal planting window unexpectedly received rain, confounding any treatment effects (Ford et al., 2023; Ford et al., 2022). Controlled evaluation of how nanocellulose hydrogel impacts soil water availability in different forest soils will help determine whether they confer benefits to seedlings during establishment.

To better inform future work, we conducted a series of pilot experiments aimed at gaining some preliminary understanding about how nanocellulose hydrogels impact soil water content.

Methods

We conducted four tests to develop some understanding of nanocellulose hydrogel behaviour in soils. All tests used 1000 mL jars (lids off). We used two soil types: forest soil (high in organic matter) and sand. These were selected because of their contrasting properties.

Test 1 measured rates of water loss from nanocellulose hydrogel amended soils. In jars, we applied 50 or 100 mL of nanocellulose hydrogels between two 50 g layers of dry forest soil or sand. We weighed jars over time to estimate water loss.

Test 2 evaluated water loss from soil amended with nanocellulose hydrogel and water when the amendments are mixed with the soil to distribute it throughout the soil. Using dry sand or forest soil, we added 100 g soil, 25 mL hydrogel, 25 mL water, and mixed the soil and amendments together in jars. This mixture was covered with 100 g dry soil. Jars were weighed over time to estimate water loss.

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Test 3 estimated rates of water loss from soils amended with nanocellulose hydrogels placed at different depths. To the jars, we added 100 mL of nanocellulose hydrogels to 100 g of dry sand or dry forest soil in the following configurations:

- Bottom 20 g soil, covered with 100 mL nanocellulose hydrogels, topped with 80 g soil,
- Bottom 50 g soil, covered with 100 mL nanocellulose hydrogels, topped with 50 g soil, and
- Bottom 80 g soil, covered with 100 mL nanocellulose hydrogels, topped with 20 g soil.

Test 4 evaluated if water loss from soil amended with nanocellulose hydrogel differed from soil amended with equivalent volumes of water. We added 100 mL of nanocellulose hydrogels to 100 g of dry forest soil in the following configurations:

- Bottom 50 g of soil, 100 ml nanocellulose hydrogel, covered with 50 g of soil, or
- Bottom 50 g of soil, 100 ml water, covered with 50 g of soil.

We also evaluated whether rates of water loss differed between nanocellulose hydrogels, water, and nanocellulose hydrogels mixed with water in the absence of soil. To an empty jar, we added:

- 100 mL water,
- 100 mL nanocellulose hydrogels, and
- 100 mL water + 100 mL nanocellulose hydrogels.

Preliminary results and implications

Test 1 showed average daily water loss was 4.1-5.6% lower from forest soil compared to sand (Figure 1). There was <1% difference in average daily water loss from different volumes of nanocellulose hydrogels within the same soil types.

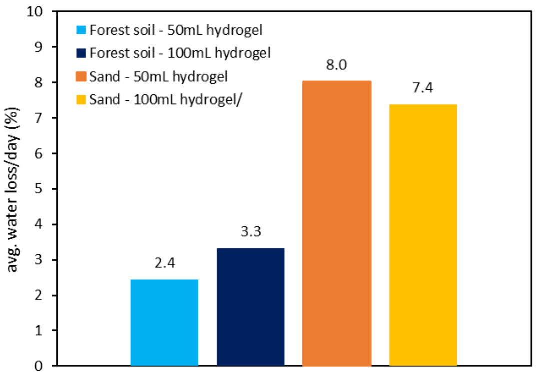

Figure 1 shows the average rate of water loss (%) / day with the value placed above each bar.

Test 2 showed that when nanocellulose hydrogels and water were mixed with soil, daily average water loss from forest soil (1.3 %/day) was lower relative to sand (3.6 %/day) (Figure 2).

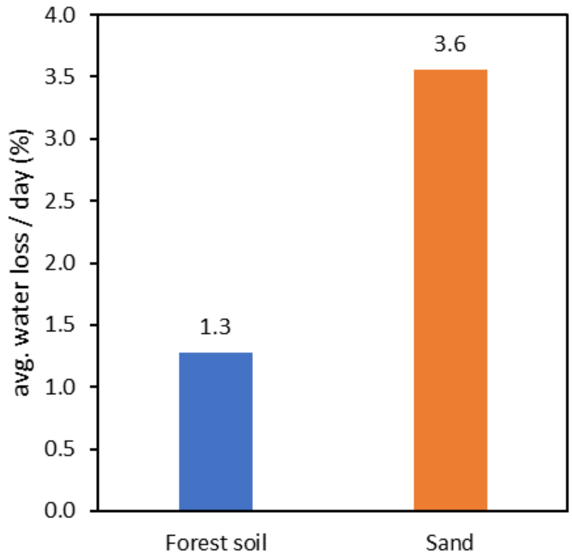

Figure 2 shows change in water content over time for the sand and forest soil with hydrogels mixed with soil and water and covered.

Different soils exhibited varying rates of water loss when amended with nanocellulose hydrogels. This suggests that the nanocellulose hydrogel's ability to supply water to soil is partially dependent on the interaction between the hydrogel properties and soil properties. For example, forest soil contains more organic matter than sand. This organic matter might interact with the nanocellulose in the hydrogel to bind water, reducing rates of water loss. In the forest soil, the hydrogel might change the nature of water-soil contact more significantly than in sand. The nature of these soil type differences will be further explored in future experiments.

Test 3 showed deeper placement of hydrogels in the soil slowed rates of water loss. Covering nanocellulose hydrogels with 80 g of dry soil resulted in water loss that was 2% and 3.8% lower compared to nanocellulose hydrogels covered with 50 and 20 g of dry soil, respectively (Figure 3).

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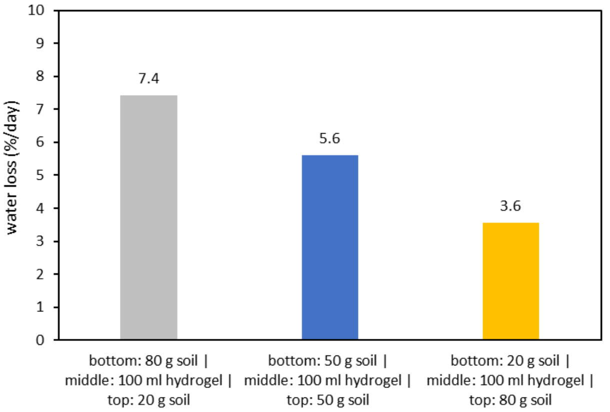

Figure 3 shows the average rate of water loss (%) per day for different burial depths, with deeper burial depths resulting in reduced rates of water loss

Test 4 showed that when comparing forest soil amended with nanocellulose hydrogel or amended with the equivalent amount of water, rates of water loss were 53% higher from the just water amended soil (Figure 4).

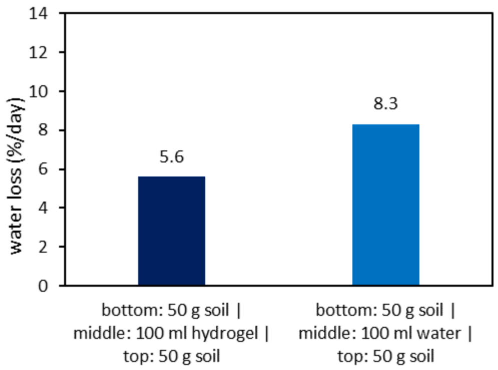

Figure 4 The rate of water loss from the soil amended with hydrogels is lower than from the soil amended with an equivalent amount of water

However, when we measured water loss from water, hydrogels, and hydrogels mixed with water in jars without soil, rates of water loss were similar (Figure 5).

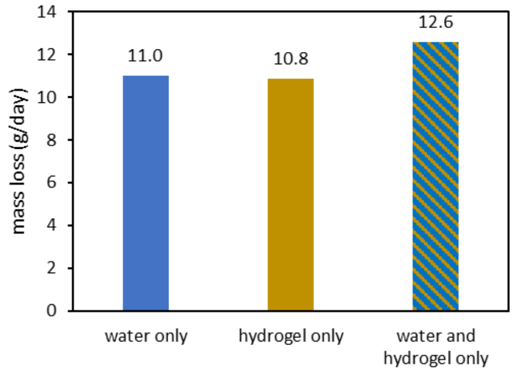

Figure 5 The rates of water loss (g/day) for water, hydrogel, and water + nanocellulose hydrogel amendments without soil are similar

These nanocellulose hydrogels are composed of 1% nanocellulose and 99% water, and they will quickly loose water to the atmosphere if they are not covered. However, the results also suggest that adding nanocellulose hydrogels to soils slows rates of water loss relative to just water. We cannot resolve the mechanisms responsible for this yet, however, the performance of trees planted with nanocellulose hydrogels, synthetic hydrogels and water will be compared in an upcoming pot trial. Because the nanocellulose hydrogel is a liquid consistency, its effect is unlikely to be attributed to changes to soil physical properties that affect water holding capacity such as porosity or pore size distribution. However, the nanocellulose hydrogels could be affecting the way water occupies soil pores, leading to lower rates of water loss. For example, there could be chemical interactions occurring between the soil and nanocellulose hydrogels. Cellulose is hydrophilic and this attracts water, but soil may not be sufficient to change the evaporation rate of water from the hydrogel alone. When added to soil, these interactions could influence how water is bound or released, reducing soil evaporation rates in soil amended with nanocellulose hydrogels relative to just water.

Next steps

The next steps are to complete water retention curves for soil amended with different amounts of nanocellulose hydrogels. Soil water retention curves will be run by the soil physics laboratory in Manaaki Whenua – Landcare Research. We will use Pumice and Brown soil, and four levels of nanocellulose hydrogels.

Water retention curves use pressure plates to assess how water is held by and released from soil over the whole moisture spectrum based on soil characteristics. Pressure plates operate by exerting controlled, incremental suction on a soil sample, providing a relationship between soil water retention and soil water content at various tension levels. How an amendment impacts soil water retention is a function of both soil and amendment properties. This work will inform if the nanocellulose hydrogel increases soil water retention and by how much relative to unamended soil. Unlike synthetic hydrogels that swell and hold water, and release water through osmotic pressure gradients, physical pressure, desorption, or degradation of the material, the nanocellulose hydrogels are standardized to 1% nanocellulose/99% water during manufacturing

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and cannot be rehydrated. Test 4 showed that water freely evaporates from the nanocellulose hydrogels when exposed to the atmosphere. This could impact how we interpret the water retention curves. We are planning to add nanocellulose hydrogels to the top of intact soil cores, however, this method could underestimate the impact that the hydrogels have on the soil water retention curves as we anticipate some water from the nanocellulose hydrogels to be lost to the atmosphere through evaporation.

References

Ford, C., Coker, G., Smaill, S., Fleet, K., Hill, S., Moore, J., Lloyd, A., & Stovold, T. (2023). *Investigation of extending the planting season into late March using hydrogels Final report: 12 months* (Precision Silviculture Programme, Forest Growers Research. Report No: PSP-T007, Issue.

Ford, C., Coker, G., Smaill, S., Lloyd, A., Stovold, T., Fleet, K., Hill, S., & Moore, J. (2022). *Investigation of extending the planting season into late March using hydrogels and growth promoters.* (Precision Silviculture Programme, Forest Growers Research. Contract 9738., Issue.

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