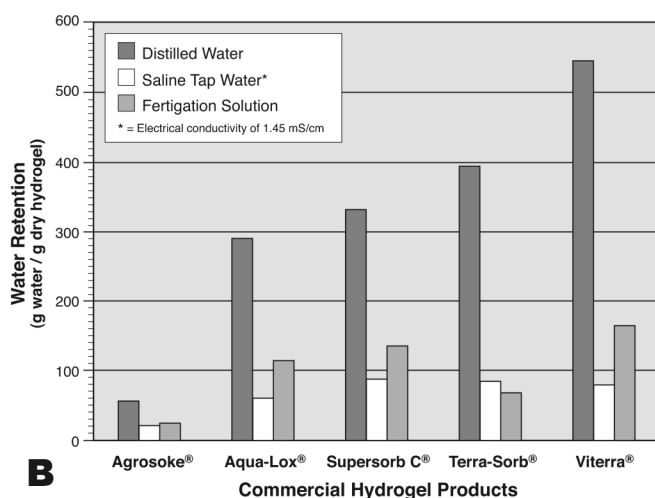


Uses for Hydrogels in the Nursery and During Outplanting

by Thomas D. Landis

Introduction

Hydrophilic gels, or “hydrogels”, which are commonly known as superabsorbents, are crosslinked polymers that can absorb 400 to 1500 times their dry weight in water (Figure 1A). Most of the early hydrophilic polymers were destined for non-agricultural uses, most notably baby diapers, but have also found uses in such diverse applications as oil recovery, food processing, water purification, and wound dressings (Peterson 2002).



Hydrophilic polymers can be categorized into three classes (natural, semi-synthetic, synthetic), but can be chemically manipulated to produce products with different characteristics in each class (Mikkelsen 1994).

1. Naturally occurring polymers are starch-based polysaccharides that are made from grain crops such as corn and wheat. Natural polymers are most commonly used in the food industry as thickening agents.
2. Semi-synthetic polymers are derived from cellulose, which is chemically combined with petrochemicals. One of the first hydrogels specifically designed for horticulture was a polyethylene polymer combined with sawdust (Erazo 1987).
3. Synthetic polymers are solely made from petrochemicals. Linear chain polyacrylamides are used for erosion control, canal sealing, and water clarification whereas crosslinked polyacrylamide hydrogels are used in horticulture (Peterson 2002).

The absorptive capability of hydrogels is affected by the chemical composition as well as environmental factors, such as the dissolved salts in the surrounding water solution. Mikkelsen (1994) states that divalent ions, such as calcium (Ca^{++}) and magnesium (Mg^{++}), are more restrictive than monovalent ions, such as ammonium nitrogen (NH_4^+) and potassium (K^+). One research trial soaked commercially available hydrogels in several different solutions including distilled water, moderately saline tap water (electrical conductivity of 1.45 mS/cm), and a dilute fertilizer solution. After soaking, the saturated hydrogels were allowed to drain to determine their absorptive capacity. The optimal absorption is reflected by the weight of water retained in the distilled water treatment, in which the hydrogels varied considerably (Figure 1B). Agrosoke® absorbed and retained considerably less water than the other hydrogels, with Viterra® retaining the most. The effect of dissolved salts of the amount of water that can be absorbed by the various products can be seen in the other two treatments: the saline tap water and the

Figure 1 - Hydrophilic gels, commonly known as hydrogels, are dry crystals that can absorb many times their own weight in water (A). The amount of water that can be retained depends on their chemical composition and environmental factors like the salts dissolved in the surrounding solution (B) (A, courtesy of David Steinfeld; B, modified from Wang and Gregg 1990).

fertilization solution. The tap water reduced the water retention of the commercial hydrogel products substantially, from a 65% decrease in Agrosoke® to almost 85% in Viterra®. Because it contained a variety of fertilizer ions, the water retention for dilute fertilizer treatment was different again (Wang and Gregg 1990). The bottom line is that the laboratory absorption values using distilled water are significantly different than the amount of water that can be absorbed and retained in the nursery or on the outplanting site.

Exactly how hydrogels will benefit plants depends on how they are applied. When incorporated into growing media or soil either at the nursery or on the outplanting site, hydrogels absorb and retain water that would normally be lost to evaporation or leaching. They have also been shown to retain nutrient ions that could be leached out of the root zone (Mikkelsen 1994). When applied as a root dip, hydrogels coat fine roots and protect them against desiccation. One potential benefit that I hadn't considered is that hydrogel dips may function similar to the natural polymeric mucilages produced by healthy roots. One recent study demonstrated that mucilage weakens the drop in water potential at the root-soil interface, increasing the conductivity of the flow path across soil and roots and reducing the energy needed to take up water (Carminati and Moradi 2010). Hydrogel root dips provide the same function, improving root-to-soil contact (Thomas 2008), and filling-in air spaces around transplants or outplanted seedlings (Figure 2).

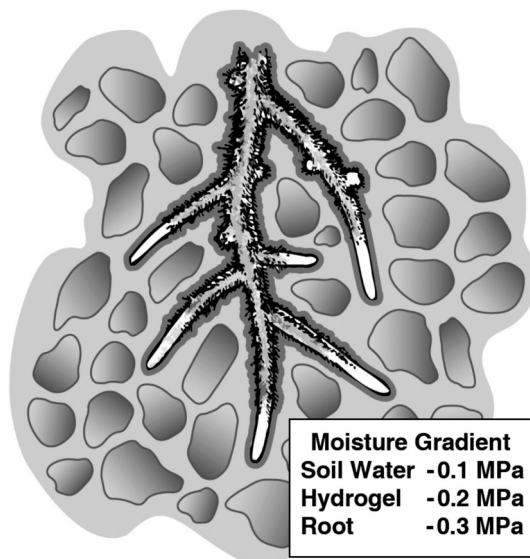


Figure 2 - When hydrogels are applied as root dips, they function like the mucilage naturally produced by healthy roots and improve water uptake by increasing root-to-soil contact and filling-in air spaces.

Application of hydrogels in nurseries, reforestation, and restoration

The main use of hydrogels has been to retain water for plant growth especially when irrigation isn't provided, but new uses are continually being discovered.

1. Gel seeding - This was one of the first applications of hydrogels in horticulture and involves sowing seeds mixed into a hydrogel. The objective is that the hydrogel will retain moisture around the germinating seeds and improve establishment either in a nursery or on an outplanting site. Research trials coating leguminous tree seeds with hydrogels before sowing in a greenhouse or in field soil showed mixed results among plant species; larger-seeded species survived and grew better. One hypothesis was that coating seeds with hydrogels may reduce germination and emergence by reducing aeration around the seeds (Henderson and Hensley 1987). In a more recent test, hydrogels were applied to seeds of Scotch pine (*Pinus sylvestris*) and Austrian pine (*Pinus nigra*) prior to germination tests in the laboratory, greenhouse, and in a bareroot nursery. The hydrogel treatment reduced germination percentage for both species in the laboratory but Scotch pine germinated better than the controls in the greenhouse. In spite of these germination problems, the authors considered that the improved seedling growth after 2 years in the bareroot nursery justified the use of hydrogels in future trials (Sijacic-Nikolic and others 2010). The paucity of other published trials in recent years suggests that gel seeding has little application in forest and native plant nurseries or for direct seeding on project sites.

2. Root dips - The concept of dipping plant roots before transplanting or outplanting has been around for many years because it is intuitively attractive. Roots of nursery plants dry as they are exposed to the atmosphere during harvesting and handling and so it would only make sense to rehydrate them or apply a coating to protect them (Chavasse 1981). Southern nurseries have been dipping the roots of their bareroot stock in a clay slurry for decades, but many have switched to hydrogels in recent years (for example, Bryan 1988). In the western states, the use of root dips is less common but some forestry organizations sell protective root dips as part of their tree distribution programs (for example, Kansas State Forest Service 2010). For a comparison of the various root dip products and their effectiveness, see "Protective root dips: are they effective" (Landis 2006).

John Sloan did a very comprehensive literature review of root dips and concluded that they were detrimental to bareroot stock when applied before storage (Sloan 1994). After outplanting, most of the research at that time showed that hydrogel root dips do not increase survival or growth under very dry conditions and are merely an added expense. One conclusion of this review that I strongly agree with is that, while rootdips can be beneficial in protecting seedlings from exposure to sun and wind, tree planters should not assume that root dipping will restore seedling vigor after improper handling.

Another limitation of comparison trials of root dips is that all too often no appropriate control was included. Many tests were done against no root dip at all but, because all hydrogels are applied in a water slurry, it just makes sense to use a water dip as a control. One recent research study did just that, and tested 3 hydrogel-based root dips against a water dip control (Bates and others 2004). The seedlings of 4 bareroot conifers were dipped into one of 3 commercial root dips or a water control. When evaluated for survival, none of the products showed a significant improvement over the water dip; likewise, the commercial root dips gave no appreciable shoot growth benefit after 2 years (Figure 3).

The vast majority of research has been with bareroot conifer seedlings and, interestingly enough, I could only find one published article on dipping the roots of container plants in hydrogel prior to outplanting. When 2 species of Eucalyptus container seedlings had their root plugs dipped in a hydrogel slurry, mortality at 5 months after outplanting was more that cut in half

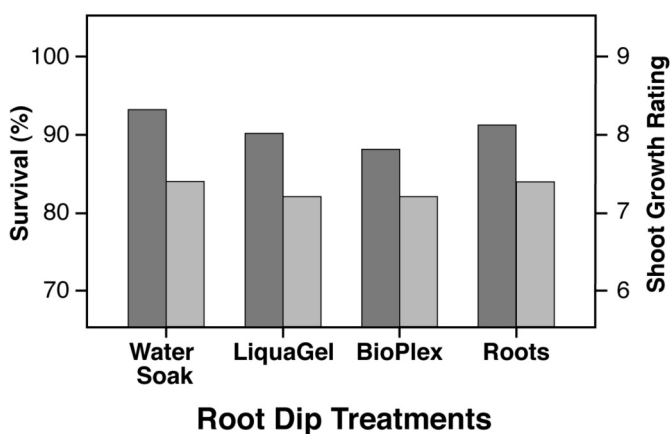


Figure 3 - Compared to a water soak, none of three hydrogel root dips improved survival or shoot growth of four conifer seedlings two years after outplanting (Bates and others 2004).

(Thomas 2008). Likewise, only one study looked at the effects of hydrogel dips on bareroot hardwood seedlings. When the roots of red oak (*Quercus rubra* L.) seedlings were dipped into a hydrogel slurry, and then subjected to drought stress, the hydrogel-treated seedlings had greater root moisture content and less root membrane leakage than plants without root dipping. These differences were not reflected in increased growth, however (Apostol and others 2009).

Both of these studies stress the importance of using the fine grade of hydrogel when root dipping; using hydrogel with dry particle sizes from 0.2 to 0.3 mm covered roots much better than larger grades which clumped and fell off the roots (Sarvas 2003). Terra-Sorb® is available in 3 particle diameters: coarse (2 to 4 mm), medium (0.75 to 2 mm) and fine (0.10 to 0.75 mm), with the fine grade recommended for root dipping (Plant Health Care 2010).

I also could find only one article on the use of hydrogel dips before transplanting in a bareroot nursery, which I assume would lessen transplant shock. Dipping bareroot Norway spruce (*Picea abies*) seedlings prior to mechanical transplanting increased shoot height and root collar diameter compared to the controls (Sarvas 2003).

3. Amendment to container growing media - Another application that has been widely tested is the incorporation of hydrogels into growing media prior to sowing as a means to hold more water and reduce moisture stress. In addition to increasing water holding capacity, hydrogels have been shown to retain nutrient ions against leaching especially in growing media with low cation exchange capacities. One trial found this to be true for the cations ammonium and potassium, but not for the anionic nitrate which is one of the major causes of nutrient runoff from nurseries (Henderson and Hensley 1985).

Many earlier studies showed that, while hydrogels definitely increased the water holding capacity of the growing medium, this was not always reflected in increased plant growth. When birch seedlings were grown in a hydrogel-amended medium, subsequent growth was actually reduced compared to the control seedlings (Tripepi and others 1991). The authors suggest that the reduced growth could be a result of reduced aeration resulting from less macropore space in the gel-amended media. This observation was supported by reduced root mass in the seedlings from the gel treatment. Another study found that air space

in pine bark and pine bark/sand media was reduced in the hydrogel-amended growing media (Fonteno and Bilderback 1993).

In operational practice, I'm not aware of any nurseries who use a growing medium amended with hydrogels, although many such products are available for the non-professional or home gardener (Figure 4). Good growers want complete control of the water-holding capacity of their growing media, which would be lost with hydrogel amendments. Also, the swelling hydrogel particles have to expand somewhere after hydration and undoubtedly reduce the amount of macropores which are so essential for good drainage and air exchange.

4. Soil amendment during outplanting - The final application for hydrogel is to amend soils on the outplanting site, especially on droughty or severely-disturbed sites. The method of application is important and incorporating hydrogels in the rooting zone is much more effective than applying them in a band



Figure 4 - Many brands of growing media for the home gardener contain hydrogels.

or layer (Kjelgren and others 1994). When 8 grams of hydrogel was applied per kilogram of 3 different soil textures, the available water content increased 1.8 times that of the unamended control for the clay, 2.2 times for the loam, and 3.2 times for the sandy loam soil (Abedi-Koupai and others 2008). In another study, 2 rates of hydrogel were added to 5 different soil textures ranging from sand to clay and then seedlings of 9 different tree species were planted in pots with both treatments and a control (Agaba and others 2010). The plants were subjected to moisture stress treatments in a greenhouse until some seedling mortality occurred. The percentage of plant available water increased from around 100% in the clay to almost 300% in the sandy soil, and these results were mirrored very closely by the survival of the tree seedlings (Figure 5). As can be seen, hydrogel amendments are most effective on sandy soils and in droughty environments. When a sandy soil was amended with a range of

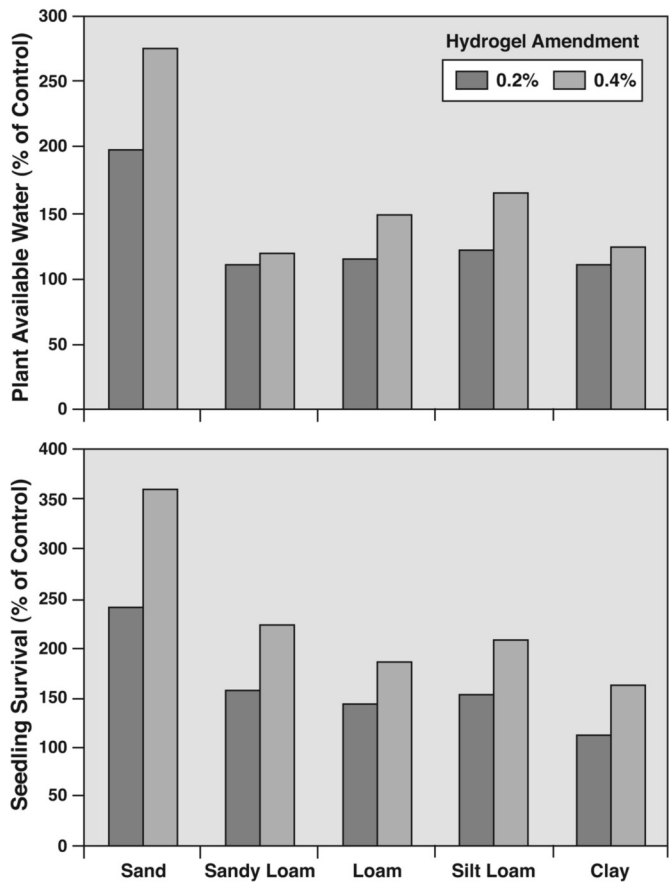


Figure 5 - Hydrogel amendments incorporated into a range of soil textures significantly increased plant available water and seedling survival compared to the controls (modified from Agaba and other 2010).

hydrogel treatments and planted with *Pinus halepensis* seedlings, the water retention of the soil increased exponentially with increasing additions of hydrogel. When the seedlings were subjected to controlled desiccation, the seedlings in soils with the highest amount of hydrogel survived twice as long as in the plants in the control soils. Water potential measurements showed that seedlings in the amended soils had considerably less moisture stress than the controls. Shoot growth and root growth were also significantly increased with the hydrogel amendment (Huttermann and others 1999).

One of the things almost never presented in research studies is cost of the hydrogel treatment. The only reference that I found was for Eucalyptus seedlings where a sandy soil was amended with hydrogel; the cost per plant was increased 17 to 27% while improving survival by a factor of three (Callaghan and others 1989).

Summary

Hydrophilic polymers have been used in agriculture for over 40 years, and a variety of products are available for a wide range of uses both in the nursery and on the outplanting site. When incorporated into growing media or soil either at the nursery or on the outplanting site, hydrogels absorb and retain water that would normally be lost to evaporation or leaching. Hydrogels have also been shown to retain cationic nutrients against leaching. When applied as a root dip, hydrogels protect the roots against desiccation and increase the root-to-soil contact after outplanting. Because of the extreme variation between products and environmental conditions, it is impossible to generalize about whether to use hydrogels or not. As with most things in our business, growers or plant considering the use of hydrogels should conduct small scale trials under their own conditions. For root dips, just giving plants that added measure of care may increase outplanting performance.

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