The Use of Rootdips on North American Conifer Seedlings: A Review of the Literature

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Many foresters are root dipping their bareroot conifer seedlings before planting or have done so in the past. This paper discusses different rootdip substances and reviews the many research studies on root dipping published in the last 25 years. Root dipping can help tree seedlings maintain water in their roots before planting. However, rootdips do not improve seedling survival after planting on harsh sites and they have been shown to be detrimental during storage. Tree Planters' Notes 45(1):26-31; 1994.

North American foresters often look for products and methods that can improve the survival and growth of planted tree seedlings. Root dipping is one practice that has been used. Root dipping is the process of coating the root system of bareroot seedlings with some kind of moisture--holding or growth-stimulating substance before planting.

Rootdips of various types have been used on conifer seedlings for 40 years. Foresters and nursery managers have root-dipped seedlings to prevent them from drying out in storage, to prevent roots from desiccating at the planting site, and to improve seedling survival and growth after planting.

The substances that are being or have been used for root dipping generally fit into one of four categories: (1) soil slurries; (2) vermiculite or ground sphagnum moss; (3) hydrophilic gels; and (4) other materials, including organic compounds, bioregulatory compounds, pesticides, or other chemicals.

Soil slurries are most often made from clay or loam soils mixed with water to form a thick mixture. When coated on the root system, the clay particles hold water tightly and resist drying.

Number 4 agricultural grade **vermiculite** has been used with water to make a rootdip that does not hold moisture as tightly as clay particles. Ground vermiculite has been used to a limited extent, as has ground peat moss. Ground vermiculite suspended in water has texture and other properties similar to those of a clay slurry.

There are four kinds of **hydrophilic gels** used in agriculture (Johnson 1985):

1. Hydrolyzed starch-polyacrylonitrile graft co-polymers
2. Urea-formaldehyde resin foams
3. Vinyl alcohol-acrylic acid co-polymers
4. Cross-linked acrylamide co-polymers

These gels can absorb between 40 and 500 times their weight in water. The amount of water held by the expanded gel depends on the chemistry of the polymer and the conditions under which it was formed, as well as the chemical composition of the soil solution (Johnson 1984). Some of the commercial hydrophilic gels that have been used for root dipping include Agricol®, Aquagel®, Collatex®, Terra Sorb®, Hydrosource®, Broadleaf P4®, Waterlock®, and Viterra®.

Other chemicals and bioregulatory substances have also been tried for root dipping. Some of them contain humic substances or products of fermentation. Manufacturers claim that these products increase seedling survival and growth by enhancing nutrition or environments for beneficial microorganisms, or through other, secret processes. They are unlike the rootdip substances I have just described because they do not attempt to hold water in the root zone. Instead, they attempt to increase seedling vigor or provide nutrients.

History

Root dipping was conceived in the late 1950's as a way to protect southern pines against desiccation when their roots were exposed to sun and wind (Slocum and Maki 1960). This procedure was often called "puddling" and used a thick slurry made from clay soil and water (Hermann 1962, Rook 1970, Slocum and Maki 1960). Puddling was later used to protect the seedlings from desiccation during storage (Dierauf and Marler 1969 & 1971, Broerman and Hamner 1966, Mullin and Hutchinson 1977, Williston 1967, Mullin and Bunting 1979). Other substances that held water were also tried throughout North America.

In the early 1970's the USDA Forest Service's Intermountain Region made root dipping in a vermiculite and water mixture a standard step in preparing bareroot seedlings for planting. Vermiculite, like clay, is able to absorb and hold water that would otherwise evaporate or drip off the roots. A variation of the vermiculite method was developed on the Targhee National Forest. A pump was used to keep the vermiculite suspended in water. The pump ground the vermiculite to form a slurry that looked, felt, and acted much like day slurry. Other readily available materials that can hold water, such as ground peat moss (Dahlgreen 1976) and sawdust (Rook 1970), also have been used.

The hydrophilic gels appeared in the late 1960's and have gained popularity as they have improved over the years. Testing began in the early 1970's (Owston and Stein 1972, Miller and Reines 1974, Mullin and Hutchinson 1977). The purpose of hydrophilic gels, like many other rootdips, is to coat the roots with water-filled granules that gradually release loosely bound water as the soil dries around planted seedlings. Early formulations tended to deteriorate after only a few months of use in the soil. However the most recently developed polyacrylamide formulations can last more than 5 years.

Effectiveness

Table 1 presents the results of a number of rootdip studies on conifer seedlings. Most of the references deal with clay and hydrophilic gel slurries. The effects of root dipping seem to vary with the species, site, and methods of study.

In table 1, the studies are classified into three categories:

- Seedlings were root dipped before storage to determine the impacts on storage.
- Seedlings were root dipped and then intentionally exposed to dry air, sun, and/or wind for a given length of time to determine if the rootdip can ameliorate the harmful effects.
- Seedlings were root dipped and not exposed to dehydrating conditions to see if the rootdip has beneficial effects after planting.

Within each group of research studies, the reported results were mostly in agreement.

In the first category, the investigators found that rootdips can be detrimental to seedlings during storage (Williston 1967, Dierauf and Marler 1969, Owston and Stein 1972).

Research in the second category indicates that clay slurries and hydrophilic gels can prevent desiccation and increase seedling survival when roots are exposed to dry air for extended periods before planting (Williston 1967, Dierauf and Marler 1969 & 1971, Owston and Stein 1972, Tabor and Davey 1966, Goodwin and Williams 1980). However, when planting stock is properly handled and protected against detrimental exposure, as in the third category, almost all of the studies show rootdips do not increase seedling survival or growth (table 1).

In the third category, some research shows rootdips to be least effective under droughty conditions where the most improvement in seedling performance might be expected (Echols and others 1990, Sloan 1994). Magnussen (1986) showed that a Waterlock® rootdip increased the survival of white spruce during 2 weeks of drought after planting but had no effect if the drought lasted longer than 2 weeks. Similarly, Tung and others (1986) found that Terra Sorb® delayed some Douglas-fir mortality by 2 to 3 weeks during summer but did not affect season-end survival or growth. Echols and others (1990) improved loblolly and shortleaf pine survival on a moderate site using Terra Sorb® but there was no improvement using the rootdip on a harsh site. They suggest that the rootdip may have helped the seedlings planted on the moderate site through a short-term drought.

This seems to indicate that the amount of water held by rootdips is sufficient to keep the seedlings alive for a short time. However, it is not great enough to change dry planting site water relations over the course of a summer. Another reason for the short-term effects of the rootdips is that as a seedling establishes itself in the soil, its root system expands beyond its original form where the rootdip substance remains. The new roots, the more efficient water absorbers, leave the rootdip particles behind as the roots grow out from the seedling. Then, as the rootdip particles dry, they contract, leaving an air space next to the roots until the dry conditions subside.

There were many other studies in the third category (table 1). Kroll and others (1985) improved loblolly pine survival using a Terra Sorb® rootdip on a droughty site. The other studies reported no improve-

Table 1-*Summary of results for published rootdip field studies with North American conifers*

Species	Study type	Results	Reference
Douglas-fir *Pseudotsuga menziesii* (Mirb.) Franco	3	Symbex® rootdip did not affect seedling survival or height growth after 3 years.	Dunsworth (1985)
	2	Rootdips prevented desiccation in root systems exposed for 40 minutes. Xanthan gum was more effective than clay or alginate. All three of the rootdips increased plant moisture stress during storage.	Owston and Stein (1972)
	3	Terra Sorb® rootdip delayed 1st-year mortality but did not affect seedling season-end survival or growth.	Tung and others (1986)
Douglas-fir *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco	3	Vermiculite, peat moss, and Viterra© rootdip treatments did not increase seedling survival or growth.	Ryker (1981)
	3	Neither vermiculite nor vermiculite slurry improved seedling height or root growth. Thick slurries were detrimental.	Sloan (1994)
Noble fir *Abies procera* Rehd.	1,2	Rootdips prevented desiccation in root systems exposed for 40 minutes. Clay was more effective than xanthan gum or alginate. All three of the rootdips increased plant moisture stress during storage.	Owston and Stein (1972)
Jack pine *Pinus banksiana* Lamb.	3	Terra Sorb® and Terra Verde® rootdips did not consistently increase seedling survival.	Alm and Stanton (1990)
	3	Agricolg rootdip and clay rootdip treatments did not increase seedling survival or growth.	Mullin and Hutchinson (1977)
Loblolly pine *Pinus taeda* L.	1	Benomyl® fungicide added to clay rootdip is detrimental during storage.	Boyer and South (1987)
	2,3	Clay root dipping before packing increased survival when seedling's roots were exposed for 5 to 50 minutes. Little difference when roots were not exposed.	Dierauf and Marler (1969)
	2,3	Clay root dipping improved survival and growth of seedlings following exposure of roots, but did not increase survival of unexposed seedlings.	Dierauf and Marler (1971)
	3	Terra Sorb® rootdip increased survival on a moderate site, but did not increase survival on harsh sites.	Echols and others (1990)
	3	Clay slurry and Terra Sorb® rootdips did not increase seedling growth or survival.	Goodwin (1982)
	2	Clay rootdip increased survival of seedlings exposed for 15 and 30 minutes before planting.	Goodwin and Williams (1980)
	3	Seedling survival was poor on droughty site. Terra Sorb® rootdip increased survival. Clay rootdip increased survival slightly.	Kroll and others (1985)
	2	Alginate increased the time to total stomatal closure during moisture stress in a greenhouse.	Miller and Reines (1974)
	2	Clay rootdip increased survival for seedlings with roots exposed for up to 30 minutes and grown in a greenhouse. Rootdip had no effect on early growth.	Tabor and Davey (1966)
	1	Packaging with hydrophilic gels improved seedling survival over packaging with clay slurry.	Venator and Brissette (1982)
	1,2	Clay root dipping before packing decreased the effects of exposure but was detrimental to unexposed seedlings.	Williston (1967)
Lodgepole pine *Pinus contorta* Dougl.	3	Vermiculite, peat moss, and Viterra® rootdip treatments did not increase seedling survival or growth.	Ryker (1981)
	3	Vermiculite, vermiculite slurry, and Terra-Sorb® did not improve survival, or seedling root growth.	Sloan (1994)

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Species	Study type	Results	Reference
Longleaf pine *Pinus palustris* Mill.	1	Prestorage Benomyl® and clay rootdip increased seedling survival over clay slurry rootdip.	Barnett and others (1988)
Ponderosa pine *Pinus ponderosa* Laws.	3	Vermiculite, peat moss, and Viterra® rootdip treatments did not increase seedling survival or growth.	Ryker (1981)
	3	Vermiculite, vermiculite slurry, and Aquagel® did not improve survival or shoot and root growth.	Sloan (1994)
	3	Hydrophilic gel impregnated with auxin (IBA) increased seedling growth and survival. 2,4-D was detrimental when used with hydrophilic gel.	Tuskan and Ellis (1991)
Red pine *Pinus resinosa* Ait.	3	Waterlock® did not increase seedling survival or growth during imposed drought.	Magnussen (1986)
	3	Clay rootdip decreased survival.	Mulin and Bunting (1979)
Shortleaf pine *Pinus echinata* Mill.	1	Prestorage Benomyl® and clay rootdip increased seedling survival over clay slurry rootdip.	Barnett and others (1988)
	3	Terra Sorb® rootdip increased survival on a moderate site, but did not increase survival on harsh sites.	Echols and others (1990)
Slash pine *Pinus elliottii* Engelm.	1	Seedlings were compared for more than 8 weeks of storage without refrigeration. Some seedlings were root dipped in clay, some were stored in sphagnum moss, and others were stored in poly-lined kraft bags. No difference in survival up to 4 weeks. Less than acceptable survival after 8 weeks.	Broerman and Hammer (1966)
	3	Seedling survival was very poor on droughty site, Terra Sorb and clay rootdips did not increase survival.	Kroll and othres (1985)
White pine *Pinus strobus* L.	1,2	Clay root dipping before packing increased survival when seedling's roots were exposed for 5 to 50 minutes. Decreased survival when roots were not exposed.	Dierauf and Marler (1969)
	3	Clay rootdip did not increase survival.	Mullin and Bunting (1979)
Black spruce *Picea mariana* (Mill.) B.S.P	3	Agricol® rootdip and clay rootdip treatments did not increase seedling survival or growth.	Mullin.and Hutchinson (1977)
Engelmann spruce *Picea engelmannii* Parry .	3	Vermiculite, peat moss, and Viterra® rootdip treatments did not increase seedling survival or growth	Ryker (1981)
	3	Neither vermiculite nor vermiculite slurry improved seedling height or root growth. Thick slurries were detrimental.	Sloan (1994)
White spruce *Picea glauca* (Moench) Voss	2,3	Terra Sorb® increased survival following root exposure but did not when roots were protected.	Alm and Stanton (1990)
	3	Waterlock® rootdip increased survival during the first 2 weeks of drought after planting, Did not increase survival or growth when drought lasted longer than 2 weeks.	Magnussen (1986)
	3	Clay rootdip did not increase survival in three tests and was detrimental in a fourth.	Mullin and Bunting (1979)

Study type t = seedlings were root dipped before storage to determine the effects on storage; type 2 = seedlings were root dipped before storage and then intentionally exposed to dry air, sun, and/or wind; type 3 = seedlings were root dipped and not exposed to dehydrating conditions to see if the rootdip had beneficial effects after planting.

ment in seedling performance due to root dipping of Douglas-fir (Dunsworth 1985, Tung and others 1986, Ryker 1981, Sloan 1994), jack pine (Aim and Stanton 1990, Mullin and Hutchinson 1977), loblolly pine (Dierauf and Marler 1971, Goodwin 1982), lodgepole pine (Ryker 1981, Sloan 1994), ponderosa pine (Ryker 1981, Sloan 1994), red pine (Magnussen 1986), slash pine (Kroll and others 1985), white pine (Dierauf and Marler 1969, Mullin and Bunting 1979), black spruce (Mullin and Hutchinson 1977), Engelmann spruce (Ryker 1981, Sloan 1994), and white spruce (Aim and Stanton 1990, Magnussen 1986, Mullin and Bunting 1979). The evidence overwhelmingly indicates that rootdips did not improve seedling survival when the seedlings were not intentionally exposed to sun or wind.

Hydrophilic gel rootdips have another use that is worthy of note. Some researchers use hydrophilic gels to deliver growth hormones or other substances to the seedling. Tuskan and Ellis (1991) loaded a hydrophilic gel with indol-3--butyric acid (IBA) and 2,4-dichlorophenoxyacetic acid (2,4-D) for root dipping ponderosa pine seedlings. Although there were no differences in the greenhouse, IBA increased survival and growth in the field. However, the 2,4-D was detrimental to survival and growth in the greenhouse and in the field tests. More studies to test hormones, pesticides, and other substances for root dips and to determine if hydrophilic gels are the most effective means of delivering these substances to the seedlings are needed.

Rootdips can be beneficial in protecting seedlings from exposure to sun and wind. However, tree planters must resist thinking that they can use root dipping to restore seedling vigor after seedlings have been damaged by improper handling. Proper handling of bareroot seedlings includes guarding against root exposure. Rootdips are not a miracle cure. We must do everything we can to protect bareroot seedlings from damage and to maintain their vigor, whether the seedlings are root dipped or not.

Summary

Several kinds of rootdip formulations have been used during the last 40 years. The most popular are the clay slurries and the hydrophilic gels. One purpose of root dipping is to prevent seedlings' root systems from drying out between the nursery bed and the planting hole. Rootdips have been shown to be detrimental to seedlings during storage. Rootdips do moderate the damaging effects of seedling exposure to sun and wind for a short time.

A second purpose of rootdips is to increase survival and growth of the seedling after planting. Most of the studies reported here show that they do not increase survival or growth under very dry conditions and are merely an added expense. The effects of rootdips under more moderate to moist conditions have not been studied. Considering that root exposure is so harmful to a bareroot seedling, there is no reason to allow it. If seedling root systems are not exposed to drying agents, root dipping is unnecessary.

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