MSU Research Update:

Improving conifer plantation establishment:

Impacts of pre- and post-planting treatments

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Background: How to deal with transplant stress

Nearly all conifers grown for landscape nursery stock or Christmas trees in Michigan and the Great Lakes region are established by planting seedlings or transplants. Plant moisture stress after planting (transplant shock) can be a major limiting factor in the establishment of conifer plantations. Initial survival and growth of newly planted conifers is related to several factors including weather immediately before and after planting, soil conditions, and planting stock quality (Grossnickle, 2005, 2018; Pinto et al., 2016). A variety of techniques and products have been promoted to improve transplant success. These include various root dips, shade blocks, and mulches. Root dips used in conifer establishment include polymers, bio-stimulants, and mycorrhizae, applied alone or in combinations. Polymer root dips are promoted to retain moisture in the root zone and prevent root desiccation before and after planting. Some studies have shown positive responses of transplants to root dips (Alm and Stanton, 1993; Magnussen, 1986), although results vary, and some studies have shown negative effects (Crous, 2017). Bio-stimulants include a range of products designed to enhance root growth after planting. These are often bio-based products that may include kelp extract, plant hormones, and/or nutrients (Khan et al., 2009; Thompson, 2004). Mycorrhizal root dips include inoculum of endo- and/or ecto-mycorrhizae. All conifers that are grown as landscape trees and Christmas trees in Michigan form mycorrhizal associations. Off-the-shelf mycorrhizal inoculants are purported to improve root function of newly planted seedlings by augmenting mycorrhizal fungi that are native in the soil (Castellano, 1996; Rudawska et al., 2017). Mulch can also improve initial seedling survival and growth by reducing evaporation from the soil surface and reducing weed competition, resulting in increased soil moisture (Cregg et al., 2009; Landgren et al., 2021). In addition to approaches to improve below-ground conditions, artificial shading using shade blocks or shingles has been shown to reduce heat load and transpirational water loss of conifers in clear-cuts (Helgerson, 1989; Helgerson and Bunker, 1985; Petersen, 1982) and in regenerating the blast zone at Mount St. Helens (Logan, 1985). Similarly, film-forming anti-transpirants can reduce seedling water loss and may potentially reduce tree stress (Simpson, 1984). More recently, forest regeneration specialists have investigated biochar as a means to improve soil water- and nutrient-holding capacity to improve tree performance (Dumroese et al., 2020), but to date the results with conifers have been mixed (Slesak and Windmuller-Campione, 2023).

Our approach

In order to evaluate the potential of various approaches to reduce transplant stress and improve tree survival and growth in the Great Lakes region, we initiated a series of trials with Christmas tree growers in Michigan (Image 1). We were specifically interested in combining approaches that are applied to trees before planting (e.g., pre-plant root dips) with those that are applied post-planting (e.g., mulch, shade blocks).

2021 Trials: We established initial trials in spring 2021 at four locations, Sidney, MI (Korson's Tree Farm), Gobles, MI (Wahmhoff Farms), Horton, MI (Gwinn's Christmas Tree Farm), and Allegan, MI (Badger Evergreen Nursery) (Image 2). At each farm, we applied four root dip treatments (control, two polymer gels, and a polymer gel + bio-stimulant + mycorrhizae product) and five above-ground treatments (mulch, shade, mulch + shade, anti-transpirant, and control), resulting in 20 treatment combinations (Table 1). Fraser fir transplants (2+2 or plug+2) were installed using the growers standard planting equipment and procedures. At all locations, trees were machine-planted. Immediately prior to planting, we dipped transplants in selected root dips, including an untreated control (water only). We applied root dips by dipping seedling roots into each product mixed in 5-gallon plastic buckets per labeled recommended rates (Image 3). Care was taken to prevent cross-contamination between treatments when applying dips and during planting. After the trees were planted, we applied mulch and shade treatments. Trees were mulched to 3" depth in an 8" radius around each tree (Image 4). Mulches consisted of ground wood chips or ground bark, depending on the farm. Mesh shade blocks (8" x 12" Mesh Envelopes, PacForest Supply Co., Springfield, OR) were installed on the south side of trees (Image 5). We applied an anti-transpirant (Wilt-Pruf) immediately after planting by spraying the product on the seedlings to run-off. The anti-transpirant was re-applied in mid-July. Each test consisted of 400-600 trees, depending on the location. Two of the farms (Sidney and Horton) provided supplemental irrigation while the other two did not. Survival was excellent (95% or greater) across all farms and neither root dips or mulch improved survival. For the farms that did not irrigate, however, mulch and shade blocks improved shoot growth (Table 2). Root dips did not improve leader growth relative to the control trees (water dip) on irrigated or non-irrigated farms. The anti-transpirant reduced seedling transpiration rate but also reduced seedling photosynthesis, resulting in a net decrease in tree growth (Table 2).

2022 Trials: In 2022 we focused our investigations on farms that did not irrigate and added smaller, choose and cut farms. In addition to Gobles and Allegan, we added plots in Milford,

Image 1. Completed 2021 plot installation in Allegan, MI.

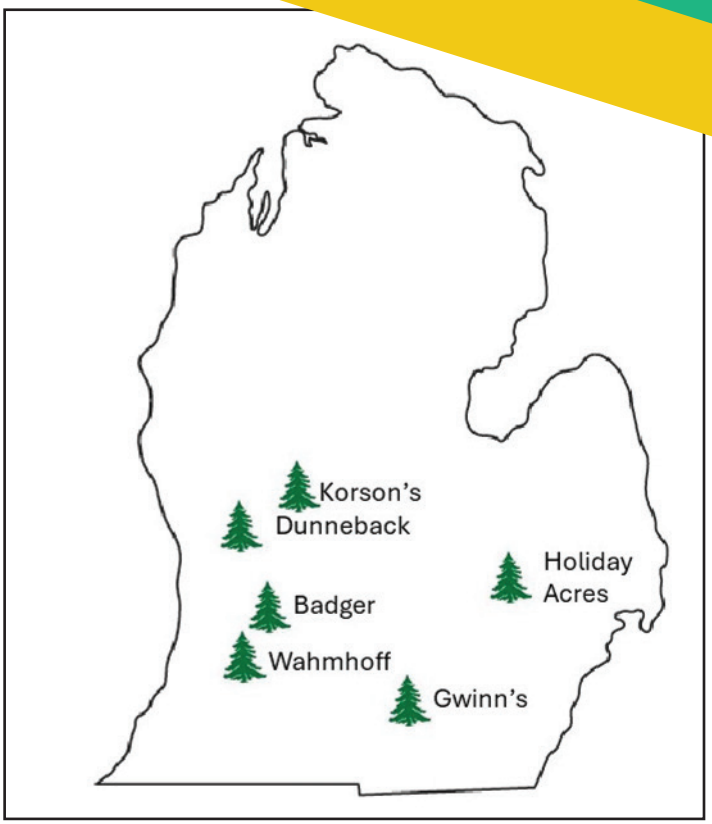

Image 2. Location of MSU seedling establishment trials 2021-2023

TABLE 1. Study locations and treatment applied for the MSU Seedling establishment studies, 2021-2023.

2021		
Locations	**Below-ground treatments**	**Above-ground treatments**
Allegan	Control (water)	Control
Gobles	Polymer gel (Terra Sorb)	Mulch (varied by farm)
Horton	Polymer gel (SoilMoist™ Fines)	Shade blocks
Sidney	Polymer + Mycorrhizae + Biostimulant (DIEHARD™ Root Dip)	Mulch + Shade
		Anti-transpirant (Wilt-Pruf®)
2022		
Locations	**Pre-plant treatments**	**Post-plant treatments**
Allegan	Control (water)	Control
Gobles	Mycorrhizae (MycoApply® Injector Ecto)	Mulch (Woods Ecology® Bags)
Grand Rapids	Polymer gel (SoilMoist™ Fines)	Fertilizer (Osmocote Plus 15-9-12, 5-6 mo. release)
Milford	Polymer + Mycorrhizae + Biostimulant (DIEHARD™ Ecto Root Dip)	Mulch + Fertilizer
2023		
Locations	**Below-ground treatments**	**Above-ground treatments**
Allegan	Control (water)	Control
Gobles	Mycorrhizae (MycoApply® Injector Ecto)	Mulch (Woods Ecology® Bags)
Grand Rapids	Polymer gel (SoilMoist™ Fines)	Shade
Milford	Polymer + Mycorrhizae + Biostimulant (DIEHARD™ Ecto Root Dip)	Mulch + Shade
	Fertilizer (BEST PAKS® 20-10-5)	
	Biochar	

Image 3. Applying seedling dips prior to planting.

Image 4. Close-up of wood chip mulch.

MI (Holiday Acres Tree Farm); and Grand Rapids, MI (Ed Dunneback and Girls Farm Market) (Image 2). All planting procedures were the same as the 2021 trial except at Grand Rapids, trees were planted by hand in furrows opened up with a tractor-mounted planting disk. After all seedlings were planted, we applied the post-planting treatments, which included Mulch only, Fertilizer only, Mulch + Fertilizer, and untreated control. Fertilized trees received 12 g of controlled release fertilizer (Osmocote Plus 18-5-12, 5-6 mo. release, ICL Specialty Fertilizers, Summerville, SC). We included the fertilization treatments based on results in similar trials at Oregon State University that indicated fertilizer pouches installed near seedlings at planting improved initial tree growth (Chal Landgren, personal communication). We standardized the mulch application using bagged ground wood mulch (Wood Ecology's® Best Natural Wood Mulch) around each tree (Image 6). As in 2021, none of the root treatments affected seedling growth or survival. However, mulch and fertilizer affected survival at some farms. Mulch application increased tree survival averaged across all farms (Table 3). Application of controlled release fertilizer reduced overall tree survival (Table 3).

2023 Trials: In 2023, we established plots on the same farms as 2022, and we continued to refine our treatments. For the fertilizer treatment, we procured the same fertilizer pouches used in the Oregon State trials (BEST-PAKS® 20-10-5 controlled release planting packets, J.R. Simplot Company, Boise, ID). Trees were assigned at random to receive one of five root-dip or subsurface treatments (Table 4): control (water dip only), Die-Hard Ecto root dip, Myco-Apply root dip, Best-Paks fertilizer packet, or Biochar application. The fertilizer packets were installed using a dibble-bar to make a slit immediately next to the planting site for each tree (Image 7). For Biochar we applied 2 cups of medium grade biochar (BiocharNow, Loveland, CO) as a surface application in a 12" radius around the tree that was gently incorporated into the soil. All trees were subjected to surface treatments which included a 2 x 2 factorial (with or without wood-chip mulch

TABLE 2. Mean 2-year leader growth (in cm) of Fraser fir transplants at two irrigated and two non-irrigated farms following treatments applied immediately before and after planting. (2021 study installations)

Below-ground treatments			Above-ground treatments		
Root dip	**Irrigated**	**Non-irrigated**	**Treatment**	**Irrigated**	**Non-irrigated**
Control	11.7a	12.3a	**Control**	12.1ab	10.0c
DieHard	12.2a	10.8b	**Mulch**	10.6b	12.0b
Soil Moist	11.0a	12.0ab	**Mulch + Shade**	11.8ab	14.6a
TerraSorb	11.2a	10.7b	**Shade**	12.9a	12.6b
			WiltPruf	10.3b	8.3c

Note: Means within a column followed by the same letter are not statistically different at 95% probability. Each mean is the average to 200 to 250 trees.

Image 5. Shade blocks were installed on the south side of each tree.

Image 6. Applying wood chip mulch.

and with or without shade blocks). Root dips did not affect survival, but survival increased on mulched plots relative to the untreated control (Table 4). We assessed soil moisture at two of the farms (Gobles and Allegan) in early summer 2023, which was abnormally dry. During a 7-week period in May and June, the MSU Enviroweather station in Allegan recorded a total of 0.51" of rainfall. Available soil moisture was significantly higher on plots with mulch than without during the drought (Image 8).

Discussion and Summary: In 12 individual trials (4 sites x 3 years), we did not observe any effect of root dips on tree survival or leader growth compared to dipping seedlings in water prior to planting. Given the range of root dips trialed, several factors may account for the lack of treatment effects. Polymer root dips can be beneficial in preventing roots from desiccation during storage and handling. In our studies, planting stock was handled and planted by the crews on the cooperating farms who were careful to protect and properly care for trees at the planting site (e.g., kept trees shaded, avoided unnecessary environmental exposure). Under more stressful handling or exposure, it is possible polymer root dips may have provided more benefit. For the mycorrhizal products, it is likely that trees were already infected with mycorrhizae when they arrived from the nursery. It is also possible the trees were inoculated with spores at the planting

TABLE 3. Effect of pre-plant and post-plant treatments on 2nd year seedling survival of Fraser fir transplants at four farms in Michigan (2022 study installations)

Pre-plant		Post-plant	
Treatment	**Survival (%)**	**Treatment**	**Survival (%)**
Control (water)	92.7a	Control	95.1ab
Diehard	95.6a	Fertilizer	87.4c
MycoApply	93.0a	Mulch	98.0a
SoilMoist	94.2a	Mulch+Fertilizer	93.8b

Note: Means within a column followed by the same letter are not statistically different at 95% probability. Each mean is the average of 400 trees.

Key results from MSU Seedling establishment studies

- Mulch: Consistently improved growth and survival under drought conditions (mulch increased soil water content + reduced tree stress)
- Root dips: No effect on seedling survival or leader growth (12 individual trials)
- Mycorrhizae: No effect of commercial ecto-mycorrhizal inoculum on survival or leader growth
- Anti-transpirant: Reduced transpiration rate - but also reduced photosynthesis and leader growth
- Shade blocks: Improved leader growth in some cases (could be due to shade avoidance or reduced drought stress)
- Fertilizer: Decreased year 1 survival but increased year 2 leader growth (we suggest growers avoid fertilizer at planting unless trees are irrigated)
- Biochar: No effect on survival or leader growth through year 2

Image 7. Installation of BEST PAKS fertilizer packets with a dibble bar.

Image 9. Needle nitrogen concentration was assessed on all plots each fall,

site since mycorrhizal spores are ubiquitous and long-lived (Benucci et al., 2020). In either event, adding commercially-sourced inoculum at planting did not provide a benefit in terms of either survival or growth of the trees.

The reduction in growth of trees following fertilization in 2022 was surprising. Although fertilizing trees at planting is not typically recommended, we expected a top-dressing of a relatively small amount of controlled-released fertilizer to be benign. The reason for the adverse effect of fertilizer at planting is unclear, but may be related to adverse effects of osmotic water stress. We did not observe an adverse effect of the fertilizer paks installed in the 2023 trial.

The treatments that provided consistent benefits on non-irrigated plots were mulch, and to a lesser extent, shade blocks. The improvement in growth and survival associated with mulch appears to be largely related to improvement in soil moisture and tree water status. In the 2023 trial, we observed increased soil water content and improved plant water potential for trees that were mulched.

What about nutrient 'tie-up'?

A common concern expressed by growers when discussing mulch is the potential for microbes to utilize soil nitrogen to break down wood-based mulches. This is often referred to as nutrient tie-up and leads to concerns that applying mulches with a high ratio of carbon to nitrogen (C: N) will lead to nutrient deficiencies. In our trials, we deliberately used wood-based mulch with a high C: N ratio in order to investigate this phenomenon. Each fall we collected needle

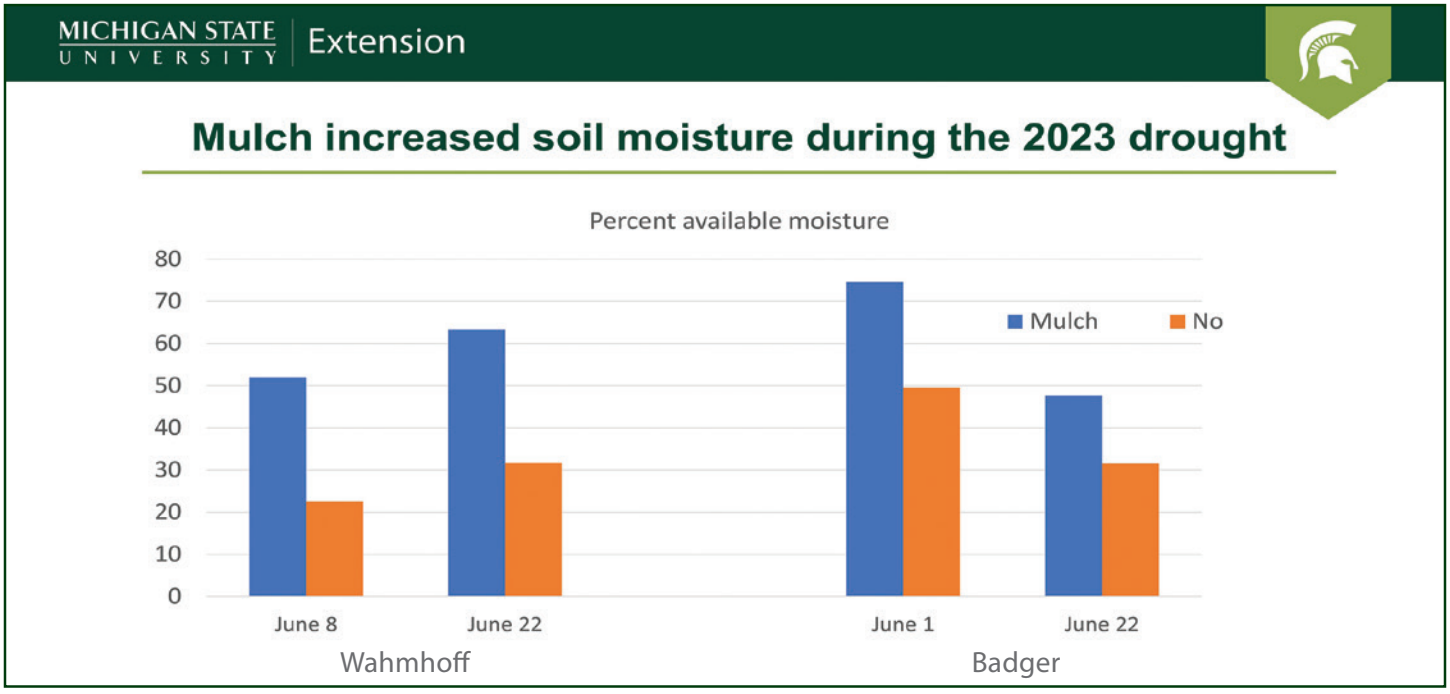

Image 8. Available soil moisture at two farms in early summer 2022 on plots with or without mulch.

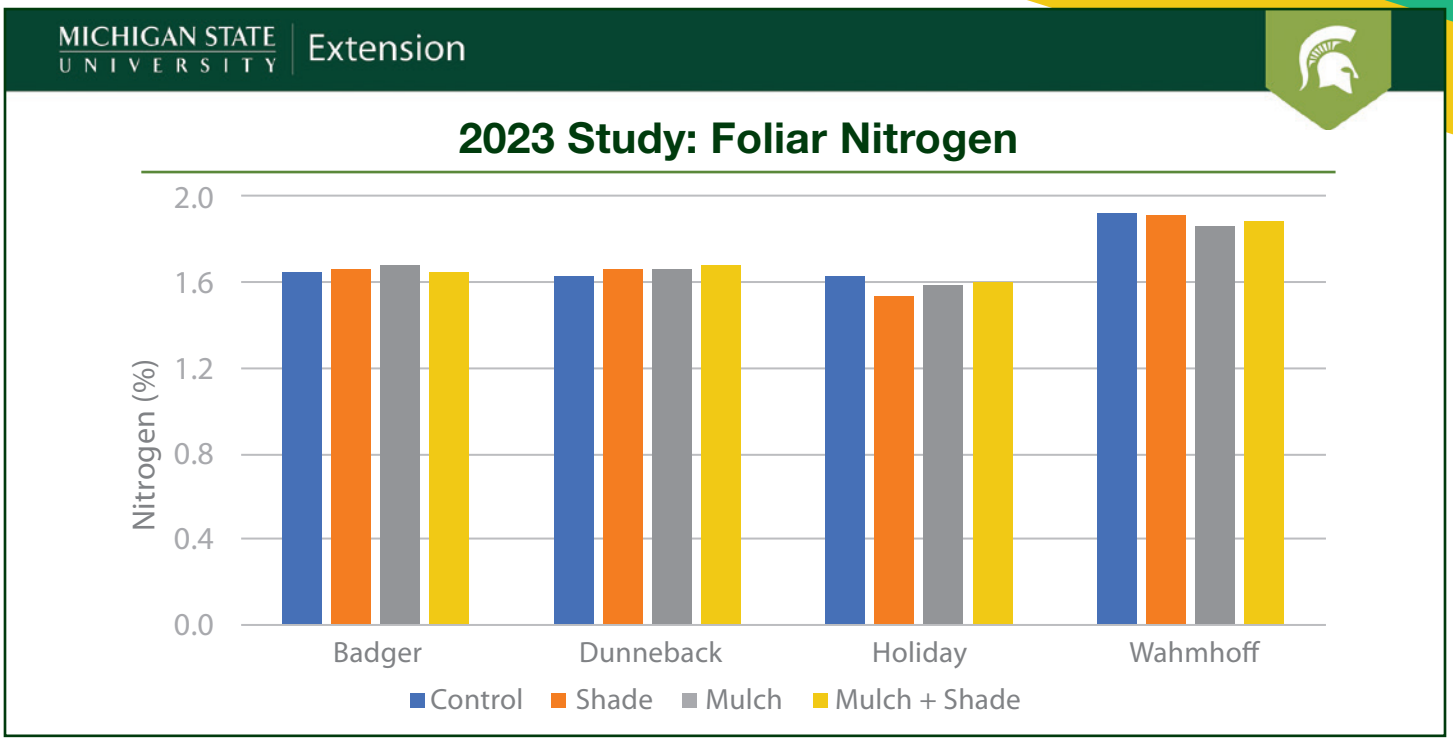

Image 10. Mean needle nitrogen concentration of Fraser fir trees in response to mulch and shade treatments at four farms in 2022.

samples for foliar nutrient analysis on all of our tests (i.e., the 2021 tests were sampled after year 1, 2, and 3; the 2022 tests have been sampled twice; the 2023 tests were sampled in fall 2023) (Image 9). Out of these 22 sets of analyses (two of the 2021 tests were not sampled after year 3), there were no instances where foliar N of mulched trees was less than that of the corresponding non-mulched trees (see Image 10 as an example). This suggests that while soil microbes certainly use N to break down organic matter (including mulch), the amount taken up is not sufficient to cause an observable N deficiency in crop trees.

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TABLE 4. Effect of pre-plant and post-plant treatments on 2nd year seedling survival of Fraser fir transplants at four farms in Michigan. (2023 study installations)

Below-ground		Above-ground	
Treatment	**Survival (%)**	**Treatment**	**Survival (%)**
Control (water)	98.0a	Control	94.4b
Biochar	97.1a	Shade	97.1ab
DieHard	97.6a	Mulch	99.4a
MycoApply	96.0a	Mulch+Shade	98.1a
Fertilizer PAKS	97.5a		

Note: Means within a column followed by the same letter are not statistically different at 95% probability. Each mean is the average of 400 trees.

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