Effects of Irrigation Frequency and Grit Color on the Germination of Lodgepole Pine Seeds

Jeremy R. Pinto, R. Kasten Dumroese, and Douglas R. Cobos

Jeremy R. Pinto is Tribal Nursery Coordinator, USDA Forest Service, Southern Research Station, 1221 S Main Street, Moscow, ID 83843; Tel: 208.883.2352; E-mail: jpinto@fs.fed.us. **R. Kasten Dumroese** is Research Plant Physiologist, USDA Forest Service, Southern Research Station, 1221 S Main Street, Moscow, ID 83843; Tel: 208.883.2324; E-mail: kdumroese@fs.fed.us. **Douglas R. Cobos** is Director of Research and Development, 2365 NE Hopkins Court, Pullman, WA 99163; Tel: 509.332.2756; E-mail: doug@decagon.com.

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Abstract: Nursery cultural practices during germination can be highly variable between existing production facilities. Although nursery guidebooks suggest keeping seeds moist, there are no known scientific answers indicating what sufficient moisture levels are. This study objective was to characterize differing irrigation regimes and grit color choices on different germination parameters (Germination Capacity, GC; Peak Value Germination, PV; Germination Value, GV; and Germination Rate, GR_{50}) using seedbed temperature and soil matric water potential (Ψ) measurements. No significant differences were observed between irrigation frequency and grit color for GC and GR_{50}. The indices of germination speed, PV and GV, were significant for irrigation frequency ($P < 0.05$), but not grit color. No correlations were observed between seedbed temperature and GC, PV, and GV parameters, and only weak correlations were observed between GC, GV, PV, and Ψ. Despite the lack of significance and correlations, Ψ values indicated that germinating seeds were still in contact with adequately moist soils at low irrigation frequencies. These results have implications in current nursery management and may contribute to watering reductions and potential cost savings.

Keywords: seedbed temperature, water potential, germination rate, germination capacity

Introduction

To ensure that uniform crops are grown in the nursery, considerable effort is exercised in the care of seeds before they are sown. Seed treatments, in the form of soaking, stratifying, and scarifying, are often used to break seed dormancy and increase germination capacity (Krugman and others 1974). Post sowing, the abiotic elements of light, temperature, and moisture are critical factors that also contribute to total germination (capacity) and rate of germination (Landis and others 1998). In container nurseries, seeds that have high germination capacity and fast germination rates are most desirable. Despite relative uniformity in seed treatments prior to sowing, nursery culture regimes during germination are often highly variable among existing production nurseries. Personal communication with managers of northern Idaho container tree nurseries indicate some use multiple irrigations each day to keep seeds moist (Eggleston 2006), while others use visual and tactile examination to determine irrigation (Wenny 2005). The recommendation of conifer propagation protocols advises daily misting to keep the zone around germinating seeds slightly moist to maximize germination (Wenny and Dumroese 1987, 1990, 1992).

A common feature between most forest and conservation greenhouses is that they are all heated; however, irrigation is highly variable between most facilities. Investigating the different irrigation techniques between facilities may seem trivial, but irrigation frequency during the germination period may have impacts on germination rate and the presence or absence of seedborne pathogens that cause damping-off problems during emergence (Dumroese and James 2005). While it's important for seeds to have adequate access to moisture during germination, it's also important for exposure to favorable temperatures for maximum germination.

A pilot study at the USDA Forest Service Coeur d'Alene Nursery in Idaho compared irrigation frequency on germination. Their study showed a difference in germination rates caused by irrigation frequency (Myers 2005). Unfortunately, the study was not published, and no biophysical data were collected to support the observed differences. One hypothesis is that frequent irrigation decreases seedbed temperatures, thereby contributing to lower germination rates; furthermore, by changing the color of grit (seed covering), seedbed temperatures may also be manipulated, increasing or decreasing germination. Our study objective was to analyze microsite temperature and soil matric water potential (Ψ) data at the seed level using adequate and sensitive equipment to capture differences of irrigation frequency and grit color on germination capacity and rate.

Materials and Methods

Nursery Culture

Lodgepole pine (*Pinus contorta* var. *latifolia*) seeds from Lawyers Nursery, Incorporated (Plains, MT) were cold stratified for 30 days before being sown at the USDA Forest Service Rocky Mountain Research Station greenhouse in Moscow, ID (46° 43'N, 117° 00'W). A completely randomized 3 x 3 factorial split-plot design was used on irrigation and grit color treatments with three replications. Main plots were irrigation treatments, and the split-plots were grit color. Irrigation treatments consisted of high, medium, and low frequency, where high consisted of light irrigation 3 times a day, medium was once every 2 days, and low was once every 4 days. Full irrigations (multiple passes with an irrigation boom) were carried out every 4 days to bring containers to field capacity. A per cavity breakdown of irrigation applications and rates are shown in table 1. Phosphoric acid was injected into the irrigation water to adjust the pH to 5.5. Grit treatments consisted of black, white, and neutral (natural brown). The black and white colors were made by spray painting the neutral grit color.

Seeds were sown in Styroblock™ (Beaver Plastics, Edmonton, Alberta) containers that contain 160 cavities that are each 90 ml (5.5 in^3) in volume. Each container was an irrigation replication (main plot) and was split into three sections for color treatments. Containers were filled with Sphagnum peat moss:vermiculite (1:1, v:v) medium (Sun Gro Horticulture, Bellevue, WA). Each color replication contained 32 cavities sown at 3 seeds per cavity for the germination tally. A one-cell buffer row was used around each color treatment to minimize edge effects.

Table 1. Average amount of water applied per cavity in each container.

Applications	Irrigation treatment Low	 Medium	 High
	. . . . *ml*	. . . .	
Single misting application	6.7	4.2	2.1
# applications every 4 days	1	2	12
Total applied every 4 days	6.7	8.4	25.4

Germination Counts

Germination was recorded daily for 21 days after sowing and used to calculate four germination parameters: germination capacity (GC), peak value (PV), germination value (GV), and germination rate (GR$_{50}$). Germinated seeds were scored when hypocotyls became visible through the grit. As a measure of germination completeness, GC was calculated as the total number of germinants over the entire measured period. PV, a measure of germination speed, is the maximum value obtained using: $PV = DCG \div$ days since start of test, where DCG is the daily cumulative percent germination (Czabator 1962). GV combines germination speed and completeness, calculated by $GV = (GC \div D) \times PV$, where D is the number of days in the test. GR$_{50}$ is equal to the number of days required for 50% of the seeds to germinate (Ching 1959). For measures of GC, PV, and GV, the higher the number, the better the germination parameter; for GR$_{50}$, a lower number is an indication of a better germination rate.

Instrumentation

One cell within each irrigation x grit color treatment x replication combination (n = 27) was randomly chosen for temperature collection using a copper-constantan thermocouple connected to a CR10X data logger (Campbell Scientific, Incorporated, Logon, UT). Thermocouples were placed at the soil-seed-grit interface and remained *in situ* for 21 days after sowing. Daily average temperatures for irrigation and grit treatments were calculated between the hours of 0800 and 2000. Soil water potential (matric potential) was measured in one randomly chosen cell for each irrigation x grit color treatment x replication combination (n = 27) using a T5 Tensiometer (UMS, Munich, Germany). Water potential measurements were taken in the morning prior to irrigation treatments. Greenhouse atmospheric data, including temperature and relative humidity, were also collected (Em50, Decagon Devices, Pullman, WA).

Data Analysis

Regressions and analysis of variance were done using SAS® software (SAS Institute Incorporated, Cary, NC). Assumptions for equal variances and normality were met by all data analyzed.

Results

Average daily seedbed temperature (referred to just as temperature(s) for the rest of this document) and Ψ (dependent variables) were checked for relationships to both irrigation and grit color treatments (independent variables) using 1-way analysis of variance. Grit color temperatures were significantly different ($P = 0.002$) and decreased as the color treatments moved from black to neutral to white (21.6, 21.2, and 20.9 °C [70.9, 70.2, and 69.6 °F] for black, neutral, and white, respectively; fig. 1A). Irrigation temperatures were also significantly different ($P = 0.005$), but did not show any trends (21.2, 21.6, and 20.9 °C [70.2, 70.9, and 69.6 °F] for low, medium, and high, respectively; fig. 1B). No differences were seen in Ψ and grit color ($P = 0.97$; fig.

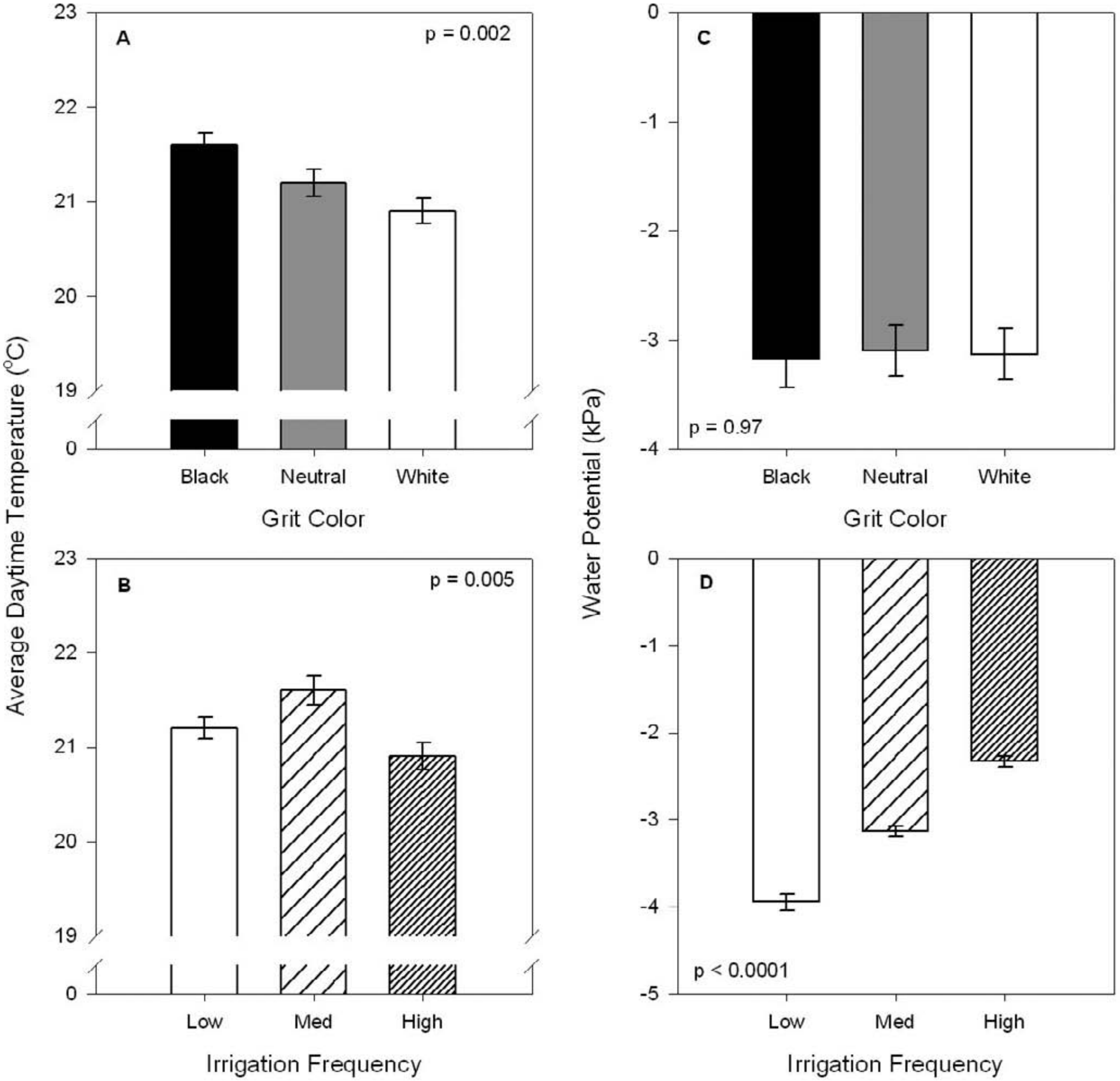

Figure 1. Irrigation frequency and grit color effects on seedbed temperature and soil matric water potential. Bars indicate standard errors of the means.

1C), but significant differences were observed in the irrigation treatments with Ψ increasing with irrigation frequency ($P < 0.0001$; fig. 1D).

Linear regression analysis was performed on germination parameters using temperature and Ψ as explanatory variables. No significant temperature relationships were detected for GC ($P = 0.45$), PV ($P = 0.69$), and GV ($P = 0.91$). Scatter plots confirm the absence of any trends (fig. 2). Conversely, significant relationships were observed with GC ($P = 0.003$; $r^2 = 0.31$), PV ($P = 0.001$, $r^2 = 0.36$) and GV ($P = 0.001$, $r^2 = 0.37$; fig. 3A, B, and C).

GC, PV, and GV all increased with increasing irrigation frequency; only PV and GV, however, yielded significant differences with irrigation frequency main effects (table 2). No significant difference in GR_{50} was observed, with the calculated day to 50% germination for all irrigation treatments occurring on day 9. Grit color showed increasing trends in PV, GV, and GR_{50}, although not significant ($P > 0.12$; table 2).

Discussion

The results of Weber and Sorensen (1990) showed that increased temperature, with 30 days of cold stratification, had a positive effect on ponderosa pine (*Pinus ponderosa*)

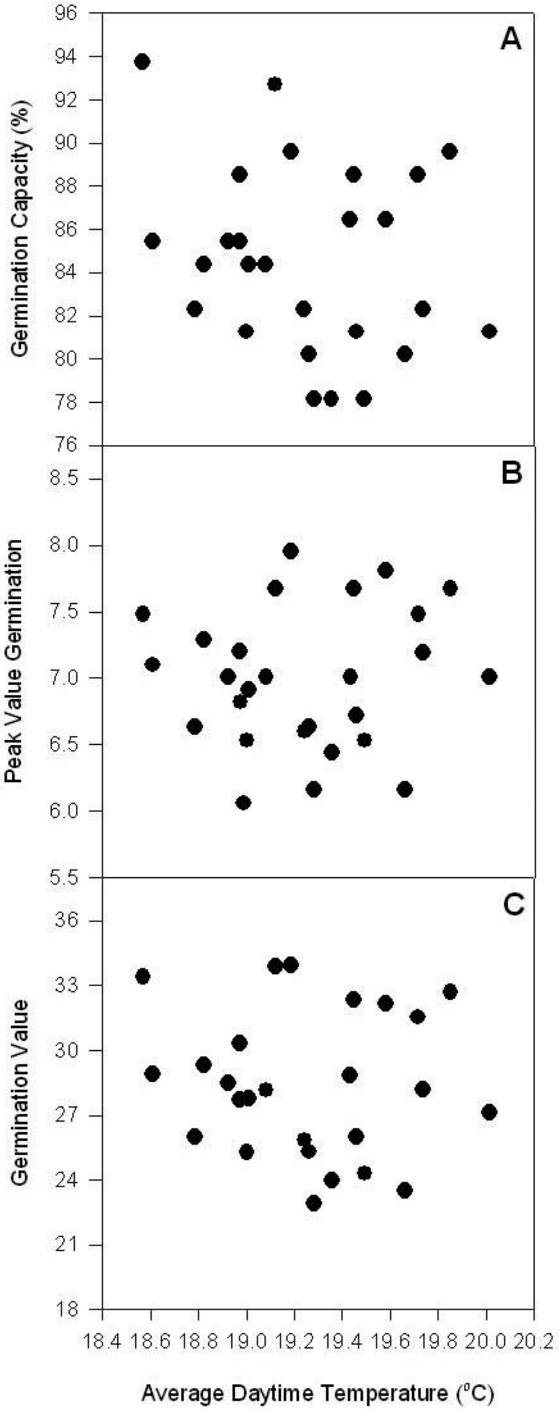

Figure 2. Average daily temperature relationship with germination capacity, peak value germination, and germination value parameters (n = 27).

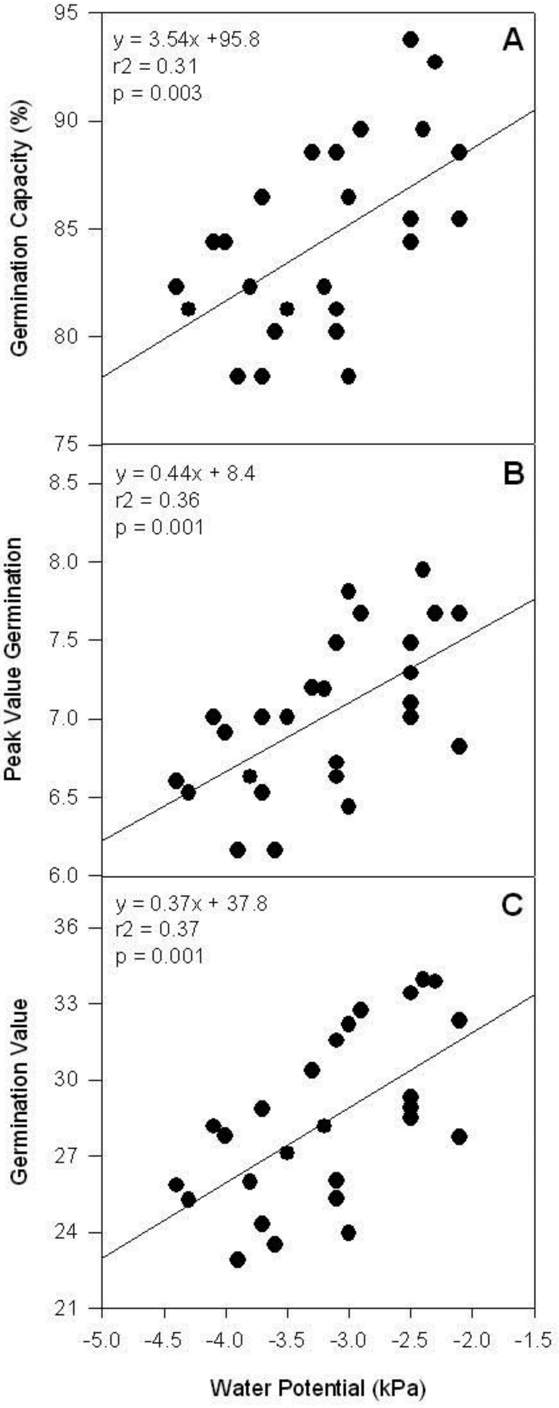

Figure 3. Seedbed soil matric water potential relationship with germination capacity, peak value germination, and germination value parameters (n = 27).

Table 2. Means (± standard errors) and *P*-values for germination parameters between three irrigation frequencies and three grit colors ($\alpha = 0.05$).

Irrigation	**Germination capacity**	**Indices of germination speed**		
frequency	**GC (%)**	**PV**	**GV**	**GR_{50} (d)**
Low	82.0 (0.95) a[z]	6.6 (0.11) a	25.9 (0.70) a	9.6 (0.24) a
Medium	84.0 (1.42) a	7.1 (0.16) ab	28.0 (1.07) ab	9.4 (0.18) a
High	86.6 (1.94) a	7.2 (0.19) b	29.9 (1.35) b	9.7 (0.24) a
***P*-value**	0.12	0.01	0.03	0.78
Grit Color				
Black	84.6 (1.78) a	7.1 (0.20) a	28.9 (1.39) a	9.6 (0.24) a
Neutral	84.8 (1.85) a	7.1 (0.18) a	28.8 (1.28) a	9.7 (0.17) a
White	83.1 (1.09) a	6.7 (0.11) a	26.7 (0.77) a	9.4 (0.24) a
***P*-value**	0.68	0.12	0.27	0.78

[z] Mean separation within columns by Tukey ($P < 0.05$); columns with the same letter are not significant.

germination speed and uniformity. In this study, we hypothesized that frequent irrigation would have a cooling effect on lodgepole pine seeds, thus lowering germination capacity and rate. However, data obtained for this species and seedlot over the 21-day period showed little difference in average daily temperature between irrigation treatments and, consequently, little difference in germination parameters. A temperature profile plot did show a temperature decrease for high frequency irrigation treatments, but temperature recovery was relatively quick, at times less than an hour (fig. 4). Similarly, we hypothesized that grit color would also have an effect on temperature and germination parameters. Black grit was expected to yield higher temperatures compared to neutral and white grit. Although temperature differences were statistically different, apparently it was insufficient to influence germination parameters. It is important to note the 3 weeks of the experiment were dominated mostly by cool, wet, and cloudy weather. With limited short wave radiation input, effects of grit color may be lessened.

Ψ was measured to describe free energy water potential movement from soil media to seeds. Although the technique used (soil tensiometer) only measured matric potential, and does not include osmotic potential, Vetterlein and others (1993) showed that measurement of matric potential proved adequate for describing soil water movement and availability for plants *in situ*. No relationships were seen between Ψ

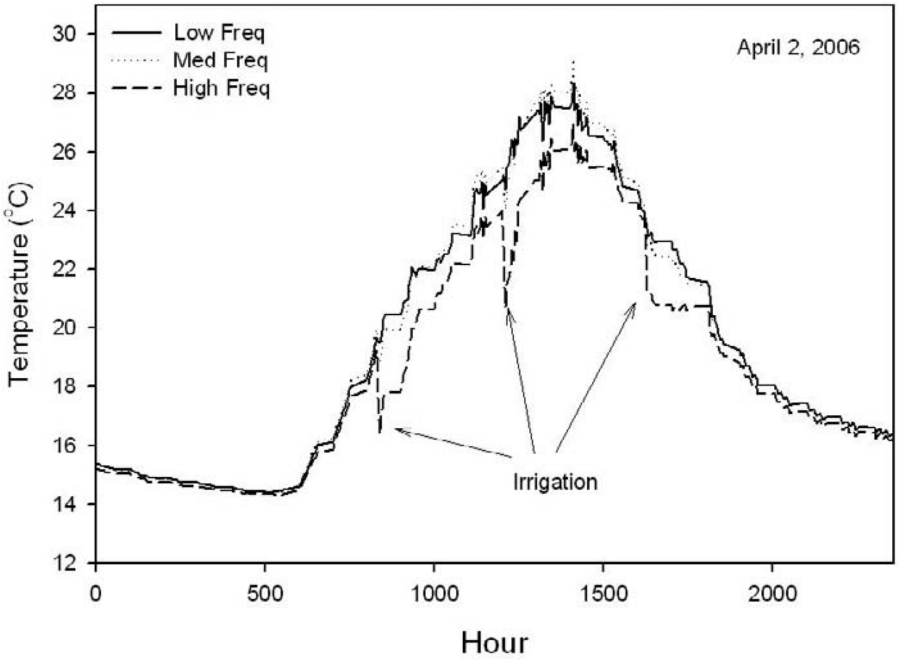

Figure 4. Average seedbed temperatures for low, medium, and high irrigation frequency treatments on 2 April 2006. Downward spikes indicate a high frequency irrigation treatment application.

and grit color and may be attributed to lack of short wave radiation input. Landis and others (1989) state that prior to germination, most soil moisture loss is due to evaporation from the top of the container. Due to decreased short wave radiation input and fixed irrigation treatments, the effects of evaporation may have been minimized, thereby creating little difference in Ψ effects with grit color.

Differences in Ψ were observed (fig. 1D) and weakly correlated with PV and GV (fig. 3B and C). A closer look at the data reveals that, despite correlations with germination parameters, the lowest irrigation frequency Ψ (–4.4 kPa [–44 bar]) was well above the field capacity value of some soils (–30 kPa [–300 bar]; Campbell and Norman 1998). Plants in soils with similar Ψ values would not be considered water stressed (Vetterlein and others 1993). Little is known about water potential of seeds in this situation. Assuming seeds germinate best at Ψ values near field capacity, the data may explain why no large significant germination differences were detected in irrigation frequencies used in this study.

Summary

Nursery managers have a plethora of cultural tools available to them when propagating seedlings in a nursery. Choosing the right tools can often be a challenge, and, in the event of wrong choices, may cost significant amounts of money. Managers turn to experts when looking for answers to specific questions about propagating seedlings, but often knowledge and/or scientific data is simply not available to guide them. This study creates a starting point in answering specific questions and addressing inconsistencies in the culturing practice of germinating seeds. Although significant differences were not seen in some germination parameters among treatments, supporting Ψ data indicated soil medium was still saturated at the lowest irrigation frequency. This elicits implications of saving person hours, water, and irrigation additives (phosphoric acid to lower soil pH) by lowering irrigation frequency. To a nursery manager, this computes to cost savings and increased nursery efficiency. Additional benefits may include reduced damping-off problems caused by over-watering germinating seeds. Further work should include other species and seedlots and hone in on specific Ψ relationships between seeds and the soil media. Additionally, further work on contributing factors, such as radiation, should also be characterized and related to improving cultural practices during germination.

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