# Quantifying Drought Stress Thresholds for Rehydration in Four *Abies* Christmas Tree Species

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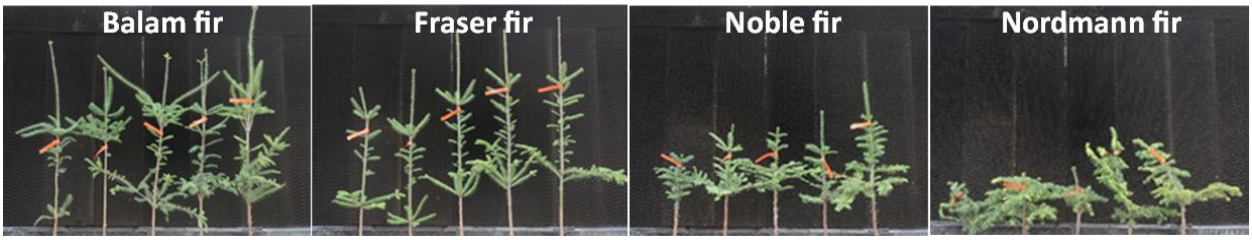
To better understand the levels of drought stress seedlings and trees can tolerate before they are irreparably damaged, a trial was conducted during fall 2025 to identify the water potentials (Ψ) and moisture content (%MC) that saplings of four Christmas tree species could be dried to and still fully rehydrate following irrigation. This trial was conducted on 4-year-old outdoor-grown potted balsam, Fraser, noble, and Nordmann fir saplings.




Methods

To induce various levels of drought stress the plants were held in a greenhouse that was maintained between 21-27°C (70 – 80°F) with 14h light. Irrigation was withheld for 3, 6, 10, 13, 17, 20, and 24 days prior to the resumption of irrigation every 3 to 4 day by submerging the pots in water for 5 minutes until completion of the trial on December 15th. Treatments included checks which were irrigated every 3 to 4 days throughout the trial and dry checks which were not irrigated once they were placed in the greenhouse. There were 5 replicate saplings of each species in each drought treatment, which were assigned to blocks 1-5 based on height. After each non-irrigated period, the weights and Ψ of 5 saplings per species were measured prior to irrigation of the root balls by soaking the pots in water for 5 minutes. The following day the Ψ of each plant was remeasured.

The impact of the drought stress treatments on the moisture status of plants at the termination of trial was determined by measuring the Ψ of all the saplings. Given that the Ψ of some of the plants were lower than could be measured, the potting media was gently

washed from the roots, which were then separated from the tops of the plants. Wet weight was measured on the tops before drying. The roots and tops of the plants were then placed in an oven (85°C) for 72 hours prior to weighing their dry weights. The percent moisture content (MC) of the tops was then calculated using the following formula: %MC = [(Wet weight – Dry weight)/Wet weight] x 100.

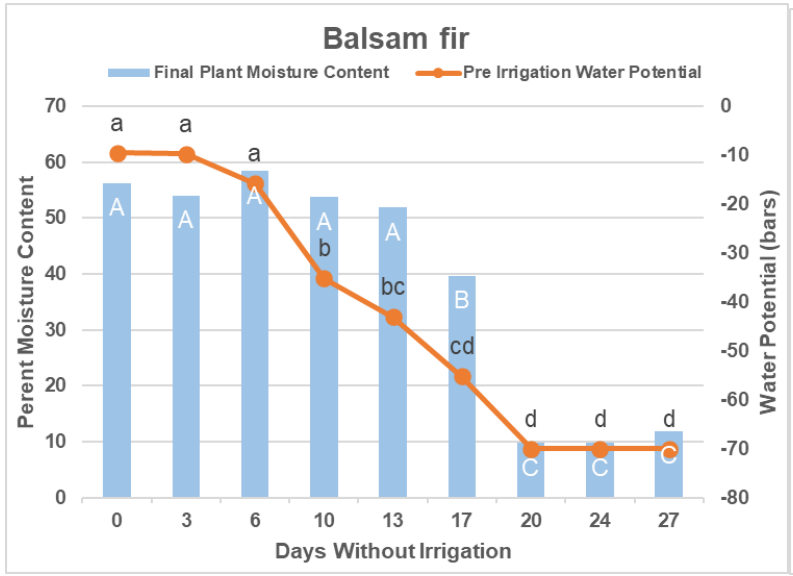
Results

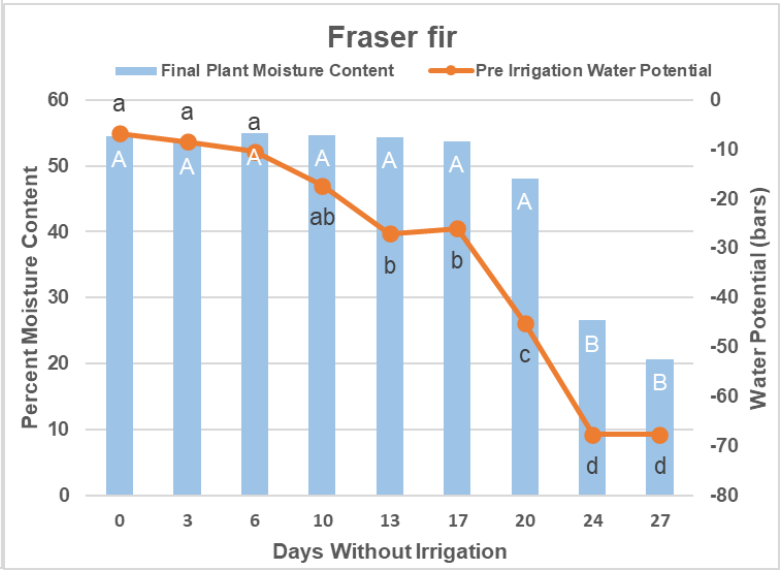
At the beginning of this trial, the initial ψ of the four species averaged -6.8 to -9.7 bars. Irrigation had to be withheld for 6 to 10 days before there was a significant reduction in the ψ of the plants. Beyond this length of time, withholding irrigation resulted in a rapid reduction in ψ. After 20 to 24 days without water, the ψ dropped below the levels (-70 bars) that could be measured with the pressure chamber.

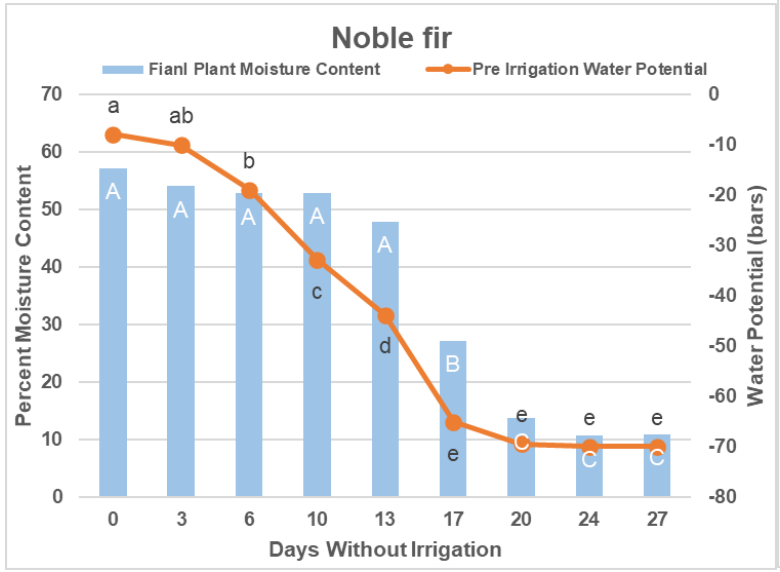
By the termination of the experiment on day 40, the average MC of the above-ground portions of the balsam, Fraser, noble, and Nordmann saplings that were irrigated throughout the experiment (irrigated checks) were 56.3%, 54.5%, 57.2%, and 52.2% respectively. Saplings that were exposed to fairly high levels of drought stress were able to rehydrate to MC levels that were not statistically different than the MC of the irrigated saplings. Balsam, Fraser, noble, and Nordmann fir saplings could be dried to similar average Ψ (-43.1 to -45.1 bars) without reducing their ability to rehydrate.

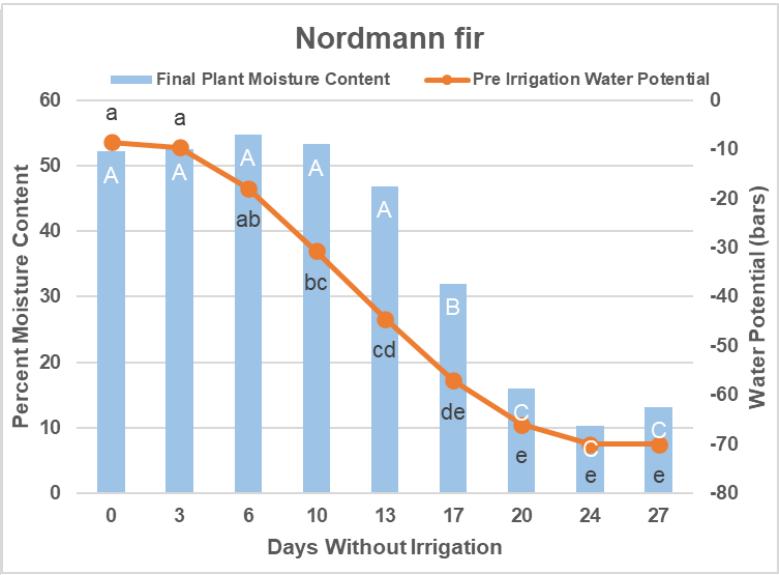
Although additional research is needed to confirm the results of this research, it provides some insights into the levels of late-season drought stress that balsam, Fraser, noble, and Nordmann fir can tolerate with no adverse effect on their ability to rehydrate to levels of non-stressed trees. The rehydration threshold Ψ of these species appears to be about -45 bars. Additional research is also needed to closely examine differences in the rate of drying of these and other Christmas tree species. While the rate of time required for drought-stressed saplings to reach specific Ψ varied in this trial, it is difficult to compare this attribute of the species tested given the differences in the sizes of the saplings.

Tests are currently underway to determine the threshold Ψ young seedlings with new, non-hardened shoots can be dried to before they are irreparably damaged. We expect the new growth will be much more sensitive to drought stress. While rehydration was the focus of this research, drought stress is likely to have significant effects on other physiological activities as well. For example, one of the drought-stressed balsam fir trees in this trial exhibited severe needle loss. The result of this work will also help guide future research relating to the predisposition of Christmas trees to diseases such as Armillaria root decay.


Balsam fir
Final Plant Moisture Content
Pre Irrigation Water Potential
Perent Moisture Content
Water Potential (bars)
Days Without Irrigation
0 3 6 10 13 17 20 24 27
a a a b bc cd d d d
A A A A A B C C C


Fraser fir
Final Plant Moisture Content
Pre Irrigation Water Potential
Percent Moisture Content
Water Potential (bars)
Days Without Irrigation
0 3 6 10 13 17 20 24 27
a a a ab b b c d d
A A A A A A A B B


Noble fir
Fianl Plant Moisture Content
Pre Irrigation Water Potential
Percent Moisture Content
Water Potential (bars)
Days Without Irrigation
0 3 6 10 13 17 20 24 27
a ab b c d e e e e
A A A A A B C C C


Nordmann fir
Final Plant Moisture Content
Pre Irrigation Water Potential
Percent Moisture Content
Water Potential (bars)
Days Without Irrigation
0 3 6 10 13 17 20 24 27
a a ab bc cd de e e e
A A A A A B C C C