The Use of Remote Monitoring and Growing Degree Days for Growing Container Seedlings

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Abstract

A remote monitoring system used in Mexico is described for small nurseries that cannot support full-time, onsite specialist growers. In addition, the concept of Growing Degree Days is described for transferring a growing regime from one site to another untested site. This paper was presented at a joint meeting of the Western Forest and Conservation Nursery Association, the Intermountain Container Seedling Growers Association, and the Intertribal Nursery Council (Boise, ID, September 9–11, 2014).

Introduction

Mexico has more than 600 container forest nurseries. The military (SEDENA) operates the largest nurseries as part of its mission to "…carry out civic actions and social work to support the growth of the country" (Eguiluz-Piedra 2003). SEDENA currently operates 20 forest nurseries, with a total capacity of 60 million seedlings. The biggest nursery has a capacity of 12.5 million seedlings, and the next biggest nursery has a capacity of 7.5 million seedlings (Eguiluz-Piedra 2003). The remaining nurseries are much smaller, averaging production of less than 250,000 seedlings per year.

The Mexican Government's National Forestry Commission—CONAFOR—contracts with nonmilitary community and private nurseries to supply communities with tree seedlings and subsidizes the planting. For political reasons, nursery production is widely dispersed. Therefore, if a private nursery operator aspires to greater production, the only route to accomplishing that is by operating multiple sites.

Very few small nurseries can afford qualified, competent staff. To address this issue and improve nursery management and production, Sistemas Agrotec S.A. de C.V. installed a remote monitoring system at a nursery near Uruapan, Michoacan, Mexico. The Agrotec view is that one skilled manager can monitor several operations from a distance and be ready to intervene. The installation allows for remote monitoring, not remote control (as is available for sophisticated greenhouse operations).

The objective of the installation was to evaluate equipment and procedures to develop a standard operating procedure (SOP) that could be transferred to other (possibly untested) sites to raise seedlings of the same quality in commercial quantities in the first year.

Remote Monitoring

The remote monitoring system was set up in 2012 using a Decagon system (Decagon Devices, Inc., Pullman, WA). The nursery produces 3 million container pine seedlings (*Pinus pseudostrobus* Lindl., *P. michoacana* Martinez, and *P. montezumae* Lamb.) annually for reforestation of community lands.

Sensors

Monitoring electrical conductivity (EC) of leachate is essential in any container nursery operation (Tinus and McDonald 1979), particularly in an outdoor compound, where a growing system with soilless media, multiple-cavity containers, soluble fertilizers, and irrigation patterns are handled by workers with little technical background or knowledge of plant physiology. Monitoring stations were set up to measure EC and irrigation with soluble fertilizer (fertigation). One block (Copperblock® 60/250 ml [15 in^3], Beaver Plastics, Ltd., Alberta, Canada) had its ventilation holes taped closed so that only drainage solution from the root plugs could flow into a large funnel and be measured for EC with the Decagon ES2 EC sensor (figure 1).

The station also monitors other parameters (figure 1): a pressure switch (Decagon PS1 sensor) inserted below an irrigation nozzle monitors whether the irrigation is on or off; a two-blade sensor inserted into one cavity (Decagon EC-5 sensor) monitors the percent moisture content of the growing medium; and a Thermoworks USB Data Logger (Thermoworks, Lindon, UT) monitors under-bench temperature. Block weight is monitored gravimetrically on a domestic scale (figure 1) and manually recorded before and after irrigation (remote monitoring is under development for block weight).

Figure 1. Monitoring station in a *Pinus montezumae* Lamb. seedling crop in Copperblock® 60/250ml (15 in^3; Beaver Plastics Ltd., Alberta, Canada) to measure irrigation, electrical conductivity, block weight, and air temperature. (Photo by Jol Hodgson, 2012)

The laptop in the nursery is accessed from a remote location over the Internet through the LogMeIn program (Boston, MA; http://www.logmein.com). The laptop is located at the nursery under cover to protect it from elements and theft. It is important that the cable also be protected from weed-clearing equipment and other hazards and that the power source and Wi-Fi be monitored regularly to ensure continuous operation. This system provides real-time data monitoring and also displays data for any time period desired. Frequency of monitoring depends on the crop's growth stage, weather conditions, and availability of personnel. The Thermoworks temperature datalogger recording interval is programmed before placement to allow for a full year's recording. Information gathered manually is documented and uploaded to "the Cloud," using Dropbox (http://www.Dropbox.com) for remote access.

Datalogging and Monitoring

The Decagon sensors described previously are connected by cable to a Decagon EM50R Datalogger, which is where each sensor can be calibrated and data can be transmitted. Each Decagon EM50R can serve five sensors.

All Decagon sensor data are accumulated in the EM50R Datalogger. Every few minutes, data are transmitted by radio to a central Decagon datastation (figure 2), where it is accumulated. The datastation is connected by cable to a laptop computer running the Decagon DataTrac3 software, which can download on demand and display the data graphically or as a spreadsheet (figure 3).

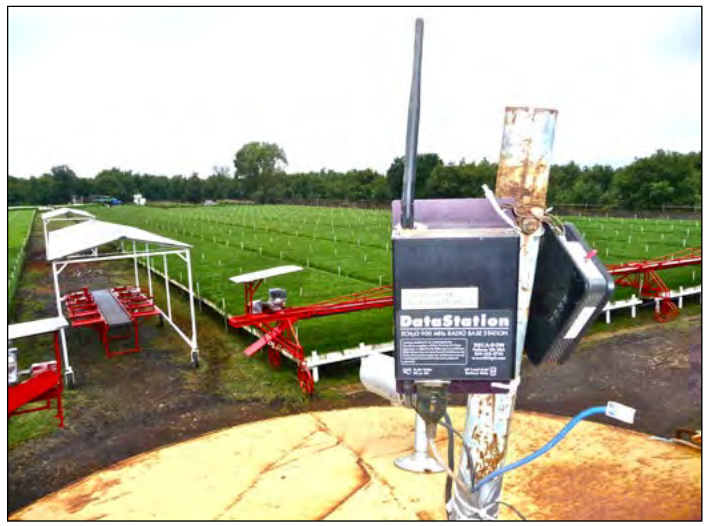

Figure 2. The data station is centrally located and can receive data from several dataloggers. Data are then transmitted to remote computers over the Internet. (Photo by Jol Hodgson, 2012)

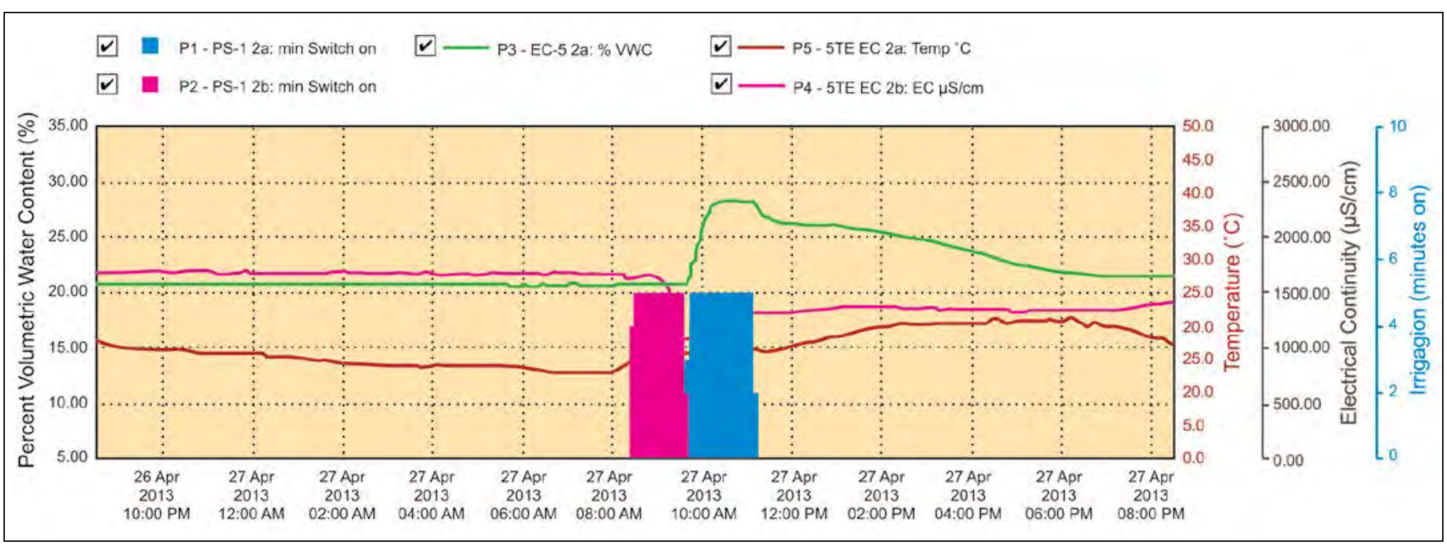

Figure 3. Typical 24-hour graph from remote monitoring includes irrigation duration (pink and blue columns), leachate electrical conductivity (pink line), growing medium moisture content (green line), and under-bench temperature (red line).

Growing Degree Days

Sistemas Agrotec S.A. de C.V. has adopted the target plant concept (Landis et al. 2010) and has developed SOPs (Grossnickle 2011) for *Pinus pseudostrobus* Lindl., *P. michoacana* Martinez, and *P. montezumae* Lamb. These SOPs aim to raise seedlings to approved quality specifications and in a hardened condition by the onset of seasonal rains at the end of May.

Established SOPs can be transferred to an untested nursery location at a higher or lower altitude by converting the growing period to Growing Degree Days (GDDs). GDD is a common parameter in agriculture (Lee 2011) but has been little used in forest nursery operations (Armson and Sadreika 1974, Hodgson 1985). GDD is an assessment of the heat value of each day and can be used to estimate the amount of seasonal growth plants have achieved. GDD is calculated by summing each day's maximum and minimum temperatures, dividing by two, and subtracting a base temperature. The cumulative GDD provides a thermal prediction of plant growth stages (Miller et al. 2001). For the Mexican nurseries in this project, a base temperature of 10 °C (50 °F) was used in the calculation of GDD (determined from the under-bench temperature datalogger) for pine species as related to seedling growth. Figure 4 provides an example of a typical growth curve for *Pinus pseudostrobus* as related to cumulative GDD. The target height for top clipping is 20 cm (8 in); this height is attained at approximately 1,400 GDD, and the SOP requires this stage to be reached by May 1. A sowing date for an untested site can be calculated using these data through retrograde extrapolation based on historical cumulative GDD for that site using local weather records.

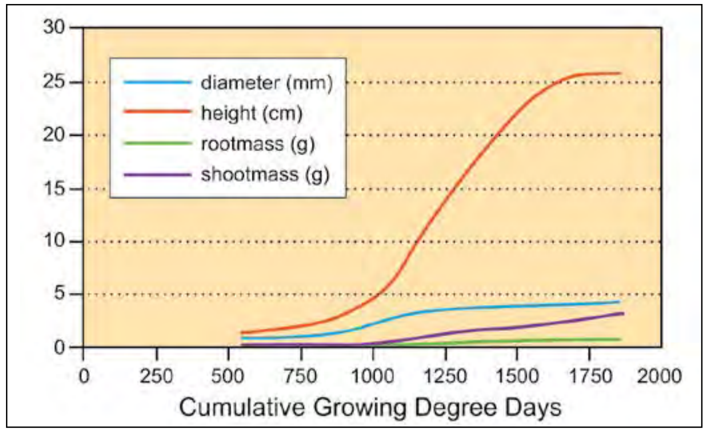

Figure 4. Growth of *Pinus pseudostrobus* seedlings relative to cumulative Growing Degree Days.

Conclusions

Commercially available equipment can be installed in a small forest nursery to provide remote monitoring of growing conditions and fertigation activities. A specialist grower can monitor several nurseries from a great distance. Remote monitoring, however, is no substitute for "eyes-on-the-crop" scouting for pests and diseases, irrigation blockages, inventory and growth measurements, and other nursery management needs.

An SOP for raising target seedlings can be transferred to an untested site at a lower or higher elevation using the GDD formula.

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