An Inexpensive and Reliable Monitoring Station Design for Use with Lightweight, Compact Data Loggers

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Abstract

We designed, constructed, and field-tested an inexpensive and reliable monitoring station that can be used with lightweight, compact data loggers. We feel this design, improved three times over 6 yr, could benefit anyone in nursery or field settings interested in acquiring environmental data. We provide step-by-step instructions on the construction of the monitoring station, with the cost of materials at less than $20 per station (not including the data loggers).

Introduction

Maximum temperatures greater than 120 °F (48.89 °C) at the soil surface in canopy gaps with a diameter of 150 ft (45.72 m) have been reported (Nauertz and others 1997). Such extreme weather conditions require researchers to invest substantial amounts of time, money, and other resources in protecting their weather-monitoring equipment from damaging environmental conditions. For example, temperature and moisture extremes within any given 24-h period can cause problems due to expansion and contraction of metal wires and other components, leading to faulty connections and eventual loss of data. Also, direct solar radiation causes breakdown of weather-monitoring equipment and its protective coverings over time.

We routinely acquire environmental data on our poplar (*Populus* spp.) progeny tests, rooting trials, and other studies so that trends can be interpreted and development explained (Hansen 1986; Wan and others 1999; Zasada and others 2001). Similarly, researchers from many fields of study in the plant sciences assess the correlation between growth and environmental parameters such as air and soil temperature, soil moisture, relative humidity, and related variables (Luomajoki 1995; Landhäusser and others 2001; Lu and others 2001). Older devices used to collect environmental data are cheaper than newer equipment, but are more cumbersome, less reliable, and less precise. In contrast, some current equipment supports rapid, reliable, and precise data acquisition, but at great cost. In addition, some new devices are complicated to program and operate, requiring a greater training investment than older devices. Also, substantial costs are incurred from securing the instrumentation in the field over extended periods of time. The cost of the monitoring station often is a major investment relative to other research supplies. Yet the price of a monitoring station may not be positively correlated with ease of use, reliability in the field, and durability during periods of inclement weather. Therefore, our objective was to design, construct, and field test a monitoring station that was less cumbersome and more reliable than older stations, while less expensive and less complicated than other new equipment.

Field Observations and Design Improvements

A prototype of our monitoring station was designed at the Forestry Sciences Laboratory in Rhinelander, WI, during the spring of 1998. The prototype consisted of data loggers mounted on a wooden post with a plexiglass shield for shade and protection from other elements. We tested the prototype at the Hugo Sauer Nursery in Rhinelander during the 1998 growing season. Two major problems were apparent: the plexiglass shield was too small to provide adequate protection, and the post became unstable as it began to rot.

The original design was revised during the fall of 1998. Four monitoring stations of the revised design were used with data loggers recording air temperature at 3 ft (91.44 cm) above the soil surface, soil temperature at a depth of 8 in (20.32 cm), and relative humidity in a field study at two sites in central and northern Minnesota during 1999 (Zalesny and others 2004). The remaining two monitoring stations were installed at the Hugo Sauer Nursery during the growing seasons of 1999 and 2000. The lightweight monitoring stations were easy to build and were constructed at a fraction of the cost of commercial stations. The monitoring stations were reliable throughout the growing season, which led to minimal loss of data from the data loggers and minimal resources invested in maintenance of the monitoring stations. The monitoring stations had to be removed from the field at the end of each growing season, however, because of increased impact of moisture on the wooden posts.

During the spring of 2001, we modified the monitoring station design, adding a piece of polyvinyl chloride (PVC) pipe that was inserted into the ground. We speculated that we could leave the PVC in the ground during winter months without damage, and we were correct. The shade framework post was inserted into the PVC and secured with two bolts the next spring, and the monitoring station and its data loggers were still operational.

The final design, which is explained in detail below, was field-tested during the 2001 and 2002 growing seasons. Two stations with data loggers were installed at each of three sites across Iowa and Minnesota as part of three field studies of *Populus* (Zalesny 2003; Zalesny and others 2003; 2005ab). The PVC remained in the field throughout the year, while the shade framework was removed during the winter. Overall, there were no structural problems with the monitoring stations across the 2 yr and three sites. We lost less than 1 percent of the potential data because of malfunction of the data loggers themselves; no data were lost because of a faulty monitoring station. Maintenance of the stations was negligible, despite strong winds, severe temperatures, wet soils, and extreme solar radiation.

The total cost of the materials to construct the final monitoring station was less than $20 (not including the data loggers). We feel this design, improved three times over 6 yr, could benefit anyone in nursery or field settings interested in acquisition of environmental data. Provided below are step-by-step instructions on the construction of the final monitoring station.

Monitoring Station Construction

Materials and Equipment. Figure 1 is a photograph of an assembled monitoring station. The materials and equipment needed to construct a monitoring station according to our specifications for use with most lightweight, weatherproof compact data loggers are as follows (figure 2): one piece of lumber, 2-in × 2-in × 8-ft (5.08-cm × 5.08-cm × 2.44-m) (A, B); 2.25-in (5.715-cm) wood screws (C); one piece of plexiglass 0.125 in (0.3175 cm) thick (D); 1.25-

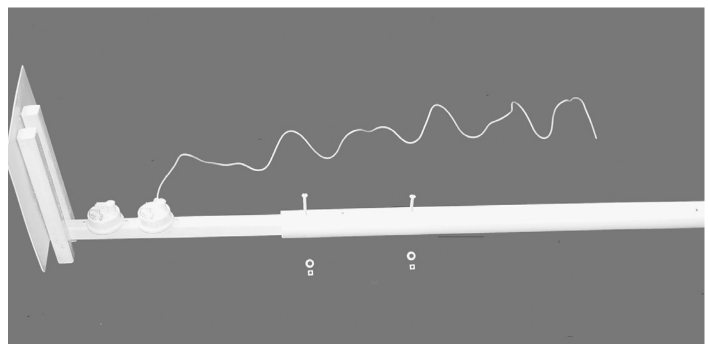

Figure 1. Monitoring station for use with lightweight, compact data loggers.

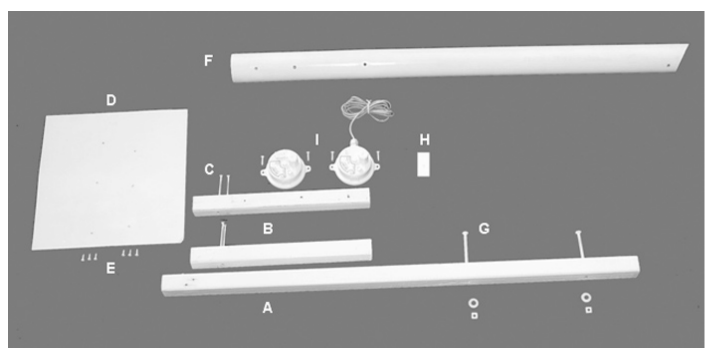

Figure 2. Materials needed to construct the monitoring station: one piece of lumber 2-in × 2-in × 8-ft (5.08-cm × 5.08-cm × 2.44-m) (A, B); 2.25-in (5.715-cm) wood screws (C); one piece of plexiglass, 0.125 in (0.3175 cm) thick (D); wood screws, 1.25-in (3.175-cm) (E); 39 in (99.06 cm) of 2-in (5.08-cm) polyvinyl chloride pipe (PVC), usually sold in 10-ft (3.05-m) sections (F); two bolts, 3 in (7.62-cm) long × 0.25-in (0.635-cm) diameter, with washers and nuts (G); a wedge. used as a spacer between the lumber and the PVC to add rigidity (H). HOBO® H8 Pro Series data loggers (I) are shown; however, other data loggers will work.

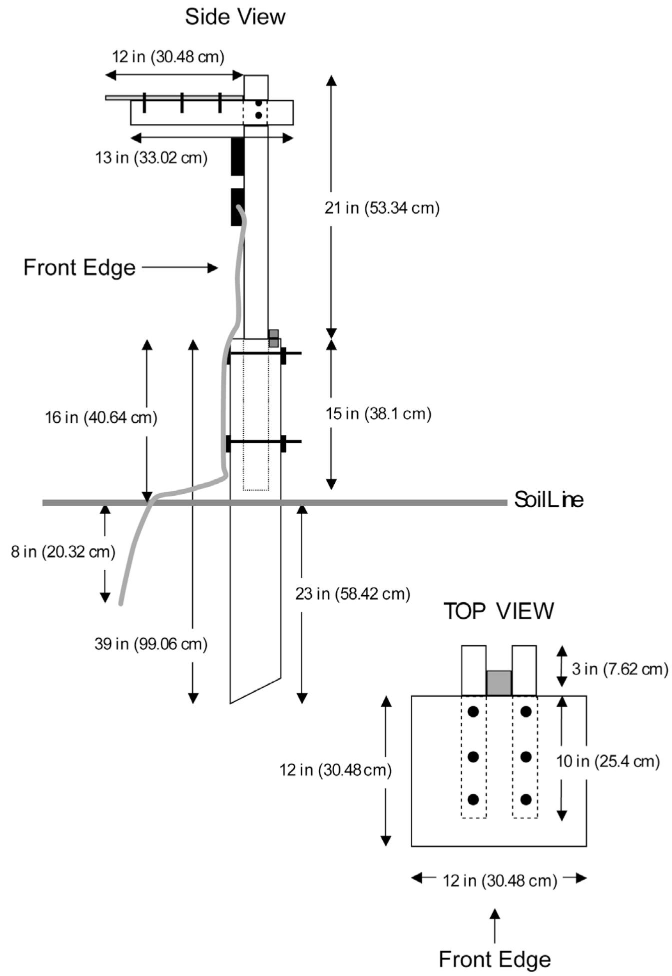

Figure 3. Specifications for assembly of the monitoring station.

in (3.175-cm) wood screws (E); 39 in (99.06 cm) of 2-in (5.08-cm) polyvinyl chloride pipe (PVC), usually sold in 10-ft (3.05-m) sections (F); two bolts, 3-in (7.62-cm) long × 0.25-in (0.635-cm) diameter, with washers and nuts (G); a wedge used as a spacer between the 2-in × 2-in (5.08-cm × 5.08-cm) lumber and the PVC to add rigidity (H); one can of white spray paint, a drill, drill bits, a compound miter saw, wrenches, a tape measure, and C-clamps.

Assembly. Figure 3 gives design specifications.

Step 1. Cut the piece of lumber into one section 36 in (91.44 cm) long (figure 2, A) and two sections 13 in (33.02 cm) long (figure 2, B) with the compound miter saw. After cutting the lumber, paint all of the components and allow to dry.

Step 2. Mark 10 in (25.4 cm) from the end of the two 13-in pieces of lumber. Use the 2.25-in (5.715-cm) wood screws (C) to attach the 13-in (33.02-cm) pieces of lumber to the 36-in (91.44-cm) piece of lumber, 1.5 in (3.81 cm) from the top. Be sure the 10-in (25.4-cm) mark is flush with the front edge of the 36-in (91.44-cm) piece of lumber. *Note:* it is advised to drill pilot holes before attempting to fasten the pieces together in order to prevent the wood from splitting.

Step 3. Cut the plexiglass into a 12- × 12-in (30.48- × 30.48-cm) square (D). Paint the plexiglass and let stand until dry. Mark 3.75 in (9.525 cm) from both sides. These marks should line up with the outside edges of the two 13-in (33.02-cm) pieces of lumber that were attached in *step 2.* Using the C-clamps, clamp the plexiglass to the horizontal 13-in (33.02-cm) pieces of lumber and drill six pilot holes, three holes for each 13-in (33.02-cm) piece. Attach the plexiglass to the horizontal pieces of lumber with 1.25-in (3.175-cm) wood screws (E). Caution: overtightening may fracture the plexiglass .

Step 4. Make a 45° cut 39 in (99.06 cm) down from either end of the piece of PVC (F). This measurement is to the long point of the angle.

Step 5. Mark 16 in (40.64 cm) down from the square end of the 39-in (99.06-cm) piece of PVC. This line is the soil surface mark. Measure from the bottom of the 36-in (91.44-cm) piece of lumber and make a mark at 15 in (38.1 cm). The difference of 1 in (2.54 cm) will keep the wood post off the ground and aid in extending the life of the monitoring station.

Step 6. Insert the 36-in (91.44-cm) piece of lumber into the PVC to the 15-in (38.1-cm) mark made in *step 5.* Drill two holes through the PVC and the lumber, one hole 3 in (7.62 cm) down from the square end of the PVC and one hole up 3 in (7.62 cm) from the soil surface mark on the PVC. *Note:* be sure the hole is the same size or slightly larger than the bolts (G).

Field Installation. Refer to figure 3 for design specifications.

Step 1. Drive the PVC into the ground to a maximum depth of 23 in (58.42 cm) using a sledge hammer or other appropriate tool, depending on soil conditions. *Note:* put a block of wood on top of the PVC in order to prevent splitting the PVC when pounding.

Step 2. Insert the 36-in (91.44-cm) piece of lumber into the PVC and line up the holes made in step 6 above. Insert the bolts and washers and fasten the nuts with the appropriate wrenches. Insert the wedge (H) before tightening. The wedge, which can be made from any material available, adds rigidity to the shade framework. Use the remaining paint to touch up any part of the shade framework that was scratched during construction or transportation to the field.

Step 3. Secure the data loggers to the shade framework just below the plexiglass with the screws. *Note:* secure the data loggers as close as possible to the underside of the plexiglass to aid in the protection of your equipment from solar radiation. If using a data logger with a soil probe, insert the probe into the ground at least 12 in (30.48 cm) from the PVC to avoid overestimates of soil temperature when the PVC heats up.

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Disclaimer

We used HOBO® H8 Pro Series data loggers (Onset Corporation, Bourne, MA) because they met our research needs. Use of specific data loggers is left to the discretion of the researcher. Endorsement is not intended by the Forest Service, United States Department of Agriculture, or Iowa State University.

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