Technical Note: Inexpensive rain gauges constructed from recyclable 2-liter plastic soft drink bottles

KEITH J. WRAGE, F. ROBERT GARTNER, AND JACK L. BUTLER

Authors are graduate research/teaching assistant, Dep. of Biology, University of South Dakota, Vermillion 57069; professor and director, West River Agr. Research and Extension Center, South Dakota State University, Rapid City 57701; and assistant professor, Dep. of Biology, University of South Dakota, Vermillion.

Abstract

A large number of inexpensive rain gauges were required for a study currently being conducted in the Black Hills of South Dakota. A gauge utilizing discarded 2-liter plastic soft drink bottles was designed and constructed at very low cost. Assembly took less than 5 minutes per gauge and required minimal equipment. The gauges have been in use for 1 growing season and have provided accurate, reliable data.

Key Words: precipitation measurement, rain gauge, soft drink bottles, recyclable

Intensive rainfall measurements were required during a study of overstory-understory interactions in relation to soil moisture in the Black Hills of South Dakota. The study required 88 sampling stations under varying ponderosa pine (*Pinus ponderosa* Laws.) canopy densities. Rainfall was to be measured weekly, or more frequently if heavy precipitation events were encountered. Project budget limitations dictated the need for an inexpensive precipitation gauge. Standard, "Forest Service type" rain gauges (18.4 cm diameter × 25.4 cm height), cost approximately $170.00 each (Ben Meadows Company). Randomness of precipitation throughfall under pine canopy ruled-out the use of the "homeowner" type gauges, usually made of plastic and having a much smaller orifice. These types can cost from about $3 to nearly $30 each. A gauge assembly similar to that described by Ohlenbush (1972) was considered, but appeared to be expensive and difficult to construct. Thus, the high cost associated with purchasing a large number of commercially available gauges necessitated the development of an inexpensive, yet effective gauge.

Methods, Materials, and Discussion

The alternative gauges were constructed using discarded 2-liter plastic soft drink bottles obtained from a local recycling center at no charge. Total assembly time was less than 5 minutes per gauge. Although 2-liter plastic soft drink bottles were selected for this study, other discarded plastic containers such as bleach bottles or 3-liter plastic soft drink bottles could also be used. Precipitation (ppt) is measured volumetrically in milliliters using a graduated cylinder. A general equation to convert milliliters (ml) of water collected to millimeters (mm) of ppt is derived as follows: ppt in mm = ml of water collected ÷ (3.1416) × (radius of the collection area of the gauge in mm)^2 × (1 mm depth in spout) × 0.001) ml per cubic mm of precipitation. This general derivation is provided to allow conversion factors to be calculated for gauges with various collection area radii. For example, to convert ml collected to mm of ppt for a 2-liter soft drink bottle gauge with a collection radius of 54.77 mm, the following equation is used:

$$\text{ppt (mm)} = \text{ppt (ml collected)} \div (3.1416) \times (0.001) \times (54.77)^2.$$

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The assembly process is depicted in Figure 1. Construction requires a ruler or tape measure, and a sharp knife or razor blade. First, remove the cap and label from the bottle. Next, rinse the bottles to remove any residue. Make a straight cut around the bottle 18 cm from the bottom (Fig. 1A). It may be easier to mark a line on the bottle first. For producing large numbers of these gauges, a large can or tube with a hole in the side 18 cm from the bottom can be used to mark a level line at the correct height.

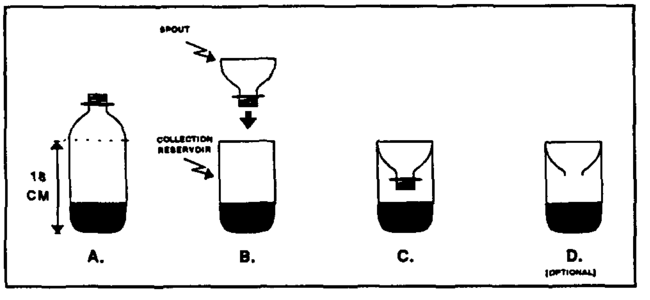

Fig. 1. Construction of a gauge.

Simply place the bottle in the tube or can and insert a permanent marker through the hole from the outside and rotate the bottle. Invert the top portion of the bottle (spout) and insert it firmly into the bottom section of the bottle (Fig. 1B). These 2 sections should fit together very tightly. Although we have not experienced any difficulties during field use, tape or some type of clip may be used to prevent separation of the parts due to high winds. The gauge is now complete and ready to be mounted as desired (Fig. 1C).

The gauges may easily be mounted in a variety of ways and locations. The mounting method used in the current study required the use of another 2-liter plastic soft drink bottle as a gauge holder as shown in Figure 2A. Mark and cut as if you were making another gauge. Return the top portion to a local recycling center. Slit the bottom section from the top edge to the top of the hard plastic base. The gauge holder can be attached to a wooden post or stake using a sheet metal screw. The gauge will slip firmly inside, yet is easily removed for measurement. In areas of low growing vegetation, the gauge can be staked to the ground using 2 stiff wires with a small hook bent on the upper end as shown in Figure 2B. When wires are inserted into the soil and over the rim of the gauge orifice, the gauge will be firmly attached at ground level.

This type of gauge has many advantages. First, it provides accurate data for research purposes. A comparison was made between the precipitation measured in standard type gauges and alternative bottle gauges using regression analysis (PROC GLM, SAS® Institute 1988). The relationship was essentially linear ($Y = -0.013 + 1.10X$, $R^2 = .99$, df = 1) and the intercept was not significantly different from zero ($P \geq 0.05$, T = -1.68, df = 1). The gauge is

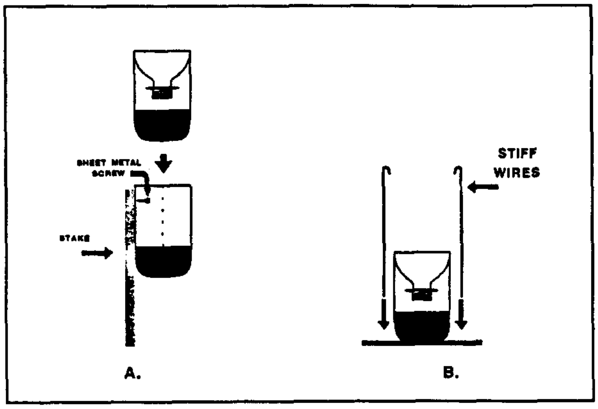

Fig. 2. Mounting methods.

also inexpensive and requires minimal preparation time. It allows the use of large sample sizes with little capital outlay. If gauges are damaged, either by livestock, wildlife, or vandals, they can be easily replaced and only the data will be lost. The gauges are capable of producing reliable, consistent data for research purposes. The funnel-shaped top section hinders debris from entering the gauge and prevents animals from altering the contents. Conversion of bottles to rain gauges is also environmentally friendly, providing a direct reuse of plastic products without energy consumption for reforming.

The flexible material will not deteriorate because of exposure to the elements. The plastic is rustproof and will not crack, even when exposed to freezing temperatures. The plastic is impervious to both oil and anti-freeze. Additionally, measuring the rainfall is simplified because the flexible container is easily squeezed to permit pouring into a graduated cylinder. Because precipitation may vary considerably even over small distances, this low cost gauge will allow researchers to collect precipitation data at specific study locations. Furthermore, water beads up on the material and flows easily into the collection reservoir. The gauges are ultra-lightweight and stackable for easy transport into remote areas.

The gauge has some disadvantages. The maximum capacity of the gauge as presented is approximately 530 ml, which is equivalent to 56.1 mm of precipitation. Maximum capacity is reached when the water level in the gauge reaches the bottom of the spout inside. Because the 2 sections of the gauge form such a tight seal, air pressure does not allow additional precipitation to enter the collection reservoir. Large precipitation events or using this gauge in areas where it is not frequently checked would present problems. However, the gauge could be modified to a maximum capacity of 820 ml or 86.9 mm by cutting off the lower portion of the spout as shown in Figure 1D.

A second disadvantage results from the transparency of the plastic material. When exposed to the sun, the moisture in the gauge evaporates and condenses on the inner sides of the collection reservoir. This moisture can be retrieved by simply tapping the gauge prior to measurement causing the moisture to return to the bottom.

The use of a small quantity of oil in the gauge will prevent evaporation. A preliminary test was conducted to determine the effectiveness of oil in preventing evaporation in this type of gauge. Four gauges, each containing 250 ml of water were placed in an environmental chamber for 10 days. Ten ml of 30 weight motor oil were added to 2 of the gauges. During field use, it would be suggested that a nontoxic oil be used in place of motor oil. The temperature was kept at 32° C and a small fan was operated continuously to simulate wind action 24 hours a day. After 10 days, the 2 gauges containing oil retained the original 250 ml, while the 2 without oil averaged only 130 ml. This suggests that oil would be required if the gauges were left for long periods of time. It should be noted that rarely would conditions be encountered that are as conducive to evaporation as our experiment for such extended periods of time.

In summary, the gauge described provides a low cost method to determine precipitation for researchers, public land managers, ranchers, or homeowners. The low cost and simple design satisfied the needs of the current project and may prove useful in other research projects requiring intensive precipitation measurement.

Literature Cited

Ben Meadows Company. 1992 Catalog. Item #110690, p. 239. Atlanta, Ga. 30341.

Ohlenbush, Paul D. 1972. Construction and use of an inexpensive rain gauge. J. Range Manage. 25:405–406.

SAS Institute. 1988. SAS/STAT User's guide, Release 6.03 Edition. SAS Institute Inc., Cary, N.C.