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Portable Soil Moisture Meters

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Summary. Soil moisture status can be measured using neutron probes, time domain reflectometry, tensiometers, gravimetric methods, and electrical resistance blocks. Most methods have limitations; they may be time-consuming (gravimetric), expensive (neutron probe, time domain), or fixed in place (tensiometer, gypsum block, and neutron probe) (Schmugge, 1980; Weems, 1991). Water management in droughty, urban areas of the country would benefit from identification of a portable, fast, and relatively inexpensive soil moisture measuring device suitable for use in urban lawns and gardens. In this study, we have identified an instrument that may be suitable for this purpose.

Many garden centers sell a hand-held meter that works on the principle of electrical potential developed across a bimetallic tip. As soil moisture content increases, so does the flux of energy. The meters have gauges that read in values, such as 1 to 10, which correspond to soil moisture content. We were interested in whether these meters are accu-

rate and reliable, since their relatively inexpensive cost (\$5 to \$15) might attract homeowners. Two brands of meters [Instamatic Moisture Meter (Luster Leaf Products, Inc., Crystal Lake, Ill.) and Plant Care Moisture Meter (no product information given)] were evaluated for horticultural use by comparing their readings in soils of known water content to readings from a portable tensiometer (Model #2900, Soil Moisture Equipment, Santa Barbara, Calif.) and gypsum blocks (Meter Model #5910-A, Soil Moisture Equipment). Soils of differing texture were used to assess whether texture affected meter performance.

Three soils of different texture (Santa Ynez clay loam; fine, montmorillonitic, thermic Ultic Palexeralf; Garretson gravelly loam; fine-loamy, mixed, non-acid, thermic Typic Xerorthents; and Metz loamy sand; sandy, mixed, thermic Typic Xerorthents; all with electrical conductivities of less than $6 \text{ dS}\cdot\text{m}^{-1}$) were excavated, air-dried, ground, and sieved to a 2-mm fraction. Large, gravelly material was retained in the Garretson soil. A soil moisture release curve for each soil was obtained by adding increasing amounts of water to 1-kg subsamples of the soil and measuring soil moisture tension with the portable tensiometer.

The experiment included all combinations of three factors: soil type, moisture level, and meter type. From the moisture release curves, three soil moisture regimes were created for each soil by mixing 10 kg of a soil in a 30-liter, 3-mil plastic bag with a quantity of distilled water to create soil tension levels of 10, 40, and 80 kPa. A fourth moisture regime incorporated only air-dry soil. Each bagged soil sample was held in a separate 20-liter container.

An electrical resistance block was

buried at 10 cm in each of the 12 containers. All readings of the tensiometer and two homeowner brands of moisture meters were made at 10 cm. Three portable tensiometer readings and three readings each of the two homeowner brands of moisture meters were made in each container. To assess their reliability, three meters of each brand were used. Readings were pooled for each type of portable device. After measuring soil moisture with each device, the plastic bags holding the soils were closed. Five successive dates were used to measure soil moisture. Readings from the five dates were used as replicates.

In order to compare devices, readings from the instruments were standardized. This was necessary because meter readings increased with water content from 0 to 8 with the Instamatic, 0 to 10 for the Plant Care, and 0 to 100 for the gypsum block meter. The tensiometer readings increased with decreasing water content from 0 to 100. Responses of all devices were standardized to a range of 0 to 100. Tensiometer values were subtracted from 100 so that 100 kPa for the tensiometer was equal 0. The moisture meters were multiplied by appropriate constants to expand their scales and the gypsum block values were unchanged. An example of this standardized response is shown in Fig. 1. The values in Fig. 1 are averages of three daily readings times 5 days. Standard errors for each device at each moisture level and soil type were obtained from a one-way analysis of variance.

Results and discussion

Measurement of soil moisture in a porous body (e.g., electrical resistance block, tensiometer) has generally been viewed as giving better correlations with moisture than have measures made directly on the soil. This is due to the heterogeneity of soils and the unpredictability of sufficient contact between electrodes and soil (Gardner, 1986). However, hand-held meters did as well as the tensiometer and gypsum blocks at distinguishing between the soil moisture extremes of 10 kPa and air-dry.

The Pearson's correlation coefficients (Table 1) indicate a close relationship of meter measurements to soil tension. Even though the moisture release curves were prepared with the tensiometer, multiple readings of

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Use of trade names is only to help in the explanations and does not imply an endorsement of these products over similar ones.

Table 1. Pearson's correlation coefficient (*r*) correlating device readings to applied water. Readings were taken over a range of moisture levels.

Soil texture	Device			
	Tensiometer	Gypsum block	Instamatic	Plant Care
	<i>r</i>			
Clay loam	0.91	0.84	0.94	0.94
Gravelly loam	0.89	0.92	0.98	0.95
Loamy sand	0.92	0.99	0.93	0.94

the tensiometer did not always give the same value at a given moisture content. This shows that each device, including the tensiometer, has limitations and possibly that there was some soil moisture variability within each container. Gypsum block readings also showed variation depending on soil texture (correlation coefficient of 0.84 for the clay loam and 0.99 for the loamy sand). There were no differences in readings among units of the same brand of homeowner device at a given moisture content.

Plotting standardized device responses (Fig. 1) results in different curves because each kind of device measures different physical parameters

for which the standardization of values may not compensate. The measured values relative to each type of device are not as important as the ability of each device to distinguish among the moisture regimes. The tensiometer could distinguish among all four regimes because the regimes were based on its moisture release curve. The homeowner meters could consistently distinguish between the 10 kPa, 40 to 80 kPa, and air-dry soil moisture regimes.

In the Metz loamy sand (Fig. 1A), the tensiometer and gypsum blocks were able to distinguish the soil moisture conditions very well. The two homeowner instruments have a

flatter response in moist soil, but still discriminated between 10, 40, and 80 kPa.

In the Garretson gravelly loam (Fig. 1B), tensiometer and gypsum block readings were able to discern between 40 and 80 kPa. The Instamatic was slightly better able to separate those soil moistures than the Plant Care.

In the Santa Ynez clay loam (Fig. 1C), tensiometer readings were distinctive for each regime, but the gypsum blocks had difficulty between 40- and 80-kPa soil tensions. This might be due to poor soil contact with the block. The homeowner devices also showed discrimination problems between these tensions.

The guidelines that came with the meters were generic and without regard to soil texture. To use these devices effectively, users should calibrate the device to gain a relative sense of how measurements relate to actual plant water requirements. This can be done by taking a "wet" reading soon after an irrigation (or rain), and con-

Fig. 1. Standardized response of moisture measuring devices to four moisture contents in three soil textures. The readings have been transformed to the same scale in order to compare them. Standard error bars appear for each device at each moisture level if they are large enough to show. A value of "air-dry" for the tensiometer is included merely as a comparison.

tinuing with more measurements as the soil dries. Inserting the probe into an obviously dry soil would give a "dry" reading. By interpolating between the dry and wet points the user should be able to determine when irrigation is appropriate.

Summary

Homeowner devices had a good ability to discriminate at the extremes of soil moisture levels in all three soil textures. There was less precision at 40 and 80 kPa in the gravelly loam and the clay loam. Lack of precision would be a problem in economic production where yield is associated with plant water status. In landscapes, yield is less important than plant health, which is often associated with over- or under-watering. On the whole, these meters would be an adequate aid in helping homeowners schedule irrigations. The ability to take multiple, rapid measurements throughout an irrigated area would help gardeners modify irrigation schedules to meet the water needs of a variety of plant types and microclimates.

A possible limitation to the hand-held meters is the shortness of the probe that is inserted into the ground. In the two models we tested, the lengths were limited to 16 and 20 cm. Soil salinity could also pose a problem because meters could be read artificially "wet" by salt presence. Inserting the probes into a dry rocky soil may pose a problem because their plastic bodies are not durable. The Instamatic, with a wand separate from the meter, was more sturdy than the Plant Care model.

Literature Cited

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