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A Simple Portable Reflectometer for Field Use[1]

S. A. Bowers and C. W. Hayden

ABSTRACT

A small, portable, battery-powered field reflectometer, which utilized an integrating sphere, was developed for measuring reflectance from soils and intact leaves. Its light source was a flashlight bulb; its wavelength selection within the range of 0.4 μ to 1.1 μ was achieved with interference filters. Comparison with laboratory instruments was favorable.

Additional index words: reflectance, soil reflectance, plant leaf reflectance.

WHEN radiant energy is incident upon a surface, it is either reflected, absorbed, or transmitted; i.e., R + A + T = 1. All three processes occur with plants, but with soils the transmittance is assumed to be zero. Understanding the response of both soils and plants to solar radiation requires an awareness of reflectance values.

Reflectance values are usually not known for a particular soil, plant, or leaf, at a particular time. Commercial instrumentation is available for large-scale measurement of reflectance in the field; it is, however, expensive. This paper describes the construction and use of a simple, inexpensive, portable instrument which can measure reflectance on a wavelength basis from soils and individual intact plant leaves. Admittedly, this instrument doesn't meet all field needs; i.e., it cannot be used for measuring reflectance from an entire crop canopy.

The use of small reflectometers on plants is not new. Shul'gin (8) constructed a reflectometer using a prism monochrometer and an incandescent light source that required an AC power source. A photomultiplier tube was used. Its wavelengths ranged from 400 mμ to 700 mμ, with measurements possible in 5 mμ increments. This description implies a delicate, sensitive instrument.

Birkebak and Birkebak (2) fabricated a portable reflectometer for measuring the reflectance from tree leaves. The sun was used as the light source. These reflectance measurements were not on a wavelength basis; instead, the reflectance was determined for the complete spectrum.

The advantage of the instrument described here is that it is inexpensive, easily constructed, and exceptionally rugged. It is truly portable in that it is operated entirely from a battery pack. Reflectance is measured by wavelengths from 0.4 mμ to 1.1 μ; according to Moon (6), about 80% of the solar energy reaching the earth's surface arrives in this wavelength range.

A diagram of the reflectometer is presented in Fig. 1. The light source is a No. 965 flashlight bulb rated for 0.50 amp at 9.84 v. The bulbs were operated at 12 v to allow greater energy through the system. This excessive voltage decreases bulb life by approximately 50%, but bulbs are cheap and easily replaced.

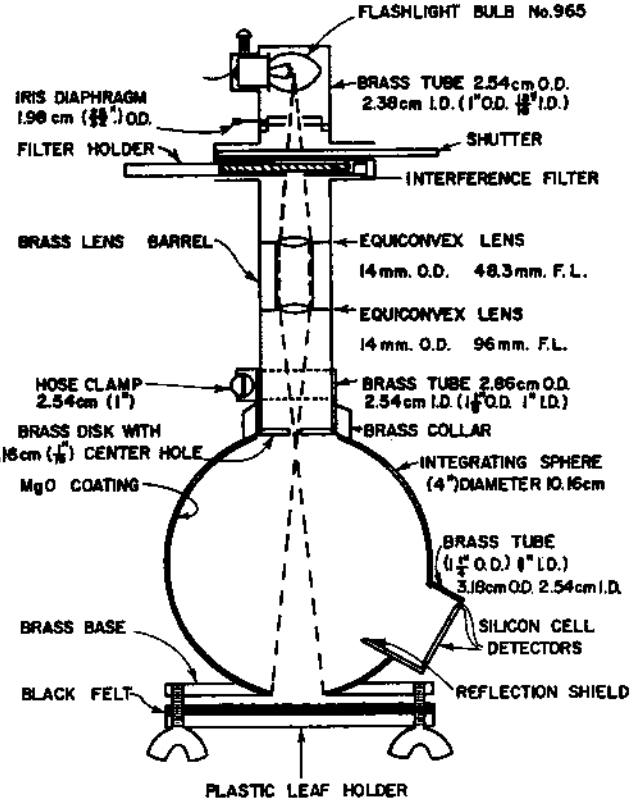

Fig. 1. Portable reflectometer for reflectance measurements from soils and plant leaves.

Immediately below the bulb is a small iris diaphragm which controls the size of the light beam. By adjusting the iris diaphragm, the beam diameter can be adjusted to conform to that of the sample port.

Beneath the diaphragm are two compartments; one holds a hand shutter and the other holds an interference filter. The hand shutter is a blackened strip of phenolic board which is inserted in the path of the light beam. Interchangeable interference filters are also placed in the path of the light beam, with each filter producing a different wavelength band. The filters are placed in the beam by hand, one at a time, in sequential order until the full wavelength range is covered. The width of the wavelength band varied with the filter; the average half-width was approximately 40 mμ.

Below the filters are two equiconvex lenses mounted 2.5 cm apart. The lenses were positioned so that the light bulb filament was at one focal point of the optical system. A brass disk through which a 0.16 cm (1/16-inch) hole was

[1] Contribution from the Snake River Conservation Research Center, Nothwest Branch, Soil and Water Conservation Research Division, Agricultural Research Service, Kimberly, Idaho; Idaho Agricultural Experiment Station cooperating. Received April 10, 1967.

[2] Research Soil Scientist and Agricultural Research Technician, Snake River Conservation Research Center, Kimberly, Idaho.

drilled was placed at the other focal point. The focal point was centered exactly in the hole; this arrangement blocked all divergent light rays and resulted in a crisp, clearly defined circle of light at the sample port. The lenses used were two of many the authors had on hand. They were selected by trial and error; other combinations would have worked equally as well.

The main component of this and most other reflectometers is an integrating sphere whose inside surface is coated with highly reflective MgO. As shown in the diagram, the incident beam traverses the sphere and strikes the sample. Radiant energy is reflected from the sample into the sphere where it undergoes multiple reflections, resulting in a uniform energy density. The sphere was made from a 10-cm (4-inch) world globe penny bank. The inside was first painted with two coats of epoxy white enamel whose pigment was 100% TiO_2. Several coats of MgO were deposited on the painted surface by burning magnesium ribbon beneath a funnel whose tip projected into the sphere.

Finkelstein (4) recommended that the total port area of the sphere should be less than 1.6% of the total inside surface area. This could not be achieved with this instrument since the size of the detector exceeded this limit. The total port area represented 3% of the inside surface area. The detector consists of a series of photovoltaic silicon cells which are sensitive over the wavelength range of 0.4 μ to 1.15 μ with a peak response at 0.85 μ. Tanner (9) published the relative spectral response of silicon cells to wavelengths from 0.4 μ to 1.1 μ.

A round brass base plate was attached to the sphere for stability when measuring reflectance of soils. For measurement from leaf surfaces, an accessory attachment was necessary. As shown in Fig. 1, a piece of plastic was cut to the same diameter as the brass base. Two thicknesses of black felt were glued to its top side and then both the felt and plastic were sprayed with flat black paint. The plastic piece was then attached to the brass base by two thumb screws. An intact leaf can then be inserted between the base and the felt surface, directly beneath the sample port, and secured in place by tightening the two screws.

Figure 2 shows the reflectometer in the field connected to an intact corn leaf. The reflectometer mount consists of a 40-inch 0.64 cm (¼-inch) pipe connected to a camera tripod. A two-jaw extension clamp was brazed to one end of the pipe; an adjustable 0.91 kg (2-lb) counterweight

Fig. 2. Portable reflectometer measuring reflectance from a corn leaf.

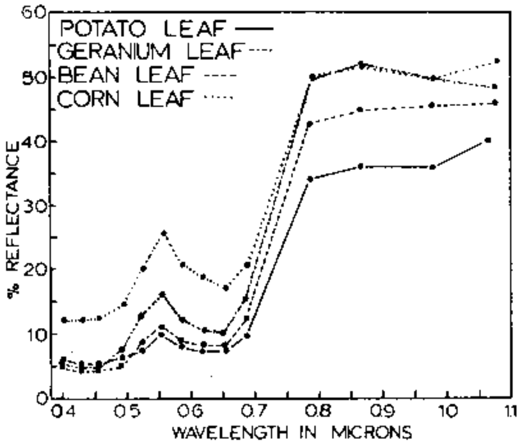

Fig. 3. Reflectance spectra from intact plant leaves.

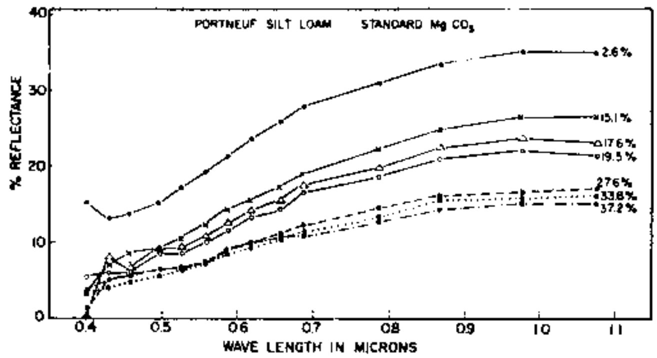

Fig. 4. Reflectance curves from Portneuf silt loam. Each curve represents a different percent moisture on a weight basis.

was attached to the other end. The clamp supported the reflectometer by its barrel. The position of the reflectometer could be adjusted for height and maintained in any orientation.

To calculate the reflectance for any wavelength, reflection measurements are first made from a standard; in this experiment, a small block of $MgCO_3$ was used. The reflectance is defined as the ratio of the measurement made with the sample divided by the measurement made with the standards. The resulting quotient is expressed as a percent.

When using silicon cell dectectors, the output should be measured in amperes rather than volts because a linear relationship exists between irradiance and the output current. The output current was measured with a portable Keithley Model 600A Electrometer.[3]

Figure 3 shows the reflectance spectra from several different leaves. With the exception of the geranium leaf, the spectra were obtained in the field from intact leaves. In every case, the resulting curves display the characteristic form attributed to all fresh leaves and agree with the results shown by Shul'gin (8), Rabideau et al. (7), Billings and Morris (1), Gates et al. (5), and many others. Figure 4 shows the reflectance spectra from a Portneuf silt loam soil in both dry and wet states. The results generally agree with with those of Bowers and Hanks (3), who showed that as surface soil moisture content increases, reflectance decreases. Figure 5, a replot of part of the data of Fig. 4,

[3] Trade names are included for the benefit of the reader and do not imply endorsement or preferential treatment of the product named by the United States Department of Agriculture.

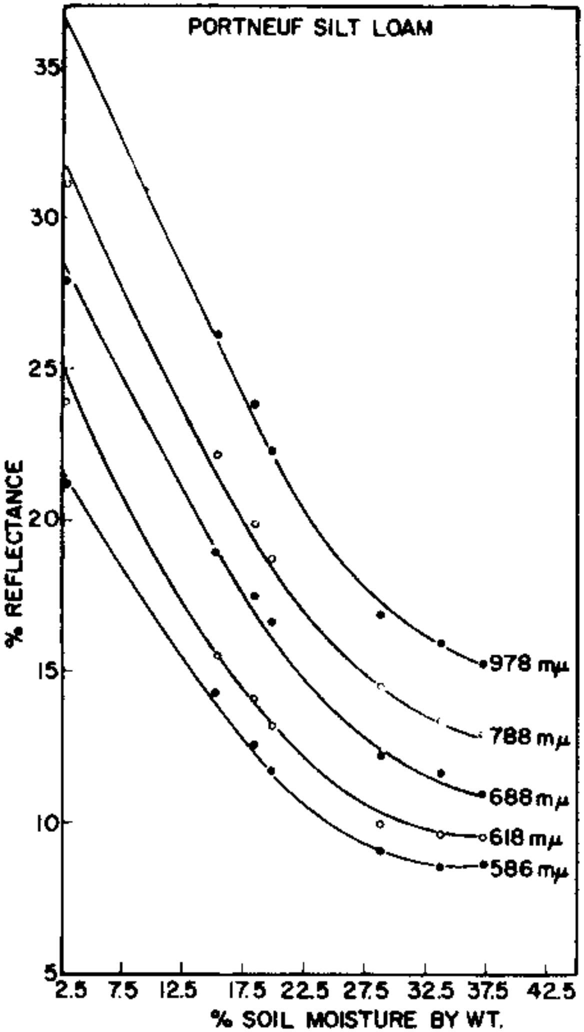

Fig. 5. Reflectance versus soil moisture at particular wavelengths.

demonstrates the potential of reflectance techniques for soil moisture determinations.

Figure 6 shows a comparison between the results from the portable reflectometer and a Beckman Model B Spectrophotometer[3] equipped with reflectance attachments. The instrument presented here does not possess the precision and accuracy of the more expensive laboratory spectrophotometers; the very nature of its wavelength selection system

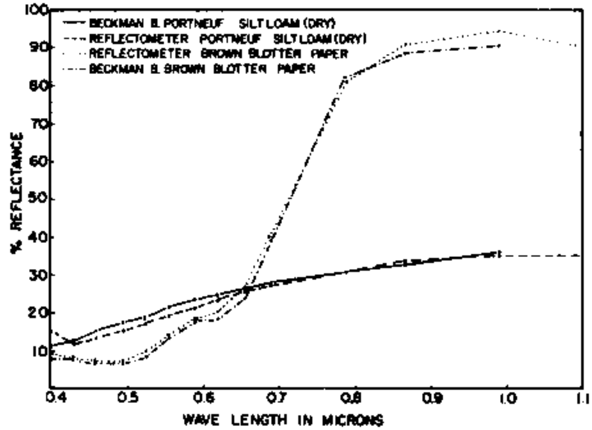

Fig. 6. Comparison of reflectance spectra secured with a Model B Beckman Spectrophotometer and the fabricated portable reflectometer.

makes such accuracy impossible. It was intended, however, that this instrument be portable, rugged, inexpensive, and yet give reliable values in a field situation. It does meet these requirements.

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