A Newly Devised Solarimeter for Measuring Photosynthetically Active Radiation

ZENBEI UCHIJIMA

Researcher, 1st Laboratory of Physics, Division of Meteorology, Department of Physics and Statitstics, National Institute of Agricultural Sciences

Introduction

With development in research work of photosynthesis in plant communities and of potential photosynthesis, there is an increasing demand of information for photosynthetically active radiation (PAR) as energy source of photosynthesis. Photosynthetically active radiation denotes the total radiant energy between the wavelengths 0.4 and 0.7 μ (Gaastra, '59), while in the USSR the radiant energy between the wavelengths 0.38 and 0.71 μ is adopted as PAR (Nichiporovich, '60). However, those measurements which have been made of the two different definitions of PAR suggest that the difference in absolute amount of radiant energy between them can be practically disregarded.

Varieties of instrument are widely used by the plant ecologist or agronomist to measure visible light corresponding roughly to PAR under field conditions. Light detectors such as selenium and silicon cells have a disadvantage for measuring PAR, because the spectral response is largely different from a "block type" response and they are also temperature dependent.

Thermopiles are probably the most useful detector for measuring PAR, because they have a flat spectral response in the wide range of the wave length. The flat spectral response can be relatively easily modified to the "block type" response with cutoff filters.

A newly devised instrument (solarimeter for measuring photosynthetically active radiation), which is described here, uses the thermopilies and two filters of infrared and ultraviolet absorbing glasses. As will be illustrated later, the IR-cutoff is not so sharp, and there is some unwanted loss in PAR, but it seems that the errors are within acceptable limits.

Instrument

Photographs of the complete instrument and of the digital integrator are shown in Fig. 1. The basic detector of the instrument is a thermopile of the type commonly used among meteorologists. Another thermopile is inserted into the electric circuit to compensate the temperature dependence of the instrument.

To make the instrument suitable for measuring PAR, the two filters are fitted over the detector to eliminate the infrared and ultraviolet components from incoming radiation flux. Light diffuser of plastic is mounted over the filters to retain the good angular response of the instrument.

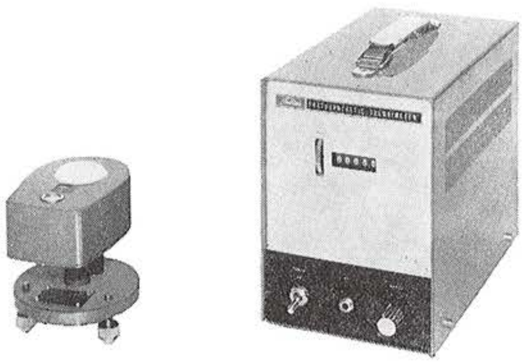

Fig. 1. Solarimeter for measuring PAR and digital integrator.

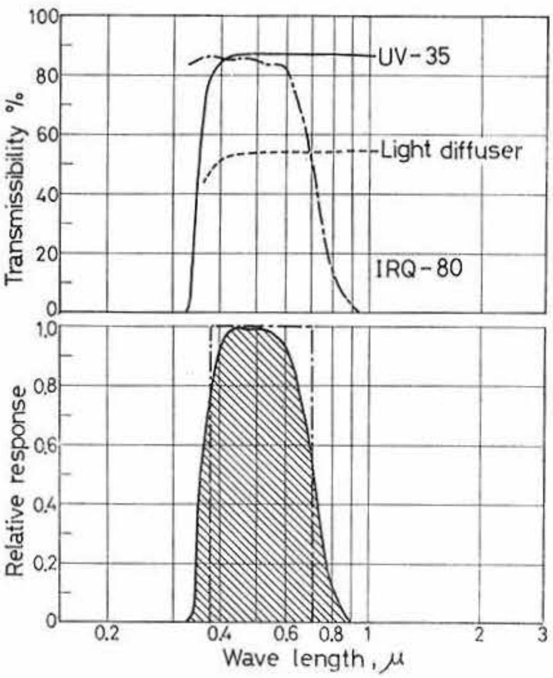

Fig. 2. Top : Spectral transmissibility of filters and light diffuser.
Bottom : Spectral response of the instrument.

The glass filters used in this instrument are UV-39 and IRQ-80, respectively. The thickness of each filter is 4.0 mm. The spectral transmissibility of these filters and the spectral response of this instrument are presented in Fig. 2. As can be seen in Fig. 2, the spectral cutoff of the both sides of PAR is not so sharp, but errors to be caused by such an incomplete cutoff seem to be within acceptable limits.

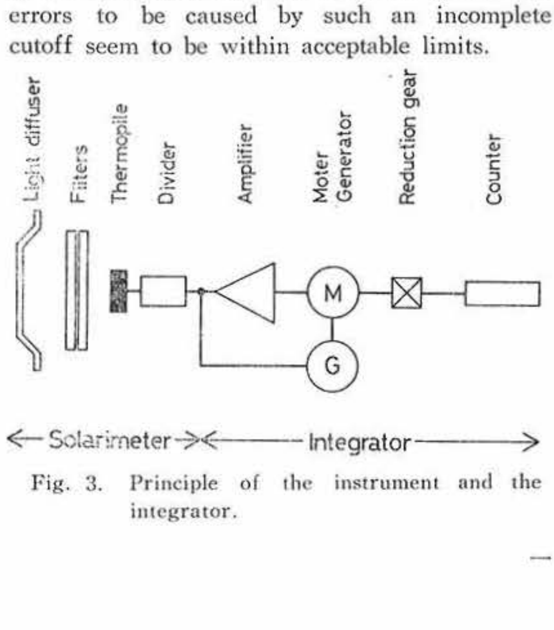

Fig. 3. Principle of the instrument and the integrator.

For radiation recording, the instrument is connected to a potentiometric recorder (full scale 5 or 10 mV) or to a digital integrator made specially for this purpose. The output of this instrument is 5 mV per 1 ly/min (=cal/cm^2 min) of PAR. The accuracy of the instrument is about $\pm$ 5 %.

The output showed no temperature dependence within the range from -20 to $+50$°C. Fig. 3. shows the schematic diagram of the instrument and the integrator. A two-range switch, attached to the integrator, provides a range of one digit per 0.1 ly/min (position 1) or range of one digit per 0.01 ly/min (position 2).

The angular reponse of the instrument is shown in Fig. 4. The deviation of the response from cosine law at high angles of incidence is due to the light diffuser not being a complete hemisphere. These measurements were made with radiation from a tungsten lamp.

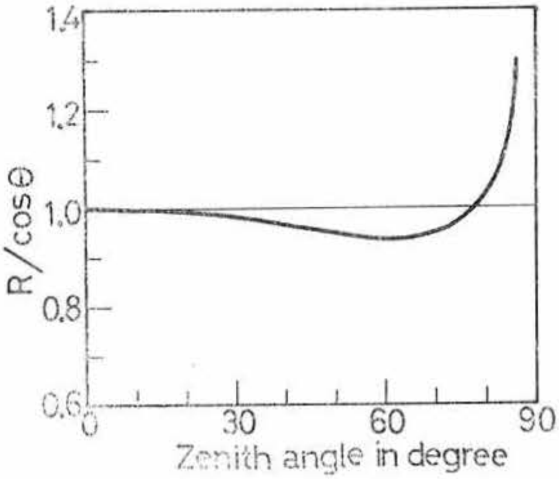

Fig. 4. Angular response of the instrument.

Trial recordings of solar radiation

The instruments have been tested for ten months at Tokyo (National Institute of Agricultural Sciences) and Kitamoto (Agricultural Experimental Station). During these tests, simultaneous recordings were taken with ordinary solarimeters without filters. It was assumed that the filtered instrument measured the radiation in the PAR region (0.38-0.71 μ) and the ordinary solarimeter did the total short-wave radiation (0.3-3.0μ).

The results of the comparison showed that at Tokyo (which has the temperate and humid climate and polluted atmosphere), the proportion of PAR to the total short-wave radiation was somewhat low compared with those reported by MaCree ('66) and Tooming et al. ('67 a and b). The proportion obtained at Tokyo was between 30 and 40 % on clear days. An example of the daily course of the proportion of PAR obtained at Kitamoto (about 40 km northwest from Tokyo) is presented in Fig. 5. The mean of the proportion of PAR (the proportion of daily total of PAR to daily total of total short-wave radiation) was found to be 45.3 %, in good agreement with those reported by other researchers (MaCree, 66, Tooming et al., '67 a, b and Guliaev, '63, '65).

Although they have reported that the proportion of PAR decreases gradually with increasing the zenith angle of the sun, our measurements did not show a clear dependence of the proportion of PAR on the zenith angle of the sun. The difference in the zenith angle dependence of the PAR proportion seems to be due to the lack of the good angular response of the instrument (see Fig. 4.).

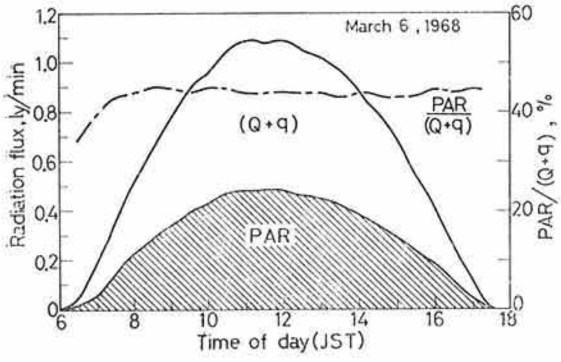

Fig. 5. Comparison of photosynthetically active radiation with total short-wave radiation (Q+q).

It can be concluded from the results mentioned above that the instrument is useful with acceptable errors for measuring the daily amount of photosynthetically active radiation. However, there is need for further improvement of the angular response of this instrument.

References

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