

Application of a new calibration method to an unventilated dynamic diffusion porometer

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Summary

It is shown here that evidently a new calibration method that appeared to be valid for a ventilated dynamic diffusion porometer can be used for the unventilated types as well. A discussion on the method and the results obtained is given.

Introduction

During the past decade a growing interest has been shown in the possibilities for measuring directly leaf epidermal resistance against water vapour diffusion. From these possibilities impetus may be expected to such fields as breeding for potential production making use of collected knowledge on ecophysiological variability in the field (e.g. Gifford & Musgrave, 1973; de Parcevaux, 1973), improving field evaporation predictions (e.g. Monteith, 1973; Wartena, 1974) and extending knowledge on plant-water relationships in the field (e.g. Lange, 1972; Thurtell, 1974).

Description and appreciation of measuring methods of epidermal resistance have been given recently (Stigter, 1972; Stigter et al., 1973; Slavík, 1974). An improved ventilated dynamic diffusion porometer, its new calibration strategy and method, and field results obtained with it, have been described in detail (Stigter et al., 1973; Stigter & Lammers, 1974) and reviewed (Stigter, 1974). A guide to users of porometers was drafted (Stigter & Lammers, 1974).

Commercially available porometers have so far all been of the unventilated dynamic type, the most widely used ones provided with a large Aminco LiCl humidity sensor (Slavík, 1974). A porometer, made by TFDL (after Kanemasu et al., 1969), is of the latter type. It was therefore of general interest to investigate whether the new calibration method, shown to yield excellent results with the venti-

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lated prototype provided with a small LiCl humidity sensor, would also be applicable to this unventilated type.

Porometer and calibration procedure

The mentioned unventilated diffusion porometer had already been improved in comparison with former versions. Polypropylene was used in stead of the water absorbing perspex as a cup material and a low diffusion resistance anticonvection membrane had been built in the porometer opening. We now also applied to it the new calibration strategy and method.

The essence of the calibration lays in harnessing the uneasy properties of the electric humidity sensor, in dynamic use, indicating the course of humidity within the sensor cup. Strategically the most important point is to use the same, not too high, fixed electrical resistance of the sensor as an accurately reproducible point of departure in both calibration and field measurements. And secondly, it is important to introduce a waiting time, at that fixed point, prior to each measurement.

With this in mind the porometer was used in a series of measurements over dummy resistances. These were nickel multipore membranes calibrated, by using the ventilated porometer (Stigter et al., 1973), against a standard set for which the resistances had been independently determined by calculation and evaporation measurements (Stigter & Lammers, 1974). A waiting time of two minutes appeared to be a correct value, just as for the ventilated porometer. After these two minutes the porometer was placed onto a temperature-controlled filter paper, saturated with distilled water, with the respective dummy resistances in between. The transient times between two fixed electrical sensor resistances, further on the scale in comparison with the point of departure and indicated by a needle moving over that scale, were measured by means of a stopwatch.

Results and discussion

As had to be expected from earlier results (Kanemasu et al., 1969) a straight line was obtained through the measuring points in a transient time (Δt) against diffusion resistance (R) diagram (Fig. 1). The new calibration method now makes use of a solution of the equation for the change of water vapour concentration with time in an apparent calibration volume V_t :

$$\Delta t = K (R_1 + R_p) = \frac{V_t}{S_p} (R_1 + R_p) \ln \frac{e_1 - e_p(t_i)}{e_1 - e_p(t_f)} \quad (1)$$

where: S_p = porometer opening; R_1 = (dummy) leaf resistance; R_p = porometer resistance; e_1 = absolute humidity at the real evaporating surface; $e_p(t_i)$, $e_p(t_f)$ = absolute humidity at respectively the initial and final fixed sensor electrical resistance indications of the Δt measurement; K = slope of the calibration lines.

The equation applies to a first-order system. The dynamic response of the sensor to a sudden new evaporation condition as effectively such a first order system could be understood from LiCl sensor theory and experience (Kobayashi, 1960). The

CALIBRATION METHOD UNVENTILATED DYNAMIC DIFFUSION POROMETER

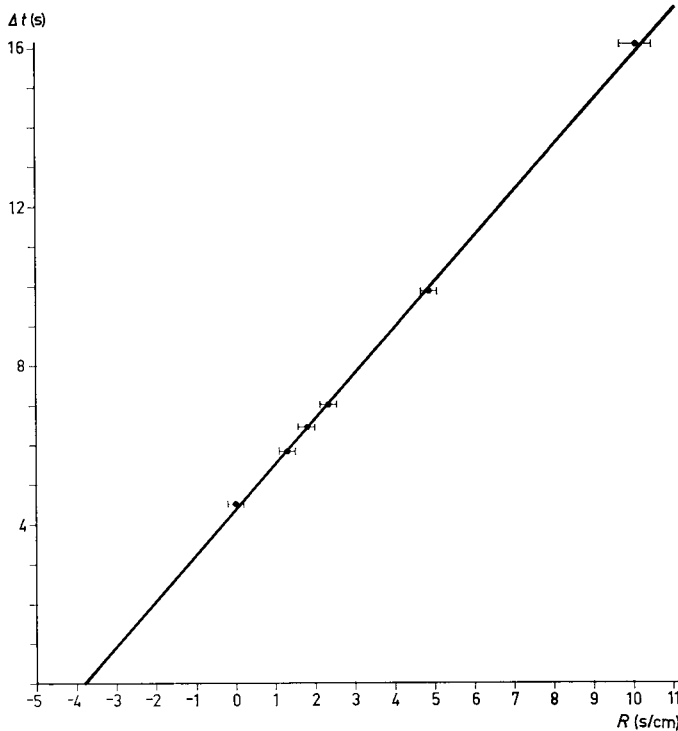


Fig. 1. Example of a calibration line. The porometer resistance is found, at the abscissa, to be 3.8 s/cm (including the hole in the bottom over the filter paper). From this line V_t is found to be 90 cm³ (at 27 °C).

validity of this model for the ventilated porometer, where the porometer volume is part of V_t , could be understood from sensor properties and the low diffusion resistance over the sensor surface (Stigter & Lammers, 1974). This latter fact was recently again confirmed (Nobel, 1974).

The straight lines such as in Fig. 1, and thus the validity of the first-order system model also for the unventilated type, must stem from two facts. Firstly, the resistance against diffusion of still air below the sensor is taken into account in R_p . Secondly, the effect of divergence of diffusing vapour to other parts of the porometer must be constant or negligible in this respect.

The advantage of our model is that V_t can be taken as a calibration constant, momentarily dependent on temperature of the sensor only and dependent on time as properties of the sensor change in the processes of ageing. In this way the problem of the dependence of K on temperature of the evaporating surface, thoroughly hampering the classic way of calibration, is solved (Stigter et al., 1973). This can be understood from the fact that the straight lines indicate that the value of the sudden rate of evaporation applied to the porometer does not influence V_t . But in

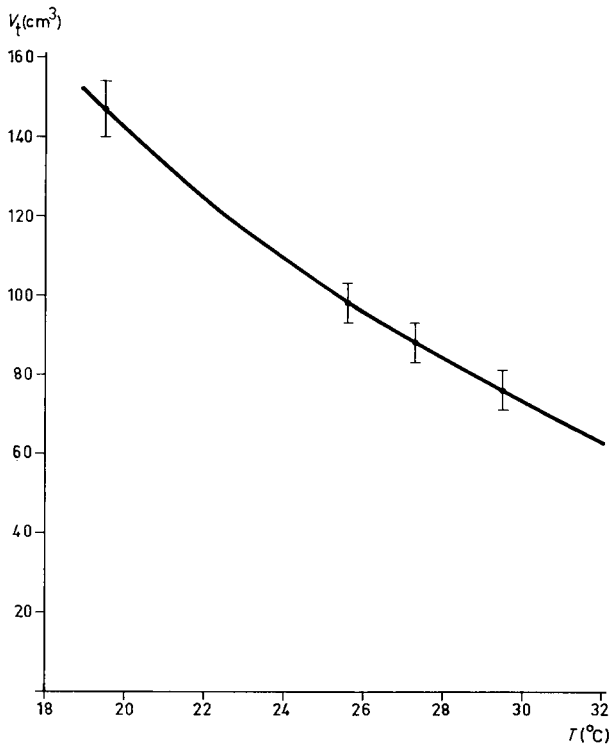


Fig. 2. Example of dependence of V_t on temperature.

that case differences of evaporation rate because of different temperatures at the evaporating surface do not have any influence on V_t , although K changes. (The height of a step function does not influence the time constant of a first-order system.)

The dependence of V_t on sensor temperature, as found here for the unventilated porometer (Fig. 2), is completely comparable to results with the ventilated prototype. A linear dependence, as found with fresh sensors (Stigter et al., 1973), could be understood from LiCl sensor experience (Kobayashi, 1960). Deviations from linearity were found with ageing of the sensors (Stigter, 1974). The sensor of Fig. 2 was more than one year old.

Conclusions

It may be concluded from results and reasoning given above that the new calibration method, used earlier in experiments with a ventilated porometer with a small LiCl sensor, can equally well be applied to the unventilated porometer with a large LiCl sensor. It is important for that purpose that the cup material is non-absorbing, that convective exchanges are negligible and that diffusional diver-

gence of water vapour not reaching the sensor takes place to an apparently constant volume or is negligibly low.

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