Delta-T Devices AP4 and the METER Group Leaf Porometer SC-1

Summary

Porometers are used by plant physiologists to investigate leaf stomatal aperture and to quantify it in units of water vapour diffusion conductance or resistance. Both porometers in this comparison have sensor heads which clip directly on to the leaf surface. The AP4 is a larger and more complex design, but has considerable advantages over the lower cost and more basic SC-1 in respect of the rapidity and convenience of field leaf stomatal measurements.

The Delta-T AP4 has been in production since 1992 without significant design changes. The METER Group SC-1 Leaf Porometer was introduced in 2005 and substantially refined in 2014 to address problems of consistency and accuracy. The new design includes a calibration plate, and a desiccant container built into the leaf clip. METER Group recommends that earlier models are upgraded to the new standard, and used only in the automatic mode for leaf conductance. The following comparison is with the SC-1 in this configuration.

AP4

Working principle

A small polypropylene chamber (cup) is clamped to the leaf surface and water vapour released through the stomata causes the chamber RH to rise. The AP4 compares the rate of RH rise to similar rates obtained directly from a conductance reference plate, then calculates and displays the leaf diffusion conductance.

General design

The AP4 straps around the user's waist and places all controls conveniently to hand to enable left or right-handed operation - leaving the other hand free to position the leaves within the sensor head. The user is guided through calibration, reading, data review and download tasks by onscreen menus.

Sensor head

The lightweight sensor head offers both circular and slotted cups, and includes a PAR sensor for recording light levels. A single RH sensor and thermistor monitor cup temperature. Leaf temperature is measured by a second thermistor pressed against the back of the leaf, and the AP4 automatically applies temperature compensation.

Operation

After positioning the sensor head on the leaf, individual leaf readings are automatically repeated until stable (typically 20 to 30 seconds) by pumping dry air into the head chamber and timing the rise of RH around the preset ambient RH level. Cup position on the leaf can be viewed through a transparent window. The AP4 requires recalibration before each measurement session. This takes 5-10 minutes with the 6-point calibration plate, which is designed for field use and needs preparing only once a day. Spot checks of calibration can be made very quickly at any time.

Leaf Porometer SC-1

Working principle

An aluminium chamber is clamped to the leaf surface and water vapour released through the stomata sets up an RH gradient along the chamber to the desiccant capsule. The SC-1 monitors the changing gradient from uniform starting conditions, extrapolates to equilibrium steady-state conditions, and after 30 seconds calculates and displays the leaf diffusion conductance.

General design

The SC-1 readout unit is simple and lightweight with a small display and keypad. A basic level of reading annotation is possible using the arrow keys. The control box has to be held continuously in use, which can be a problem when manipulating the leaf into the leaf clip.

Sensor head

The head is small and robust, incorporating the desiccant chamber. The throat depth is only 20mm which limits placement on larger leaves. There's no narrow slot for grass leaves, and no PAR light sensor. Sealing at the back of the leaf is provided by foam pads, but there's no conformable sealing on the front surface so readings on textured leaves may be suspect. The leaf chamber is a solid aluminium block which forces the leaf to the block temperature during measurement. The leaf chamber contains two pairs of RH and temperature sensors which have to be tightly matched for accuracy and response time. Annual factory recalibration is specified.

Operation

Prior to placing the head on a leaf, the head must be agitated for about 1 minute to secure uniformly dry starting conditions. The clip must then be positioned quickly on the leaf and held still, vertically, for the 30 second measurement period. It is not easy to verify the exact position of the chamber aperture on the leaf. A calibration plate and the materials for using it are included in the SC-1 Kit. Time for the single point calibration is about 5-10 minutes. The calibration plate is needed for field use, and whenever the ambient temperature changes significantly. Renewal of the leaf clip desiccant is recommended daily.

Reference: *H.G.Jones; Plants and Microclimate; 3rd edn, 2014 pp131-135. Excellent review of theory and implementation of leaf porometer systems.*

Feature comparison

	AP4	SC-1	Notes:
Range mmol.m^{-2}.s^{-1}	5 to 1200	0 to 1000 [1]	*[1] **SC-1** with leaf clip desiccant chamber, in Automatic mode.*
Accuracy	10% (5 to 800) 20% (800 to 1200)	10% (0 to 1000)	
Conductance and Resistance units	mmol.m^{-2}.s^{-1}; mm.s^{-1}; cm.s^{-1} ***and*** m^2.s.mol^{-1}; s.cm^{-1}; s.m^{-1}	mmol.m^{-2}.s^{-1}; ***and*** m^2.s.mol^{-1}; s.m^{-1}	***AP4*** *and* ***SC-1****: only one reading unit may be selected.*
Extra leaf types:			
■ **Large leaves**	✓	(✓)	*By sampling.* ***SC-1*** *reaches only 20mm from leaf edge.* ***AP4*** *reaches 70mm.*
■ **Small leaves**	✓	✓	*Both can measure leaves >6mm diam.*
■ **Narrow leaves**	✓ [2]	✗ [3]	*[2]* ***AP4*** *alternative slotted cup 2.5 x17.5mm with rounded ends.* *[3]* ***SC-1:*** *estimates of overlapped leaves.*
■ **Textured leaves**	(✓)	✗	*Depends on degree of texture.*
Leaf RH environment	Set to ±5%RH of ambient	Exposed to desiccated air [4]	*[4] Over 30s measurement period.*
Calibration plate conductance range	✓ 6-value: 15 to 500 mmol.m^{-2}.s^{-1}	✓ Single value: 240 mmol.m^{-2}.s^{-1}	
Field recalibration	Daily, and if T change > -5 or +10°C	Daily, and if T change >15°C [5]	*[5]* ***SC-1*** *daily desiccant renewal recommended.*
Factory recalibration	Not routinely required	Annual [6]	*[6]* ***SC-1*** *must be returned to factory for RH sensor matching.*
Typical time/reading (from datafile)	~½ -1 min. /reading [7]	~2-3 min. /reading [8]	*[7]* ***AP4*** *takes longer for low conductance, or high RH cycle levels.* *[8]* ***SC-1*** *Equilibration time requires continuous leaf clip agitation.*
Annotation	Max. 30 characters [9]	Max. 8 characters [10]	*[9]* ***AP4*** *has a full QWERTY keypad.* *[10]* ***SC-1*** *annotation uses arrow keys.*
Light sensor	✓	✗	***AP4*** *head has built-in PAR photodiode.*
Field Carrying Case	✓[11]	✓	*[11]* ***AP4*** *includes waist and shoulder straps.*
Weight	3.0 kg	0.5 kg (1.6kg with Field Case) [12]	*[12]* ***SC-1*** *Case required for calibration kit.*

Feature comparison basis

Factual information is taken from manufacturer's data sheets and user documentation. Performance timings are from typical measurements made under ambient conditions of 20-25°C and 50%RH, for conductances of ~50-700 mmol.m^{-2}.s^{-1}, with a typical level of annotation of results. In other conditions of temperature, RH and conductance, the times can be substantially longer than the table values. Instrument firmware versions tested were: **AP4** v.2.51; **SC-1** v. LP 1.38.

Conclusion

Leaf stomatal conductance is one of the more demanding measurements required by plant physiologists. When leaves are photosynthesising and transpiring significantly, the great variability of stomatal response between leaves requires large numbers of measurements to be taken as quickly as possible to build a comprehensive picture of the overall plant and canopy response.

Speed and convenience of measurement have always been a feature of the ergonomic design of the AP4. Two hands are free for manipulating leaves into the sensor head. The cup window allows visual positioning on the leaf, between veins if necessary, and up to 70mm from the leaf edge. Readings can be quickly annotated in plain language, and leaf PAR levels included in the dataset when desired. Changes to the leaf environment during measurement are minimised too. RH is set to within 5% of ambient, and the lightweight plastic cup assembly adapts quickly to leaf temperature. For medium to high leaf conductances (100-700 mmol.m^{-2}.s^{-1}) the AP4 can generally take readings twice as fast as the SC-1, and for intensive use it does not require an additional notebook, or the extra pair of hands of an assistant.