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A MOBILE ASSIMILATION CHAMBER FOR GAS EXCHANGE INVESTIGATIONS IN CONIFERS

There is a great variety of assimilation chambers for gaseous exchange investigations in plants (Jarvis et al., 1971). In field conditions different types of chambers are used. Some investigators use extremely simple chambers which consist of a plastic film twisted around the shoot, thus forming open-end cone- or cylinder-like chambers (Helms, 1970). Other authors use fully automatized chamber systems enabling the investigator to regulate the microclimate inside the chamber (Linder, Troeng, 1980). In view of the great variability of gaseous exchange within the crown space of an adult tree, it is necessary to measure photosynthesis and respiration at a number of different points in the crown. This calls for easily transferrable low-inertia leaf chambers. One of the essential requirements to leaf chambers in field conditions is the efficiency of their closure and the possibility of reducing the boundary-layer resistance. A simple leaf chamber will be described, which has been used successfully at investigations of gas exchange of spruce shoots.

Chamber design. The leaf chamber (Fig. 1) consists of a 40 mm glass tubing and an iris diaphragm. Air is pumped into the chamber through a small orifice. The air flow rate, 1 l·min^{-1}, is controlled by a rotameter. The chamber is fed either with external air with a CO_2 concentration stabilized by a high-capacity reservoir, or with the air from a gas calibrator with a predetermined CO_2 concentration.

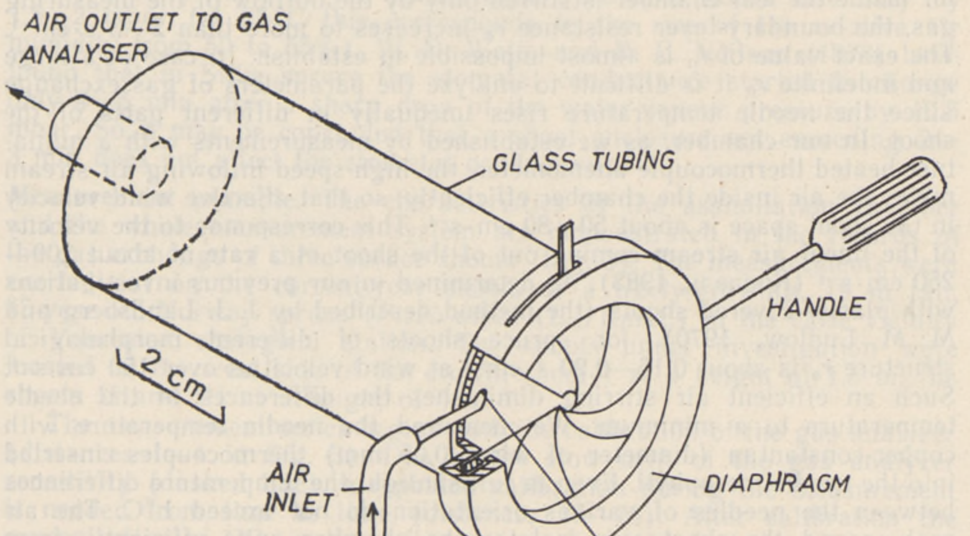


Fig. 1. Diagram of the assimilation chamber.

The inflowing air stream, led through the nozzle at a certain angle to the longitudinal axis and to the radius of the chamber, provides good mixing of the air and a low leaf boundary-layer resistance. So an additional fan is unnecessary. The air outflow to the gas analyzer is 0.75 $l \cdot min^{-1}$. The difference between the in- and outflow (0.25 $l \cdot min^{-1}$) produces a slight overpressure inside the chamber. The extra air escapes through the details of the diaphragm and the slit between the shoot axis and the diaphragm, thus forming an effective air seal. On the outflow tubing there is a sliding cylindrical shade made of thick black paper. The ends of the shade are tightened with black velvet packings.

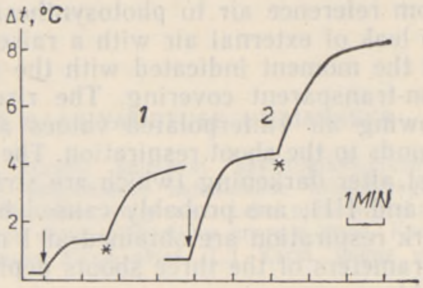
Measurement device. The open-type gas analysis system is based on the IRGA INFRALYT-4. The gasometric system is constructed according to A. Laisk and V. Oja (Лайск, 1977). One of the basic components of that system is a gas calibrator which enables a rapid change of the measurement range and recalibration of the IRGA (see Fig. 3). As a rule, the full scale of the IRGA covers about 25 $\mu l \cdot l^{-1}$ of CO_2 concentration. This corresponds approximately to the maximum rate of photosynthesis of a vigorous sun-type spruce shoot of a medium length.

Operation procedure. An appropriate shoot must be prepared for gas exchange measurement. From the base of a lateral shoot of a medium length (not longer than 8 cm) needles are removed in a 1-cm-long section, and a cut of polyvinyl chloride (PVC) tubing is attached to the shoot axis with silicon paste. That muff permits a tighter closure of the diaphragm without injuring the shoot axis with diaphragm lamellae. For measurement, the chamber operator opens the diaphragm, puts the shoot into the chamber and closes it so that the PVC tubing is clasped by the diaphragm. While manipulating the weaker shoots that had been growing in the shade, the operator holds the chamber by a handle attached to the diaphragm base. The more vigorous sun-type shoots are able to carry the chamber without any support. It takes no more than 2 s to enclose the shoot into the chamber. For dark respiration measurements the chamber is covered with a special non-transparent tubing.

Chamber characteristics. *Air flow and boundary-layer resistance.* If the air inside the leaf chamber is stirred only by the outflow of the measuring gas, the boundary-layer resistance r_a increases to more than 2—3 $s \cdot cm^{-1}$. The exact value of r_a is almost impossible to establish. In case of a large and indefinite r_a it is difficult to analyze the parameters of gas exchange since the needle temperature rises unequally in different parts of the shoot. In our chamber, as we established by measurements with a miniature heated thermocouple anemometer, the high-speed inflowing air stream mixes the air inside the chamber efficiently, so that effective wind velocity in the shoot space is about 50—80 $cm \cdot s^{-1}$. This corresponds to the velocity of the linear air stream coming out of the shoot at a rate of about 200—250 $cm \cdot s^{-1}$ (Коппель, 1983). As determined in our previous investigations with plaster-covered shoots (the method described by J. J. Landsberg and M. M. Ludlow, 1970), for spruce shoots of different morphological structure r_a is about 0.16—0.20 $s \cdot cm^{-1}$ at wind velocities over 150 $cm \cdot s^{-1}$. Such an efficient air stirring diminishes the differences in the needle temperature to a minimum. We measured the needle temperature with copper-constantan (diameter of wires 0.05 mm) thermocouples inserted into the needle mesophyll. Even in full sunlight the temperature differences between the needles of various orientation do not exceed 1 °C. The air seal around the shoot axis isolates the chamber quite efficiently from external air. H. M. Rawson and D. C. Lowe (1982) used such a method for enclosing cereal leaves into an assimilation chamber. A proper isolation of the assimilation chamber is especially important in windless

conditions, when the carbon dioxide expired by the chamber operator causes an extremely high local rise of CO_2 concentration in the ambient air, which might take the gas analyzer out of equilibrium for a long time.
Inertia parameters. It takes 20—25 s to obtain a steady-state reading of photosynthesis in our system. If the connecting tubings are long, the response time becomes longer. However, in view of the fact that the CO_2 concentration front does not disperse in the tubings, the enclosure time does not exceed 30 s. The rapid enclosure and the low inertia make this chamber also suitable for examining the transition processes of gas exchange.
Temperature regime. Glass is not the best material for building leaf chambers. If possible, the films transparent to infrared radiation should be preferred (Rawson, Lowe, 1982). However, taking into account the rapid enclosure and the simplicity of the design, we still chose glass for our chamber. Under overcast sky conditions, the air temperature rose by up to 2 °C inside the chamber in 25 s. In full sunlight, when the shoot was perpendicular to the sunrays, the temperature rise was more notable, exceeding the ambient air temperature by 3—4 °C in 30 s (Fig. 2).

Fig. 2. The rise of air temperature in the assimilation chamber above the external air temperature under different weather conditions: *1* — the sun is covered with clouds, intensity of short-wave radiation to horizontal plane, $Q=230\ W \cdot m^{-2}$; *2* — cloudless, sunrays fall perpendicularly upon the shoot, $Q=420\ W \cdot m^{-2}$. Arrows indicate the moment of enclosing the shoot into the chamber. At the moment indicated by the asterisk, the stirring of air inside the chamber is stopped.



Change in air humidity. The stomata of different conifers are sensitive to changes in external air humidity (Ludlow, Jarvis, 1971; Watts, Neilson, 1978). At the flow rate of 1 $l \cdot min^{-1}$, the air humidity rises quite slightly even at the maximal transpiration rate (4 $mg \cdot g^{-1}$ of dry weight). In steady-state conditions, the water-vapour pressure would rise only by 1.5—2 mbar (at 25 °C this corresponds to the rise of the relative air humidity from 50 to 55%). W. D. Watts and R. E. Neilson (1978) have found that in Sitka spruce the stomatal conductance started to change only 4—5 min after a sharp drop of the water-vapour pressure by 10.5 mbar. So it may be concluded that a shoot enclosure not exceeding 2—3 min does not affect the stomatal conductivity.

Measurement example. The characteristics of the assimilation chamber and the whole measurement system are demonstrated in the records of the gas exchange of three spruce shoots (Fig. 3). The measurements were carried out on the current-year shoots of a freely-growing, 19 m tall, 45-year-old Norway spruce (*Picea abies* (L.) Karst.) in the close vicinity of Vooremaa ecological station. The shoots under investigation were located on the west side of the crown, shoot I at a height of 1.5 m, the shoots II and III at a height of 6 m.

The measurement series begins with the calibration of the gas analyzer (distances 1—4 in Fig. 3). Due to the slow drift of the gas analyzer sensitivity (dashed line), a repeated calibration during the measurement is needed from time to time (distances 15—18). After calibration the concentration of CO_2 in the inflowing air is established (distances 5, 8, 11, 14). Then the shoot is enclosed into the chamber (indicated with arrows). A relatively stable reading of photosynthesis is achieved in 20 s after enclosing the shoot into the chamber. The recorded transition

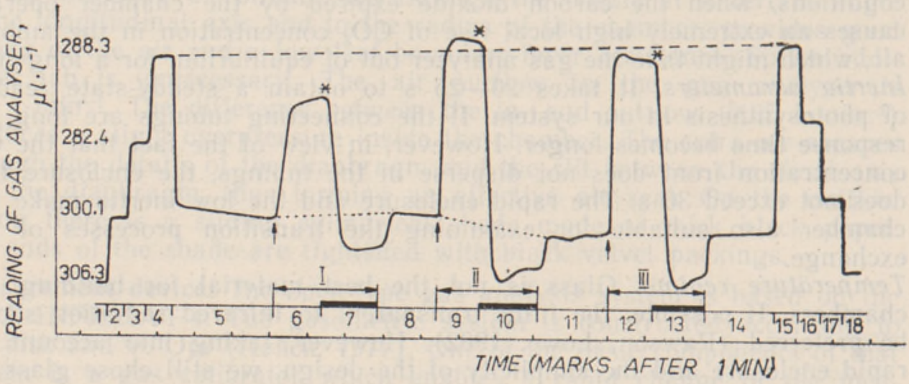


Fig. 3. A record of gas exchange measurements of three intact Norway spruce shoots (I, II and III). For explanation see the text.

from reference air to photosynthesis is smooth. This means that there is no leak of external air with a raised CO_2 concentration into the chamber. At the moment indicated with the asterisk the chamber is darkened with non-transparent covering. The rise of CO_2 concentration above the inflowing air (interpolated values are marked with a dotted line) corresponds to the shoot respiration. The higher values of respiration, registered just after darkening (which are strictly expressed in the records of shoots II and III), are probably caused by photorespiration. Stable readings of dark respiration are obtained at 1 min after darkening. The gas exchange parameters of the three shoots depicted in the Fig. 3 are presented in the Table.

Gas exchange parameters of three Norway spruce shoots

Shoot	Dry weight of needles, g	Intensity of solar radiation on horizontal plane, $W \cdot m^{-2}$	Intensity of photosynthesis, $mg\ CO_2 \cdot g\ dw^{-1} \cdot h^{-1}$	Intensity of dark respiration 1 min after darkening, $mg\ CO_2 \cdot g\ dw^{-1} \cdot h^{-1}$
I	0.380	210	2.51	1.00
II	0.464	490	3.22	0.98
III	0.677	210	2.24	0.64

It may be concluded that the gas exchange parameters in intact conifer shoots in field conditions can be adequately measured with the simplest assimilation chamber. Only care must be taken in stirring the air inside the chamber properly and sealing the chamber effectively from external air. These problems can be solved by closing the chamber with iris diaphragm and overfeeding it with reference air through a small orifice.

REFERENCES

Helms, J. A. Summer net photosynthesis of Ponderosa pine in its natural environment. — Photosynthetica, 1970, 4, 243—253.

Jarvis, P. G., Catsky, J., Eckardt, F. E., Koch, W., Koller, D. General principles of gasometric methods and the main aspects of installation design. — In: Plant Photosynthetic Production — Manual of Methods. The Hague, 1971, 49—110.

Landsberg, J. J., Ludlow, M. M. A technique for determining resistance to mass transfer through the boundary layers of plants with complex structure. — J. Appl. Ecol., 1970, 1, 187—192.
Linder, S., Troeng, E. Photosynthesis and transpiration of 20-year-old Scots pine. — In: Structure and Function of Northern Coniferous Forests — An Ecosystem Study. Ecol. Bull., 32, Stockholm, 1980, 165—181.
Ludlow, M. M., Jarvis, P. G. Photosynthesis in Sitka spruce (*Picea sitchensis* (Bong.) Carr.). I. General characteristics. — J. Appl. Ecol., 1971, 8, 925—953.
Rawson, H. M., Lowe, D. C. A chamber for rapid measurement of cereal leaf gas exchange. — Photosynthetica, 1982, 16, 67—70.
Watts, W. P., Neilson, R. E. Photosynthesis in Sitka spruce (*Picea sitchensis* (Bong.) Carr.). VIII. Measurement of stomatal conductance and ^{14}C uptake in controlled environments. — J. Appl. Ecol., 1978, 15, 245—280.
Коппель А. Т. Метод изучения потоков воздуха в пространстве побега ели европейской. — Лесоведение, 1983, № 2, 82—86.
Лайск А. Х. Кинетика фотосинтеза и фотодыхания C_3-растений. М., 1977.

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KERGE LEHEKAMBER OKASPUUDE GAASIVAHETUSE UURIMISEKS

On kirjeldatud kerget, väikesemahulist ja kiiresti suletavat assimilatsioonikambrit okaspuude gaasivahetuse uurimiseks. Kambri sulgemiseks kasutatakse iirisdiafragmat. Kambrisse juhitava õhu ülehulk tagab selle efektiivse sulgemise. Lehe piirikihi takistus alla 0,2 s·cm⁻¹ saavutatakse kambrisse juhitava õhujoa kineetilise energia arvel. Kambri ja mõõtesüsteemi omadusi näitab hariliku kuuse *Picea abies* (L.) Karst. kolme võrse gaasivahetuse üleskirjutus.

Андрес КОППЕЛЬ, Олеви КУЛЛЬ, Велло ОЯ

ЛЕГКАЯ АССИМИЛЯЦИОННАЯ КАМЕРА ДЛЯ ИЗУЧЕНИЯ ГАЗООБМЕНА ХВОЙНЫХ

Описывается легкая малоинерционная ассимиляционная камера для изучения газообмена хвойных. Для быстрого закрытия камеры используется ирисная диафрагма. Надежное изолирование камеры от внешнего воздуха обеспечивается тем, что в камеру подается воздуха больше, чем откачивается для газоанализа. Воздух в камере перемешивается за счет кинетической энергии воздушного потока, подаваемого в камеру через малое отверстие. Этим достигается сопротивление пограничного слоя листа меньше чем 0,2 с·см⁻¹. Свойства листовой камеры и газометрической системы демонстрируются на записи газообмена трех побегов ели европейской.