must await more information about chemical structure of their substrates—the walls themselves.

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Semi-fossil Lichen Fungi in Scottish Hill Soils

Recent investigations[1] into the micromorphological features of hill soils in north-east Scotland have revealed the presence, within the soil profile, of what appear to be perithecia containing dark-coloured muriform spores. These perithecia are apparent in profiles from Meall-an-t-Slughain, Aberdeenshire (at heights of 2,050 ft. and 2,300 ft.), Ben Rinnes, Banffshire (2,500 ft.), and Morven Aberdeenshire (2,025 ft., 2,800 ft. (two) and 2,850 ft.). The profiles are developed on parent materials derived from both granite (Meall-an-t-Slughain and Ben Rinnes profiles) and basic igneous rocks (Morven profiles). Peat cover is either absent or amounts to no more than 2–3 in., except on one of the 2,800 ft. profiles on Morven, which has a peat cover 14 in. thick, the base of the peat being pollen dated within the Sub-Boreal period.

In many Ascomyceteae the whole ascus undergoes digestion at maturity, thus setting free the ascospores[2], and it is likely that this has occurred in the perithecium shown in Fig. 1. The size of the ascospores (Fig. 2) is rather variable, and though the majority are of the order of 40μ × 20μ some are considerably larger, up to 60μ in length. The size of the perithecia is also rather variable; the majority are approximately 160μ in diameter, but one from the 2,800 ft. Morven profile without peat cover was approximately 270μ in diameter. Some of the perithecia exhibit well-developed ostioles (Fig. 1).

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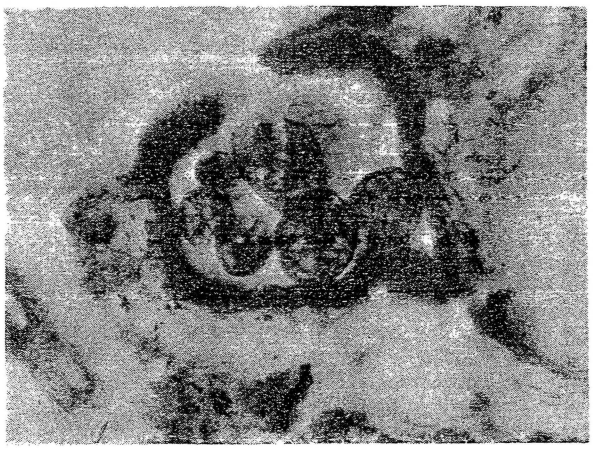

Fig. 1. Perithecium containing ascospores in thin soil section (× 270)

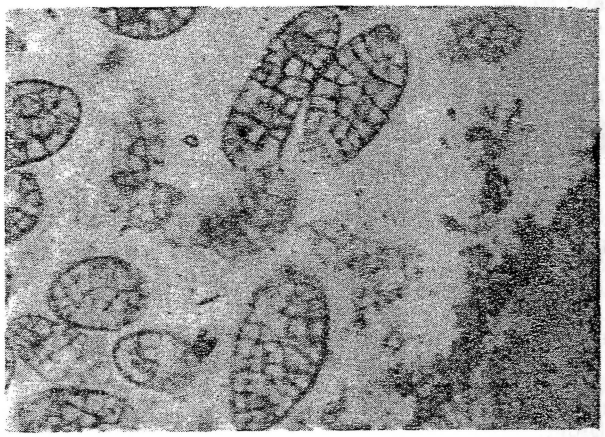

Fig. 2. Dark-coloured muriform ascospores with portion of perithecial wall in thin soil section (× 375)

Museum (Natural History), have confirmed (personal communication) our opinion that the structures described are the fungal components of a pyrenocarpic lichen probably a species of *Polyblastia*[3], although it is impossible to recognize algal tissue in the soil sections.

Within the soil profile, the presence of either perithecia or ascospores has been noted to depths of 9 in. below the mineral surface, though in the case of the 2,800 ft. Morven profile not covered by peat they are present to a depth of 19 in. The Morven profile with peat cover has a thin iron pan at 8–10 in. below the mineral surface, and above this ascospores have been found in association with pollen assemblage of Atlantic age.

This appears to be the first record of fungal component of a lichen, in a semi-fossil state.

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Nitrogen Fixation by Lichens of Arid Soil Crusts

The nitrogen budgets for natural ecological systems are poorly understood, and the contribution of particular microflora in these associations has been only tentatively assessed[1–3]. This applies especially to arid zones where soils sometimes have a surface crust of lichens, some blue green algae, and other cryptogams covering as much as 30 per cent of the total soil area. It is of considerable interest therefore to determine to what extent these lichens fix atmospheric nitrogen, since they might contribute appreciably to the maintenance of a favourable nitrogen balance in these areas.

About forty species of lichens are known to occur in the southern central arid zone in Australia, and twelve of the commonest were exposed to a gas mixture containing nitrogen enriched with nitrogen-15. Thus each lichen was incubated in a Warburg flask for 6 days at 21° C under artificial light, using the following gas mixture (in atmospheres): oxygen 0·2, nitrogen 0·2 (enriched with 35 atom per cent excess nitrogen-15), and helium 0·6. After this

period the contents of each flask were digested in acid, and converted to ammonia by distillation in a Markham apparatus and then to nitrogen gas which was analysed in an A.E.I. MS_2 mass spectrometer. Nine lichens, including *Parmelia adhaerens* Nyl, apud Cromb., *P. australiensis* Cromb., *P. semiviridis* (F.v.M. ex Nyl.) P. Bibby, *Caloplaca citrina* (Hoffm.) T. Fries, *Caloplaca* T. Fries sp., *Dermatocarpon hepaticum* (Lam.) Th. Fr., *Diploschistes scruposus* (Schreb.) Norm., and *Lecidea decipiens* Ach., with one unidentified species, showed no significant fixation. There was a significant incorporation of nitrogen gas, however, into *Collema coccophorus* Tuck. (0·97 and 0·69 atom per cent excess in duplicate samples), whereas *Lecidea crystalifera* Tayl. (0·022 atom per cent excess) and *Parmelia conspersa* (Ehrh.) Ach. (0·0073 atom per cent excess) had a marginal fixation only.

Collema coccophorus has a blue-green algal symbiont (*Nostoc* sp.). The lichen is minute but very widely distributed in the soil lichen crust. Shields, Mitchell and Drouet[4] have suggested that this species might fix nitrogen in the arid soil-crust in California. *Lecidea crystalifera*, which is also widespread in this area, has a green algal symbiont (*Protococcus*), hence the fixation associated with this lichen is of interest and will be investigated further. The lichen has a small squamulose thallus with long rhizoids penetrating up to 1 cm into the soil. *Parmelia adhaerens* similarly has a green algal symbiont (*Protococcus*), and occurs on rocks where it is fairly widespread.

This preliminary work suggests that the lichen crust may contribute appreciably to the nitrogen balance in Australian arid soils.

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Measurement and Control of the Rate of Carbon Dioxide Assimilation by Glasshouse Crops

In recent experiments on the effect of environment on glasshouse crops, the net assimilation rate[1] and other indices of growth are found by measuring the dry weight and leaf area of plants sampled from the crop at intervals of the order of 10 days. During this time the intensity of the solar radiation reaching the plants fluctuates over the whole range between zero and the maximum value, so that a series of different combinations of light intensity and plant temperature occurs even if the air temperature and content of carbon dioxide are successfully maintained constant. Such experiments are thus difficult to interpret, especially as the rate of uptake of carbon dioxide by individual leaves is not related linearly to light intensity at all levels of temperature and carbon dioxide concentration[2], and even when light and all other environmental factors are held constant the rate may vary with time of day[3].

Interpretation is easier if the rate of assimilation of carbon dioxide can be measured during an interval of the order of 10 min rather than 10 days. In apparatus designed for this purpose, air is made to pass at a known rate through an enclosure containing a leaf[2,4] or a whole plant[4] and an infra-red gas analyser is used to measure the concentrations of carbon dioxide in the incoming and outgoing air. With difficulty, it might be possible to make a glasshouse sufficiently airtight for this method to be used to measure the net rate of assimilation of carbon dioxide by the plants contained in it.

An alternative approach is to make no attempt to seal the glasshouse or to make air flow through it at a constant rate. Instead, carbon dioxide is injected from a weighed cylinder at a rate varied to maintain a constant concentration, $[CO_2]_1$, in the glasshouse air, which is stirred by fans to distribute the gas uniformly. In the course of a time interval, Δt, the loss in weight, Δw_c, of the cylinder of carbon dioxide represents the net amount supplied to the plants and soil plus that lost by ventilation. To estimate the loss by ventilation, nitrous oxide, which is absent from the outside air and is not absorbed or produced by plants or soil, is injected into the glasshouse air from a weighed cylinder at a rate varied to maintain a concentration:

$$[N_2O]_1 = b([CO_2]_1 - [CO_2]_0) \qquad (1)$$

where b is a constant and $[CO_2]_0$ is the concentration of carbon dioxide in the air outside the glasshouse. The density, ρ, of nitrous oxide happens to equal that of carbon dioxide, although the technique does not depend on this being so. If Δw_n is the loss in weight of the cylinder of nitrous oxide during the time interval Δt, the rate of carbon dioxide uptake by the plants is:

$$C = S + \frac{1}{\Delta t}\left\{\Delta w_c - \frac{\Delta w_n}{b} + v\rho\left(\frac{\Delta[N_2O]_1}{b} - \Delta[CO_2]_1\right)\right\} \qquad (2)$$

where S is the rate of carbon dioxide output from the soil and v is the volume of the glasshouse. $\Delta[N_2O]_1$ and $\Delta[CO_2]_1$ represent any small changes in concentration between the beginning and end of the time interval due to imperfections in the control system.

In preliminary experiments, infra-red gas analysers have been used to measure $[CO_2]$ and $[N_2O]$, as the two gases have well-separated infra-red absorption bands. By using the signals from these analysers to give proportional control of the concentrations of the gases in the air of a small ($v \approx 5 \times 10^7$ cm^3) glasshouse, the fluctuations in the control system have been small enough for $\Delta[N_2O]_1$ and $\Delta[CO_2]_1$ to be negligible when Δt is of the order of 10–100 min, and when $[CO_2]_1$ is about 1,000 vol. per million, which is near the level required to give maximum uptake by leaves in bright light[2]. Under most weather conditions, changes in $[CO_2]_0$ also remain negligible for long periods and it is only necessary to confirm this by measurements at the beginning and end of each time interval. It is then possible to make $b = 1$ in equation (1) and equation (2) can be simplified to:

$$C = S + \frac{\Delta w_c - \Delta w_n}{\Delta t} \qquad (3)$$

For ordinary agricultural soils, S is small and can readily be measured[5]. Although it depends on temperature, it changes only slowly because of the large thermal inertia of the soil. It can be minimized, for experimental purposes, by growing the plants in sand, when the only source of carbon dioxide will be the roots and their associated micro-organisms.

Equations (2) and (3) thus provide a basis for measuring the rate of assimilation of carbon dioxide by all the plants in a glasshouse over an interval of time so short that the intensity of the solar radiation and the other components of the environment remain nearly constant. So also will the relevant physical properties of the plants, such as the leaf area index, the stomatal resistance and the diffusion pressure deficit in the tissues, and the chemical properties, such as the concentration of assimilates accumulated in the leaves.

By conducting a long series of these brief experiments at various intensities of solar radiation and at various levels of the environmental factors influencing the uptake of carbon dioxide, it would be possible to find the relation between this uptake and the factors on which it depends.