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A LONG-TERM CARBON DIOXIDE ENRICHMENT EXPERIMENT EXAMINING THE INTERACTION WITH NUTRITION IN SITKA SPRUCE

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Introduction

It is important to understand the response of trees and forests to predicted global climatic change – increase in temperature and in the carbon dioxide (CO_2) concentration in the atmosphere. It has already been shown by many workers that global change will affect tree growth, but the responses differ with species. Some people have reported increases in biomass with increasing CO_2 concentration, while others have reported little or no effect. Most experiments so far have been short-term and have used seedlings or immature material (Eamus and Jarvis, 1989).

The experiment described here is a result of research carried out by Edinburgh University and the Institute of Terrestrial Ecology (Lee *et al.,* in preparation). Sitka spruce (*Picea sitchensis* (Bong.) Carr.) have been grown in elevated CO_2 for four years and have reached the stage where growth in pots is no longer viable. The Forestry Commission (FC) has suitable facilities (described below; see front cover) for continuation and enhancement of the Edinburgh experiment. FC staff have recently joined a European Community sponsored project on the likely effects of rising CO_2 and temperature on European forests, co-ordinated by Paul Jarvis at Edinburgh.

Facilities

The open-top chambers (OTCs) in Glendevon in Perthshire were originally set up to examine the effects of air pollution on tree growth (Durrant *et al.,* 1993). These chambers have now been extended to 3.5 m in height, and modified to accommodate both the trees which have had long-term CO_2 treatment in Edinburgh and some one-year-old trees which have been germinated and grown in ambient or elevated CO_2.

The chambers were originally designed for long-term use in adverse climatic conditions. They are octagonal in construction, 3 m in diameter and made from lightweight aluminium sections clad in 3 mm horticultural glass. An internal glass shelf 0.3 m below the eaves helps to prevent air incursions by deflecting the air into the upward-moving air stream provided by the ventilation fans. The fan/filter system is a backward curved centrifugal fan mounted on top of a galvanised steel filter cabinet which draws air in through a hooded inlet. Motor-driven louvred vents are fitted in the base of the unit in order to control air flow. A saving in CO_2 cost is achieved by reducing the air flow through the chambers at night; a light sensor activates the motors and closes the vents.

The treatments have been randomised with respect to CO_2, nutrition and aspect (Figure 1; see below for details) and nutrient treatment (Figure 1). Each chamber has been divided into four equal quadrants with plastic barriers extending 40 cm below the soil and 20 cm above soil level (Figure 2). Each tree in each quadrant is provided with a drip irrigation system which waters the plant to field capacity each day for 10 minutes. Two quadrants in each chamber receive full strength nutrient solution (70 kg ha^{-1} N) provided at rates calculated from the growth rate of the Sitka spruce in previous years. The remaining two quadrants receive water only. Removable walkways are used in the chambers to minimise compaction of the soil.

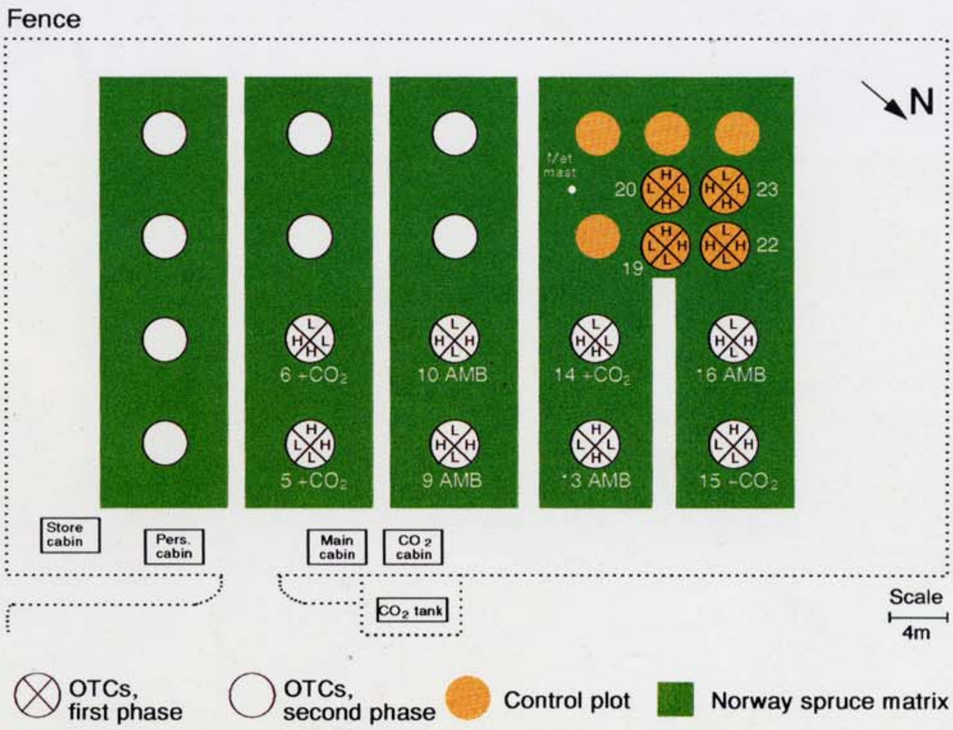

Figure 1: Randomised layout of first phase for CO_2 and nutrition

Front cover: Glendevon site showing extended open-top chambers and CO_2 tank.

Figure 2: View through the top of a chamber, showing barriers and removable walkways

The CO_2 monitoring and control system (Figure 3) consists of sample and injection sub-units controlled by a personal computer via an interface card (Barton *et al.,* 1993). A diaphragm pump draws air continuously from all the chambers through nylon sample lines. To allow for different flow resistances in the sample lines, each is fitted with a needle valve flow meter, enabling flow rates through the lines to be balanced. Each sample line contains a three-way solenoid valve which, when activated, diverts the air stream to the infra-red gas analyser (IRGA), through which it is drawn by the IRGA's internal pump. On switching, the IRGA rapidly stabilises (20 seconds) on a new sample line. The solenoids are controlled by the computer via a multiplexer and relays. The control program cycles through the chambers, spending one minute on each sample line. The first 35 seconds are used to flush the IRGA and to allow it to settle on the new reading. During the remaining 25 seconds a reading is taken every two seconds, and the average is logged to the hard disk and stored in the memory for graphical display. The elevated chambers have a natural diurnal cycle which is achieved, using the precision needle valves, by assuming the mass flow of air through the chamber is constant and requires a constant fixed addition of CO_2 to the airstream.

The CO_2 is supplied from a 16 tonne tank (Distillers M.G., U.K.) through a pressure reducing valve, and then through a fail-safe solenoid valve (in case of power failure). A data logger is used to record both environmental data and CO_2 concentration, and the information is transmitted via a modem to the Forestry Commission's research station at Alice Holt Lodge, Surrey.

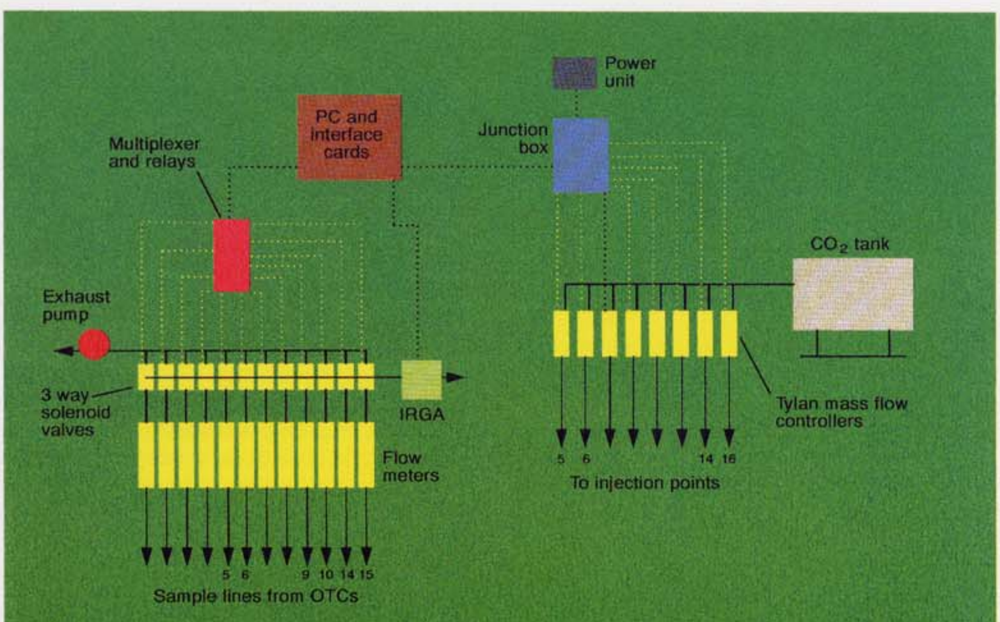

Figure 3: CO_2 monitoring and control system

Planting

Sitka spruce were purchased as 1+1 stock in 1990. They were potted in standard potting compost (peat, sand and grit) and placed in open-top chambers at the ITE (Institute of Terrestrial Ecology, Bush). These chambers are of the same design as those described above, but only 2.5 m in height. The air entering half of the OTCs was enriched by the addition of CO_2, at a concentration of 350 μmol mol^{-1} above background, i.e. on average, 700 μmol mol^{-1}. The remaining chambers received ambient air. The plants were repotted annually and fertilised throughout the growing season. Measurements of growth, biomass production (Figure 4), biochemistry, physiology and gas exchange have been taken throughout this time. After four years the plants could no longer be sustained in pots and the OTCs were no longer tall enough for all the foliage to be fumigated with CO_2. The plants were, therefore, removed from the pots and planted directly into the forest soil of the chambers at Glendevon.

Each plant is supplied with an individual irrigation system which also delivers the pre-designated nutrient supply. The nutrient treatments are based on those outlined by Ingestad and Lund (1986), which have been successfully developed and applied in large and small scale experiments in Sweden. The system was designed and installed by Biotronic (Sweden). It is computer-controlled and programmed to take into account day length, growing season, rainfall and previous growth rates, and provides nutrients at a rate calculated to give constant growth throughout the season. Two quadrants of each chamber receive a full strength solution (70 kg ha^{-1} N) while the remaining two receive water. Application of these treatments began in spring 1993 and will continue for at least two years. A further eight chambers will be converted next year and will be planted with more CO_2 pretreated trees. Non-destructive measurements of growth, phenology, biomass production, biochemistry, physiology and gas exchange will continue to be taken. Finally the plants will be harvested for analysis of biomass allocation to plant parts and partitioning of photosynthate into different carbohydrate and nitrogen compounds.

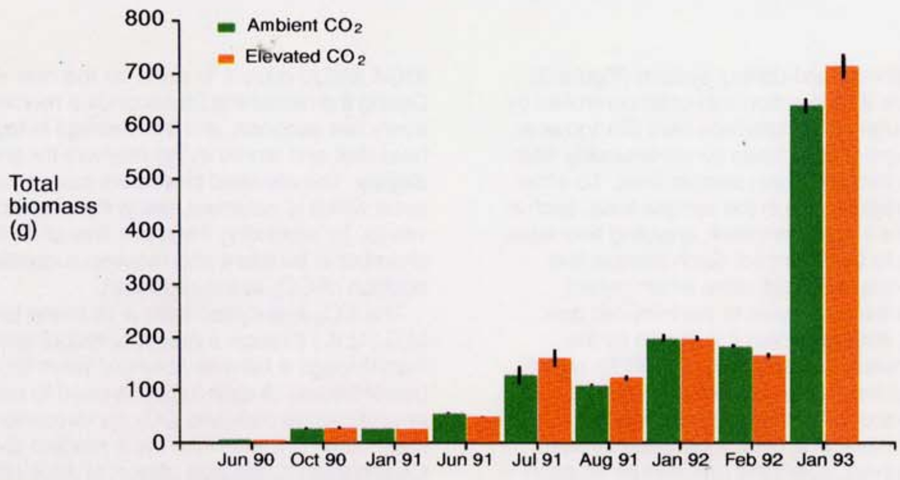

Figure 4: Measurement of biomass produced

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