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AIR QUALITY AND TREE GROWTH IN OPEN-TOP CHAMBERS

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Abstract

The effects of air quality on trees are being studied at three sites in Britain. Trees are growing in open-top chambers in filtered and ambient air conditions with outside plots to monitor the chamber effect. Results obtained at the end of the 1990 growing season show that Norway spruce, Scots pine and beech grew taller in filtered air than those in ambient air at the Headley (Hampshire) site since the last assessment in 1989. No statistically significant effects on height and diameter increment or plant biomass have been detected for Norway spruce, beech, Scots pine or Sitka spruce at the other two sites (Chatsworth and Glendevon). Visible pollution damage to foliage has not been observed at Headley.

Introduction

Air pollution, climate and nutritional problems have been associated with forest decline in several parts of the world and these declines have been the subject of considerable research. However, much of the early research focused on laboratory and growth chamber simulations of effects, often using high concentrations of pollutants. Few studies have been carried out in the field comparing ambient air conditions with pollution-free (filtered) air.

In 1985 the Forestry Commission began a research project comparing the growth of trees in ambient and filtered air at three sites: Headley, Hampshire; Chatsworth, Derbyshire; and Glendevon, Fife (Figure 1, Cover and Figure 2 respectively). At each site, open-topped chambers (Figure 3) are used to grow trees in ambient air containing the pollutant mixtures and concentrations present at the site or in air drawn through filters to remove the air pollutants.

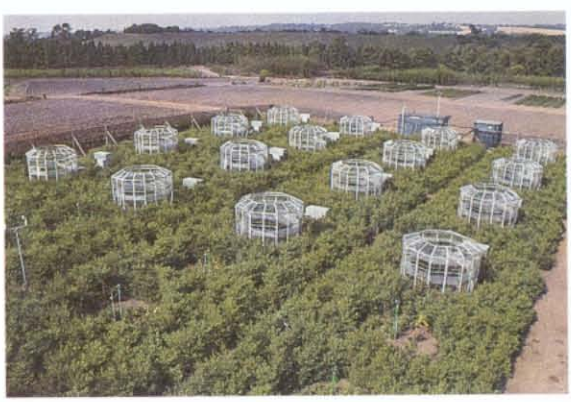


Figure 1. Headley open-top chamber site. *(39875)*

Norway spruce, Sitka spruce, Scots pine and beech were planted in March 1988. Research Information Notes 121, 182 and 183 provide background information and earlier results of the experiments.

Figure 2. Glendevon open-top chamber site. *(Forestry Commission)*

Figure 3. An open-top chamber. *(40244)*. Air is blown through filters in the cabinet to control air quality and is then distributed around the chamber through the polythene tube before being expelled through the open top.

Procedure

Each of the three sites has eight open-top chambers ventilated with ambient air, eight open-top chambers ventilated with filtered air and eight outside plots. Environmental variables and air pollutants (O_3, SO_2 and NO_x) are monitored continuously.

Transplants (1+1) of Scots pine, Sitka spruce, Norway spruce and beech were planted directly into the soil in each chamber or plot. These plants were carefully selected to represent seed origins currently being planted by the forestry industry in Great Britain.

Front cover. Chatsworth open-top chamber site. *(39876)*

Assessments of growth (height, leader extension and diameter) have been measured at the end of each growing season. In November 1989 one third of the trees were harvested and fresh and oven dry weights obtained (see Research Information Note 182). A further one third of the trees were removed in November 1990, fresh and dry weights were recorded and sub samples taken for foliar nutrient analysis (N, P, K, Ca & Mg).

Results

Comparisons of pollution climates between Chatsworth and Headley confirm that Headley has the highest ozone concentrations with a peak of 104 ppb in 1990 compared with 89 ppb at Chatsworth. Ozone levels greater than 50 ppb were recorded on 66 days at Headley and 17 days at Chatsworth.

Chatsworth has higher NO_x and SO_2 levels. NO_x revealed a peak of 196 ppb and exceeded 50 ppb on 20 occasions compared with 84 ppb and nine occasions at Headley. The maximum recorded SO_2 level was 124 ppb at Chatsworth and 85 ppb at Headley.

Typical differences in the pollution levels at the two sites can be seen in Figure 4.

In November 1990 significant growth differences were found between filtered and ambient air for Norway spruce and beech at Headley. Figure 5 shows that for all species the height differences between filtered and unfiltered air have increased in magnitude in this, the third year of exposure. The beech trees were 22% taller in filtered air ($P<0.01$) and the Norway spruce 17% taller. Stem diameter for the Norway spruce showed a 20% increase in filtered air. The destructive harvest showed that for the trees sampled fresh and dry weights of Norway spruce were increased by 45% and 49% respectively in filtered air. Scots pine showed a similar pattern in respect of height, stem diameter and dry weight increase but the differences were not statistically significant.

The growth effects detected in unfiltered air at Headley probably result from the cumulative effects of ambient pollutant concentrations since they were not accompanied by foliar injury recognizable as acute pollution damage.

No significant effects of air quality were found in height, stem diameter, fresh or dry weight for any of the species at the other two sites. Heights and diameters of Scots pine, Norway spruce and Sitka spruce were depressed in filtered air at Chatsworth and Glendevon but needle dry weights were increased.

Needle production was enhanced for Scots pine in filtered air with increases in needle dry weights for

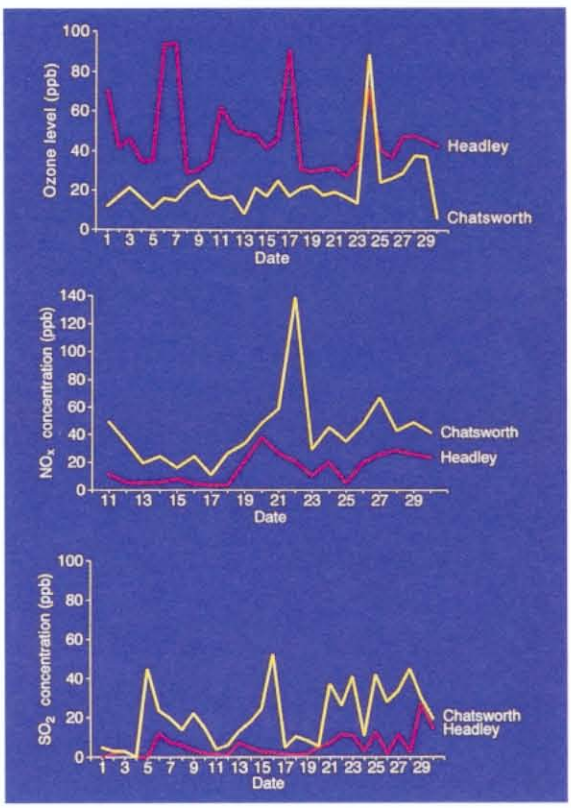


Figure 4. Pollution levels at Headley and Chatsworth. Data shows mean daily values for ozone (O_3), nitrogen oxides (NO_x) and sulphur dioxide (SO_2), at Chatsworth and Headley over typical monthly time spans in 1990.

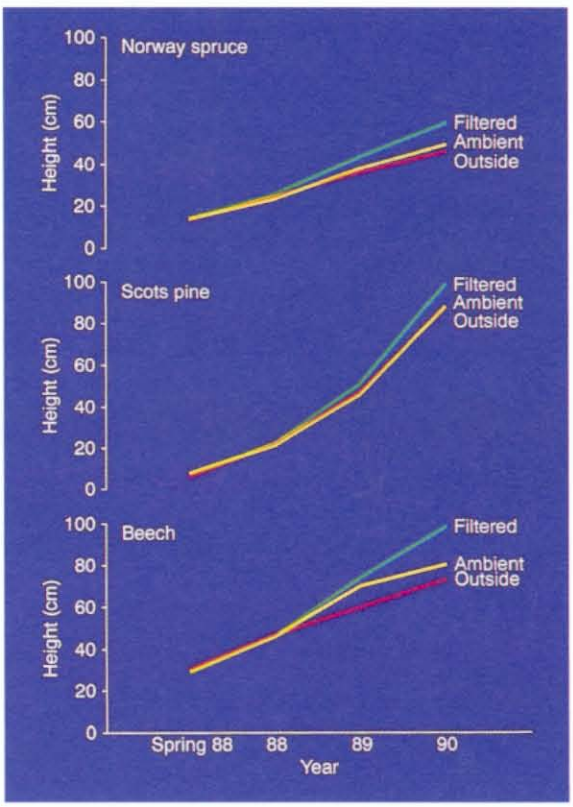
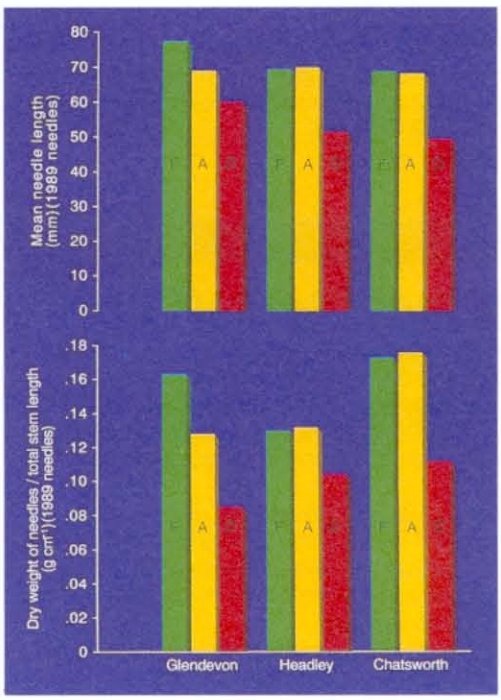


Figure 5. Growth curve diagrams - height from planting to end of 1990 at Headley. First measurement taken in Spring 1988, the remainder taken at the end of each subsequent growing season. Data are for all trees, both final crop and harvested to date. Height growth curves for the final crop trees alone show similar differences.



all three sites (Figure 6). Significant differences were found only at Glendevon, however, where the Scots pine needles were 11% longer ($P<0.05$) in filtered air. The needle dry weight:stem weight ratio was increased by 21% ($P<0.01$). This increase was accounted for by the greater needle weights in filtered air rather than by significant changes in stem weight.

The effects of the open-top chambers themselves on tree growth varied between species and between sites. At Headley, tree height, stem diameter and stem dry weight were increased for beech compared to the outside plots. Norway spruce also grew taller and had a greater stem dry weight. At Chatsworth the only significant effects ($P<0.05$) were increased stem diameter in Scots pine and increased needle weight in Sitka spruce.

At Glendevon, growth in the chambers was enhanced relative to that in the outside plots in Scots pine and Sitka spruce for all parameters measured, but only stem diameter and needle dry weights improved for Norway spruce.

Figure 6. Scots pine needle length and dry weights at Glendevon, Headley and Chatsworth. F = filtered air chamber; A = ambient (unfiltered) chamber; O = outside plot.

Conclusions

This is the second year in which tree growth has improved in filtered air at Headley compared with growth in ambient chambers and in which air quality has had no statistically significant effects at the other two sites.

The effect of the open-top chambers themselves on tree growth probably reflects the more sheltered environment within the chambers. This effect was highly significant at Glendevon but not at Chatsworth which is at almost the same elevation. Chamber effects were also significant for Norway spruce and beech at Headley.

Effects of air quality on tree growth are now beginning to emerge after three growing seasons. Growth responses in filtered air and unfiltered treatments have changed for some species and sites. This may reflect cumulative effects of air pollution, or alternatively, may result from the dry conditions during 1989 and 1990 interacting with the effects of air quality. In either case, experiments which span as many years as possible are required to identify if this divergence is sustained, accelerated, or is specific to dry summers and followed by recovery. The effect of the chambers was more marked in Glendevon and Chatsworth suggesting that the sheltering effect is more important than elevated temperature. Apparently detrimental and stimulatory effects of air pollution on physiological parameters have been identified (Taylor and Dobson, 1989), and the effects of these on growth are now being seen in the different responses of the species studied. Early indications are that the overall effects are site specific, being dependent, in particular, on the pollutant mixture and concentrations at the site.

References and Acknowledgement

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