

Forestry Commission

Research Information Note 221

Issued by the Research Division of the Forestry Authority

AIR QUALITY AND TREE GROWTH: RESULTS OF THE OPEN-TOP CHAMBER EXPERIMENTS 1991

by D.W.H. Durrant, D.A. Waddell, S.E. Benham, T.J. Houston



Abstract

This Note reports data for the growth of trees after 4 years in the open-top chamber experiments, which compare the effects of ambient with filtered air.

The growth differences detected at the end of the 1990 season (see Research Information Note 208) between trees grown in ambient air with those grown in filtered air have been maintained during 1991. At Headley, however, the difference in height growth for Scots pine has lessened (Figure 1), but needle dry weights have increased in filtered air.

Introduction

The Forestry Commission's Research Division began a series of experiments into the effects of air quality on tree growth in 1988, with trees grown in open-top chambers at three sites in the country: Headley, Hampshire; Chatsworth, Derbyshire; and Glendevon, Fife. The three sites were chosen to reflect different ambient air pollution levels.

At each site eight chambers receive ambient air, eight receive filtered air, and there are eight outside plots. These three treatments allow both the effects of air quality and of the chambers to be identified.

The major pollutants, ozone (O_3), sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) are monitored continuously, along with climatic variables –

Needle retention of Scots pine has shown seasonal and between site differences during the last 2 years. Needles persist longer in filtered than in ambient air.

Weather patterns were very different during 1991 from those of the preceding 2 years, particularly in the south of England, with lower than average temperatures and sunshine throughout the growing season and the late summer period. This resulted in lower ozone (O_3) concentrations at Headley.

sunshine, rainfall, temperatures and humidity. Four species are being studied: Sitka spruce (*Picea sitchensis* (Bong.) Carr.), Norway spruce (*Picea abies* (L.) Karst.), Scots pine (*Pinus sylvestris* L.) and beech (*Fagus sylvatica* L.).

All trees were planted in the spring of 1988. At the end of each growing season tree heights and diameters were measured. In addition, a number of trees of each species were destructively harvested to provide more detailed information on tree growth. The results of earlier assessments and harvests have been reported in previous years in Research Information Notes (see references).

Results for 1991

For the third year running the height growth of Norway spruce and beech was greater in filtered air than in ambient air at Headley, although the growth depression in ambient air was less marked in 1991 than in the previous 2 years (Figure 1). Stem and needle dry weights of the Norway spruce and Scots

ambient air, and needle dry weights were 58% ($P < 0.01$) greater in filtered air. For Scots pine stem dry weights were 9% greater in filtered air and needle dry weights 76% greater ($P < 0.01$) in filtered air compared with ambient air.

No significant effects of air quality were found on height, stem diameter, fresh or dry weights for any of the species at Glendevon. Sitka spruce continued to show a slight (non-significant) depression in growth in filtered air for all parameters measured. With Norway spruce and Scots pine, heights and stem diameters were slightly reduced in filtered air, but dry weights were increased.

At Chatsworth the results were similar for the three conifers to those reported above for Glendevon, with slightly poorer height growth (non-significant) in filtered air than in ambient air. Scots pine had larger dry weights in filtered air as was observed for Scots pine at Glendevon. Norway spruce had smaller heights and dry weight in filtered air. Sitka spruce had smaller lengths and diameters in filtered air but showed large increases in dry weights. Stem dry weights in filtered air were greater by 19% and 68% than those in ambient air for 1990 and 1991 respectively. Needle dry weights were 16% (1990) to 98% (1991) ($P < 0.05$) greater in filtered air. The beech trees at Chatsworth, which had been very slow to establish, continued to show improvements in the filtered air treatment. Heights were 25% above those in ambient air, stem diameter increased by 15% ($P < 0.01$) and stem dry weights were 80% greater ($P < 0.05$).

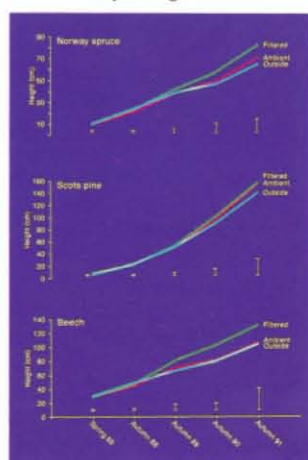


Figure 1. The effects of ambient air pollution on the height growth of Norway spruce, Scots pine and beech at Headley between spring 1988 and autumn 1991. The bars show the least significant differences (LSDs) between the filtered and ambient treatment means at each time of measurement.

pine were also greater in filtered air than in ambient air in 1991. For Norway spruce stem dry weights were 66% greater in filtered air ($P < 0.01$) than in

The stems and needles of the Scots pine harvested in 1991 were separated into year classes. Figure 2

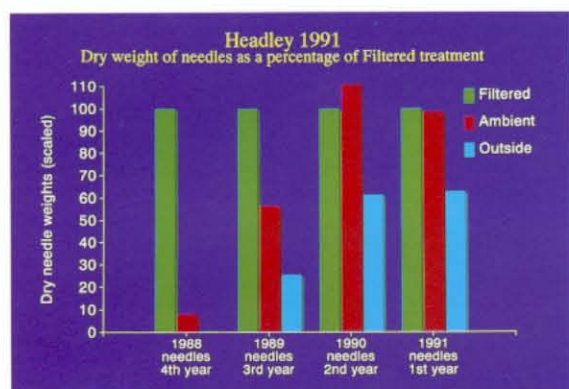


Figure 2. The effect of ambient air pollution on needle dry weights for Scots pine at Headley, expressed as a percentage of the filtered treatment.

shows the needle dry weights in polluted ambient air expressed as a percentage of those in filtered air. This partly explains the anomalies seen in earlier harvest data where heights and diameters were reduced in filtered air but dry weights increased. The increase in dry weight in filtered air is due to increased biomass in the branchwood and needles. This supports the observation that Scots pine grown in filtered air look healthier, with more green foliage.

In 1990 the number of pairs of 1989 needles of Scots pine was greater in filtered than in ambient air at Headley, but not at Glendevon or Chatsworth (Figure 3A). By 1991 this age class of needles

(1989) had experienced filtered and ambient air for 3 years and the effects seen in 1990 had intensified, resulting in fewer needles being retained in ambient, polluted air at Headley ($P < 0.01$) (Figure 3B). At Glendevon and Chatsworth 1989 needle numbers were greater in ambient air in 1990 (Figure 3A), but by November 1991 needle numbers in ambient air had fallen below those in filtered air. In 1991, the 1990 (one-year-old) needles were also examined. This age class had experienced two growing seasons of treatment and no statistically significant effects on needle retention had yet developed (Figure 3C).

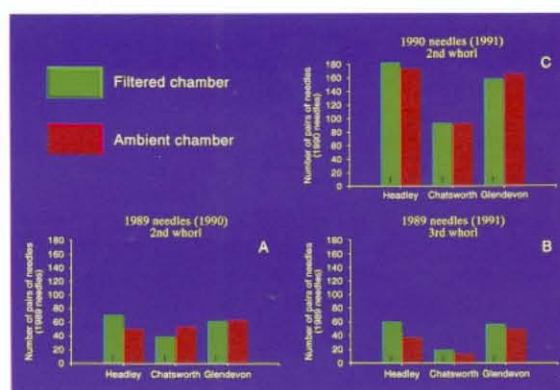


Figure 3. The effects of ambient pollution on the number of pairs of Scots pine needles at the three open-top chamber sites, in November 1990 (A) and November 1991 (B and C). In 1990 measurements were made on 1989 needles and in 1991 on 1989 and 1990 (one-year-old) needles.

Air quality and weather conditions

Analysis of the SO_2 , O_3 and NO_x concentrations measured continuously at Chatsworth and Headley confirmed that Headley has the highest ozone concentrations (Table 1). During 1991 ozone levels exceeded the EC recommended short-term critical level hourly mean of 75 ppb (parts per billion) twice at Headley but not at all at Chatsworth. The recommended 7 hour mean (09.00–16.00) of 25 ppb averaged over the growing season (1 April – 30

September long-term critical level) was not exceeded at either site. Chatsworth had higher annual mean NO_x (18 ppb) and SO_2 (7 ppb) concentrations compared with NO_x of 5 ppb and SO_2 of 3 ppb at Headley. The highest recorded concentrations at Chatsworth were 164 ppb NO_x and 129 ppb SO_2 , compared with 87 ppb NO_x and 53 ppb SO_2 at Headley.

Table 1. Air quality data for Chatsworth and Headley for 1990 and 1991, expressed as for UN/ECE level: critical level mapping.

		Summary of pollution data			
Pollutant	Pollution episodes	Chatsworth		Headley	
		1990	1991	1990	1991
O_3	Number of times 7-hour mean (09.00–16.00) exceeded 25 ppb (1 April–30Sept)	34	31	104	71
	7-hour mean (ppb) (1 April–30 Sept)	9	16	33	15
	Number of times 1-hour mean exceeded 75 ppb	4	0	49	2
	Number of times 8-hour mean exceeded 30 ppb (00.01–08.00) (08.01–16.00)	0	1	3	1
	(16.01–00.00)	13	0	48	19
		8	2	39	13
SO_2	Number of times 24-hour mean exceeded 35 ppb	3	0	0	0
	Annual mean (ppb)	5.3	6.7	1.5	3.0
NO_2	Annual mean (ppb)	8.6	16.5	2.9	3.6
	NO_x Annual mean (ppb)	9.2	18.3	3.9	4.6

O₃ concentrations were larger in 1990 than 1991 but larger concentrations of NO_x and SO₂ were measured in 1991 than in 1990. This deterioration in air quality for NO_x and SO₂ during 1991 can be associated with the comparatively cold winter. High pressure and still air conditions predominated during the first 3 months of 1991, with average temperatures as much as 2.3°C below the 10-year mean. During periods of still air dispersal does not occur, leading to high pollutant concentrations (Figure 4). The first 3 months of 1990 were very windy and included the second 'great storm' in the last week in January. The maximum recorded NO_x concentration during January, February and March 1991 at Chatsworth was 286 ppb and the 3-month mean 26 ppb, compared with a maximum of 62 ppb and a mean of 11 ppb for the same period in 1990. The improved air quality during 1991 for ozone reflects the decrease in sunshine levels.



Figure 4. Polluted air held down over low lying ground by a temperature inversion.

The summer of 1990 was considerably warmer than that of 1991. The first 6 days of May gave the highest recorded temperatures for May in 100 years.

The maximum O₃ concentration recorded at Headley during May 1990 was 102 ppb and the monthly mean was 44 ppb. This compares with a maximum O₃ concentration of only 67 ppb in May 1991, when the monthly mean value was down to 21 ppb. June and July temperatures and sunshine were above average in 1990 but below average in 1991. The first week in June was particularly cold with frosts between the 5th and 7th causing considerable damage to newly flushed tree growth in the Chatsworth area (Figure 5).



Figure 5. Late spring frost damage in the outside plots at Chatsworth, June 1991. (40296)

August 1990 was hot with some of the highest daily maximum temperatures ever recorded. This led to high O₃ concentrations at Headley with a maximum of 102 ppb and a monthly mean of 31 ppb. In contrast during August 1991 a series of weak Atlantic fronts crossing the country ensured that temperatures did not reach the previous year's records. Ozone concentrations at Headley were subsequently lower with a maximum of 77 ppb recorded. The monthly mean was only slightly reduced at 29 ppb.

Conclusion

Some effects of ambient (polluted) air on tree heights and diameters continue to be recorded at Headley, but not at other sites. This contrast, first reported from the 1990 results, has not increased further in 1991, probably because of a cool, cloudy summer reducing ozone events.

The data suggest trends which may increase in

magnitude with time and, as a result, parts of the experiment are being continued through two more growing seasons by increasing the height of the chambers. This will further extend the already uniquely long trial of comparing trees grown in ambient (normal) air with those in continuously filtered (pollutant-free) air.

References

- Durrant, D.W.H. and Willson, A. (1986). The Forestry Commission pattern of open-top chambers for air pollution research. In, *Proceedings of the European Open-Top Chamber Workshop*, Freiberg, FRG.
- Durrant, D.W.H., Waddell D.A., Benham, S.E. and Houston, T.J. (1992). *Air quality and tree growth in open-top chambers*. Forestry Commission Research Information Note 208.
- Lee, H.S.J., Willson, A., Benham, S.E., Durrant, D.W.H., Houston, T. and Waddell, D.A. (1990). *The effect of air quality on tree growth*. Forestry Commission Research Information Note 182.
- Lee, H.S.J., Willson, A., Benham, S.E., Durrant, D.W.H., Houston, T. and Waddell, D.A. (1990). *The effect of air quality on the timing of tree shoot development*. Forestry Commission Research Information Note 183.
- Taylor, G. and Dobson, M. (1989). Photosynthetic characteristics, stomatal responses and water relations of *Fagus sylvatica*: impact of air quality at a site in southern Britain. *New Phytologist* **113**, 265–273.
- Willson, A., Durrant, D.W.H., Boswell R.C. and Hall, G.J. (1986). Effects of air pollutants on trees in rural areas of Britain. In, *Proceedings of the European Open-Top Chamber Workshop*, Freiberg, FRG.
- Willson, A., Waddell, D.A. and Durrant, D.W.H. (1987). *Experimental work on air pollution*. Forestry Commission Research Information Note 121/87/SSS.