Short Time Effects of Air Pollutants to Leaf, Bark and Wood Photosynthesis of Beech (*Fagus sylvatica* L.)

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Abstract

Gaseous air pollutants penetrate stomata in leaves and lenticels in stems, thus reaching the mesophyll or parenchymal interior of the organs. As inner bark tissues in young limbs are able to perform photosynthesis, the effects of different air pollutants to chlorenchymal photosynthesis were examined. Short time exposure to selected air pollutants was studied in the aqueous phase and the inhibitory concentrations were compared between leaf, stem, bark and proper wood photosynthesis. Peridermal tissues proved to be effective barriers for pollutant diffusion. Photosynthetic cells of the proper wood seemed to be most tolerant, a fact that needs further studies.

Key words: Air pollutants, Corticular photosynthesis, Trees, Wood photosynthesis

1. Introduction

Besides the green leaf, other chlorophyll-containing tissues of a tree participate in carbon acquisition. Below the dead periderms and rhytidomes of most woody plants a green cortical tissue, the chlorenchyme is able to photosynthesise and thus reduce the respirational carbon loss efficiently (Foote and Schaedle, 1978; Nilsen, 1995; Pfanz and Aschan, 2001). Also green cells of the woody parenchymal ray cells and in young twigs of distinct species even the pith may be photosynthetically active (Pfanz *et al.*, 2002). Like gaseous air pollutants penetrate stomata in leaves they also penetrate lenticels in stems thus exerting their deleterious effects on the green chlorenchyme. Much is known on the uptake of pollutants into leaves and their action within the leaf and its mesophyll cells (Zeevart, 1976; Weinstein, 1977; Pfanz *et al.*, 1987; Van Hove and Van Kooten, 1989; Führer *et al.*, 1993; Yin *et al.*, 1996). Quite in contrast the effects of air pollutants on the limb level have been mostly neglected. The parameters studied so far are mostly tree ring width, basal area increment, stem density and chemical composition and/or isotopic composition (Weber and Grulke, 1995 and references therein). Yet, gaseous pollutants penetrate the twigs and branches of woody plants via the lenticels and partially through the dead peridermal and rhytidomal cells. Actual fluxes are not known as there are no data on resistances available (but see Groh *et al.*, 2002). As inner bark tissues are able to photosynthesise, the pollutants are supposed to react in a similar manner as within the chloroplast-containing mesophyll cells of leaves.

To compare short time effects of air pollutants on the photosynthetic action of twig organs and tissues, leaves, isolated chlorenchymes, wood portions as well as pith segments were studied. European beech (*Fagus sylvatica*) was chosen and the impact of ammonia (NH₃), nitrogen dioxide (NO₂), sulphur dioxide (SO₂), and hydrogen fluoride (HF) on the photosynthetic performance of different tree organs was studied using short time exposures. The experiments were carried out with isolated organ parts in a liquid medium in an oxygen electrode. The aqueous phase was used to mimic the situation when pollutants that have diffused via stomata and lenticels are dissolved in the aqueous phase of the respective cell walls (Pfanz, 1994).

2. Materials and Methods

A representative beech tree (*Fagus sylvatica* L.) grown on the edge of a natural deciduous forest site (120 m a.s.l.) on the southern outskirts of Essen (Germany) were selected for sampling. Leaves, twigs, bark and wood were freshly harvested from one-year-old organs directly before the measurements. Measurements were performed from June to October to allow easy peeling of periderms because of the highly active cambium. Isolated inner cortex tissues (chlorenchyma) could thus be obtained without cell ruptures. The proper wood portions of the twigs were cut out with razor blades and immediately immersed with incubation buffer. The medium consisted of 50 mM MES, 4 mM KCl, 1 mM MgSO₄, 1 mM Ca(NO₃)₂, 50 mM Glycylglycine and 50 mM Hepes, buffered at pH 6. The different air pollutants were added to the measuring solution in form of their inorganic salts so

as to mimic the real situation in the apoplastic cell wall solution (Pfanz, 1994).

3. Results and Discussion

Freshly harvested beech leaf sections showed photosynthetic control rates of approximately $3 \mu\text{mol O}_2 \text{ m}^{-2} \text{ s}^{-1}$ when no pollutant was added to the incubation medium. When sulphite was added in time steps of 15 mins to yield 3 to 15 mM sulphite in solution, photosynthetic rates decreased continuously. At 6 mM sulphite no photosynthesis was measurable but the leaves respired in the light. Respiration increased with increasing sulphite to reach values of up to $6 \mu\text{mol O}_2 \text{ m}^{-2} \text{ s}^{-1}$. Using isolated bark chlorenchyme a similar reaction was held. Although photosynthetic rates were much lower as compared to the concomitant leaves, bark photosynthesis decreased with increasing sulphite concentrations to respire in the light (Fig. 1, upper panel).

Yet respiration rates were also smaller than those of the leaf. Although no net photosynthesis was to be measured with isolated wood fractions, increasing sulphite clearly increased the mitochondrial respiration (Fig. 1, lower panel). Wood photosynthesis, which is the photosynthetic activity of the parenchymal ray cells in the wood, was shown to normally have a very low activity due to the extremely shade adapted chloroplasts (Pfanz *et al.*, 2002). A similar reaction was found using a non-peeled twig segment.

Using the same method as in the experiment of Fig. 1 the effects of other pollutants on the photosynthetic reaction of the selected tree organs and tissues were studied. Besides sulphur dioxide, ammonia, nitrogen dioxide and fluoride were used. Table 1 summarises the concentrations of the respective pollutant to yield 10 to 90% inhibition of photosynthesis. Using ammonia (or ammonium ions in the cell wall solution) the isolated bark proved to be much more sensitive than intact twig segments or leaf tissues.

Fig. 1 Influence of Na_2SO_3 on the oxygen gas exchange of leaves (circles), peeled bark (squares) (upper panel), isolated wood (triangles) and intact twig (diamonds) (lower panel) from *F. sylvatica* as measured with a Clark-type oxygen electrode. The different organs were incubated in aqueous solutions (buffered at pH 6) with the respective inorganic salts of the pollutant simulating the situation in the cell apoplast. Light intensity used was $1000 \mu\text{mol photons m}^{-2} \text{ s}^{-1}$ (means $\pm\text{SD}$, $n = 10-12$).

Table 1. Inhibition of organ photosynthesis of leaves, intact one-year-old twig segments, peeled bark and isolated wood fractions from *Fagus sylvatica* as measured by O_2 -gas exchange using a Clark-type oxygen electrode. The different organs were incubated in aqueous solutions (buffered at pH 6) with the respective inorganic salts of the pollutant simulating the situation in the cell apoplast. Light intensity used was $1000 \mu\text{mol photons m}^{-2} \text{ s}^{-1}$ (means $\pm\text{SD}$, $n = 10-12$). n.r. (not reached) means that no inhibition was to be measured with the pollutant concentrations used.

	pollutant	Inhibition [pollutant mM]		
		10 %	50%	90 %
leaf	NH_4Cl	190	300	600
	Na_2SO_3	3.5	7.5	14
	NaNO_2	3.5	25	200
	NaF	4	6	350
intact twig	NH_4Cl	3	7.5	14
	Na_2SO_3	3	7.5	14
	NaNO_2	n. r.	n. r.	n. r.
	NaF	n. r.	n. r.	n. r.
peeled bark	NH_4Cl	20	100	225
	Na_2SO_3	3	7.2	13
	NaNO_2	0.2	1.5	150
	NaF	4	11	60
isolated wood	NH_4Cl	n. r.	n. r.	n. r.
	Na_2SO_3	3	7.5	12.5
	NaNO_2	n. r.	n. r.	n. r.
	NaF	2	10	50

In contrast to the isolated chlorenchyme the intact twig segments were still shielded by peridermal layers which reduced the pollutant flux into the twig interior. The difference between the inhibitory concentrations between intact twigs and the isolated inner chlorenchymal tissue is thus an indirect measure for peridermal resistances to the diffusion of the special pollutant. Quite interestingly, isolated wood could not be inhibited in the presence of ammonia or nitrogen oxides, although sulphur dioxide and fluorides were inhibitory. Even with concentrations of 200mM ammonia no inhibition was to be recorded. The reason for this behaviour is still unclear, but it may due to an incomplete photosynthetic apparatus of these extremely shade adapted tissues (Pfan­z et al., 2002; Larcher et al., 1988; Höll, 1974).

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