Exposure of Norway spruce at the highway border: Effects on gas exchange and growth

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Summary. Six-year-old Norway spruce trees of the same clone were exposed for 10 weeks at the edge of a highway and compared with controls kept in an unpolluted area within 15 km of the first site. Significant differences could be observed with respect to growth, photosynthesis and transpiration rate, all of which were reduced after exposure at the highway.

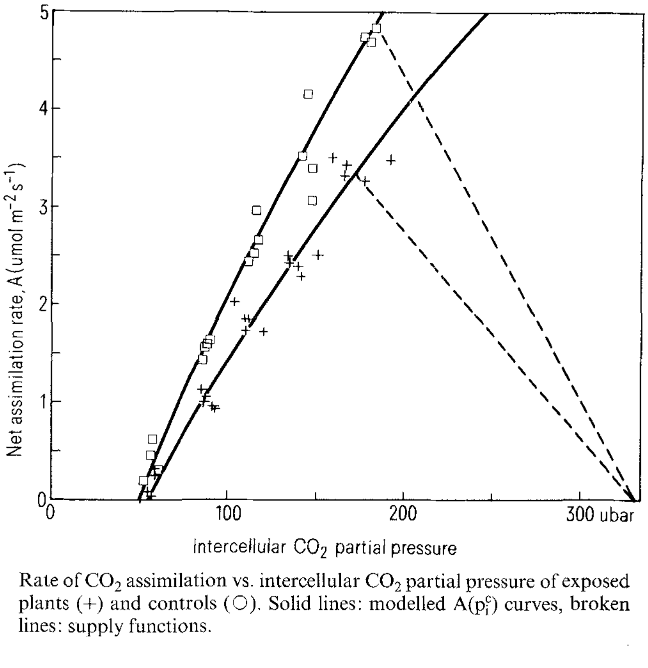
Key words. Exhaust emissions; highway; motor vehicles; Norway spruce; photosynthesis; transpiration.

Emissions from motor vehicles are frequently claimed to be major contributors to air pollution, with noxious effects on trees. However, few investigations have been carried out specifically on the toxicity of emissions for trees. Fumigations under controlled conditions were performed by Flückiger et al.[1] who demonstrated an inhibition of the regulatory ability of the stomata of *Populus tremula* leaves. Kammerbauer et al.[2] studied the impairment of photosynthetic capacity and stomatal regulation in Norway spruce, which was not observed when a catalytic converter was used. Field experiments with grafts of Norway spruce were carried out by Keller[3]. Trees kept at roadsides with heavy traffic showed an inhibition of CO_2-uptake by 40% compared to nursery controls after only 13 weeks. At the same time, peroxidase activity was significantly depressed. Visible symptoms such as color changes of the needles could not be observed.

We report here an experiment with 6-year-old Norway spruce trees from the same clone which were exposed to roadside conditions for 10 weeks. The control site was essentially free of motor vehicle emissions. A comparison revealed significant differences in growth in length, photosynthetic parameters and transpiration.

Materials and methods. Norway spruce trees raised from cuttings of the same clone (No. 1394 Bayerische Landesanstalt für Forstliche Saat- und Pflanzenzucht, D-8221 Teisendorf) were grown in plastic containers with a sand/loam/peat mix for 1 year in the open at a nursery of the Fachhochschule Weihenstephan. Shortly before sprouting on May 23, 1986, six-year-old trees were placed within 5 m of the A 9 motorway (München-Nürnberg) at Allershausen for 10 weeks. The trees were positioned on the eastern side of the road because of prevailing westerly winds. The plants were lowered into the ground in their containers and watered as required. Five controls were kept close to the Department of Botany (Weihenstephan) 15 km from Allershausen under similar conditions except for the relatively unpolluted location with NO_x levels amounting to about one tenth of the concentrations observed at the highway. On August 10, 1986, the samples were removed from the highway and left for 1 day in the control area for adaptation. Then the gas exchange parameters (CO_2 uptake, dark respiration and transpiration, under different CO_2 partial pressures at saturating light intensities, i.e. > 1700 µmol quanta $m^{-2}s^{-1}$) were measured on twigs in an open system (cuvette size: $140 \times 80 \times 60\ mm^3$) by means of an infrared gas analyzer as described in detail elsewhere[2]. The needle volume was taken as a reference. It was determined three times as the water displacement of the same twigs used for gas exchange measurements (circa 15 cm length, two needle years) minus the volume of the shoot axes, which was calculated on the basis of measurements with a vernier caliper. The needle area was calculated from the measured volume by an empirical formula which was determined from standard needles of the same type. The maximal carboxylation capacity (V_m^c) and the maximal ribulose bisphosphate regeneration capacity (J_m) were calculated according to Farquhar and von Caemmerer's model[4] as before[2,5]. Additionally, the length of the newly produced shoots was measured.

Results and discussion. Significant differences could be observed between the trees which were exposed for 10 weeks at the roadside and the controls kept in an unpolluted area 15 km away. The growth of the newly formed shoots was reduced by 25% in the exposed trees compared to the controls. A mean length of 6.7 ± 1.1 cm was determined for the newly formed twigs in the former group on the basis of the first three whorls in five plants, and 9.2 ± 1.1 cm for the latter group. In addition, the exposed trees had light green needles in contrast to the dark green of the controls. The gas exchange characteristics of the highway-exposed plants were compared with those of control plants under normal atmospheric conditions (330 µbar CO_2 partial pressure) and saturating light (table 1). The net assimilation of the exposed trees was 32% below that of the controls, whereas dark respiration rates were not affected. Transpiration rates were reduced by the same amount as the net CO_2 uptake. As the leaf to air vapor pressure deficit was kept constant during measurements this decrease of the transpiration was due to a proportional decrease of the stomatal conductances. Thus, the intercellular partial pressure of CO_2 remained nearly constant. Maximum assimilation rates at saturating CO_2, A_m, and photosynthetic parameters (which were calculated from gas exchange rates as a function of the intercellular CO_2 partial pressure) are shown in table 2. The figure shows the data obtained at low CO_2 and the modeled curves A (p_i^c) for both exposed and control trees. The decrease in the initial slope of the A($_i^c$)curve results in a decrease of 22% in the calculated value for the maximum carboxylation velocity V_m^c (table 2). However, the maximum net assimilation rate, A_m, which is limited by the regeneration of ribulose bisphos-



Rate of CO_2 assimilation vs. intercellular CO_2 partial pressure of exposed plants (+) and controls (○). Solid lines: modelled A(p_i^c) curves, broken lines: supply functions.

Table 1. Gas exchange parameters under normal atmospheric conditions (330 µbar CO_2, 210 mbar O_2) and saturating light. A: net assimilation rate, D^d: dark respiration rate (both in µmol CO_2 m^{-2} s^{-1}), T: transpiration rate (mmol H_2O m^{-2} s^{-1}); n.s.: no significant change

	Control plants	Exposed plants	% relative change
A	5.0 ± 0.2	3.4 ± 0.1	−31.5
D^d	0.27 ± 0.05	0.22 ± 0.06	n.s.
T	0.96 ± 0.06	0.62 ± 0.03	−35.4

Table 2. Photosynthetic parameters calculated from gas exchange rates as a function of intracellular CO_2 partial pressure. V_m^c: maximum carboxylation velocity, A_m: maximum assimilation rate, D^l: rate of dissimilative respiration in the light (all rates in µmol m^{-2} s^{-1}), Γ: CO_2 compensation point (µbar), q_g: ratio of conductances at maximum aperture (at low CO_2) to those at minimum aperture (in the dark); n.s.: no significant change

	Control plants	Exposed plants	% relative change
V_m^c	34.7 ± 1.2	26.9 ± 0.9	−22.3
A_m	9.8 ± 0.4	9.4 ± 0.4	n.s.
D^l	0.75 ± 0.09	0.77 ± 0.05	n.s.
Γ	48.2 ± 0.9	54.0 ± 1.4	+12.0
q_g	6.3 ± 1.4	4.1 ± 0.9	n.s.

phate, is not affected by exposure to motor vehicle emissions near the highway. This runs contrary to the typical effects of stress, which usually interfere with the maximum net assimilation rate[6,7] or impair both parameters proportionally[2,8].

The exclusive reduction of maximum carboxylation velocity could be explained as follows:

1. The amount of ribulose-1,5-bisphosphate carboxylase (= Rubisco) might be reduced after exposure. However, this is very unlikely, as Rubisco is present in excess.
2. The activity of Rubisco might be reduced due to a Mg^{2+} deficiency resulting in a lack of enzyme activation.
3. NO_x might cause pH changes by acidifying the cytoplasm, which in turn would impair the activation of Rubisco.

The dissimilative respiration in the light D^l (i.e. the CO_2 release resulting from mitochondrial respiration, which is not identical with photorespiration), is unaffected in the exposed plants. Therefore, the decline in V_m^c results in a slight rise in the CO_2 compensation point.

The values for the regulation capacity of the stomata (q_g in table 2, i.e. the ratio of conductances at maximum aperture at low CO_2 to those at minimum aperture in the dark) show a slight decrease. This leads to the question whether, and to what extent, the net photosynthesis rates of exposed plants are limited by reduced stomatal conductances. The effects of changes in stomatal conductance and photosynthetic metabolism on the assimilation rates can be evaluated on the basis of the $A(p_i^c)$ curves by using the supply function as described by Ball and Farquhar[7] and Jones[9]. In the figure the supply functions are the broken lines which connect the points on the $A(p_i^c)$ curves corresponding to the values under normal atmospheric conditions to the point on the x-axis where p_i^c equals the ambient CO_2 partial pressure p_a^c. The slopes of these are equal to the negative of the conductance to diffusion of CO_2 under normal conditions. If the stomata had been insensitive to the exposure at the highway, the changes in photosynthetic capacity would have led to only small reductions in photosynthesis rates (intersection of the steeper supply function with the lower $A(p_i^c)$ curve). The observed rates (intersection of the flatter supply function with the lower $A(p_i^c)$ curve) are still below this value for unaffected conductance. Therefore, a co-limitation of the assimilation rates of exposed plants by both stomatal conductance and photosynthetic capacity must be assumed. For a numerical estimate, limitation factors were calculated for both treatments according to the 'differential method'[9], and resulted in 0.50 and 0.55 for control and exposed plants, respectively. The limitation of photosynthesis due to diffusive resistance thus increased by 10% in the exposed plants.

The following conclusions can be drawn:

1. Both the stomata and photosynthetic apparatus of spruce needles were affected by road site conditions near the highway.
2. The regulation capacity of the stomata was reduced.
3. The carboxylation velocity of Rubisco was affected by the road side conditions.
4. The reduction in the net photosynthesis rate under normal atmospheric conditions resulted from co-limitation by both stomatal conductance and photosynthetic metabolism.
5. In cases where only a slight impairment of the photosynthetic apparatus occurs, gas exchange measurements give more accurate information about the nature of stress effects.

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A new semisynthetic ergot peptide alkaloid: DCN 203-922

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Summary. We report the synthesis, stereochemistry and preliminary pharmacological evaluation of DCN 203-922, a novel ergot alkaloid of the cyclol type, which contains in its peptide moiety the uncommon amino acid L-allo-isoleucine.
Key words. DCN 203-922; DH-*β*-ergokryptine; ergot peptide alkaloid.

Over several decades ergot peptide alkaloids have found broad application in medicine[2,3] and have stimulated continuous interest in pharmacology because of their unique ability to interact directly with various neurotransmitter systems in the periphery as well as in the CNS.

The cyclic peptide moiety controls their unusual pharmacokinetics and also provides the main site for metabolic attack. There is a substantial effect in the liver first pass, where degradation of the proline ring gives rise to a large amount of the 8′-hydroxymetabolite. However, this metabolite usually