INTERACTION OF ACID PRECIPITATION AND FOREST VEGETATION

By

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INTRODUCTION

Acid precipitation as a concept has arised during the last ten to twenty years. However, the emission of acidic gases from industrial processes, fossil fuel burning, or other sources must have resulted in acid precipitation over limited areas for centuries. In these areas, however, the injuries to vegetation caused by direct absorption of acidic gases, notably SO_2, have dominated. This absortion - in meteorological terms known as dry deposition - disturbs physiological processes in plants, eventually killing cells and tissues, and giving visible symptoms.

By better dispersion of the fumes, lower gas concentration will be experienced at ground level and direct injuries can be avoided. However, the pollutants will affect larger areas, and a higher proportion of the total deposition will occur as so-called wet deposition, in rain and snow washing the polluted atmosphere. The dry and wet processes of acid deposition are both included in the term "acid precipitation".

1) Paper presented at "XI. Internationale Arbeitstagung forstlicher Rauchschadenssachverständiger" (IUFRO S 2.09), 1.9.-6.9.1980 in Graz. This is SNSF-contribution FA 118/80.

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Acid precipitation has become an environmental problem of great concern, especially in Scandinavia and North America. In Norway a large research project to study the effects of acid precipitation on forests and fish was terminated in 1980 (report in preparation). On the forest side, the project has included studies of the ef-

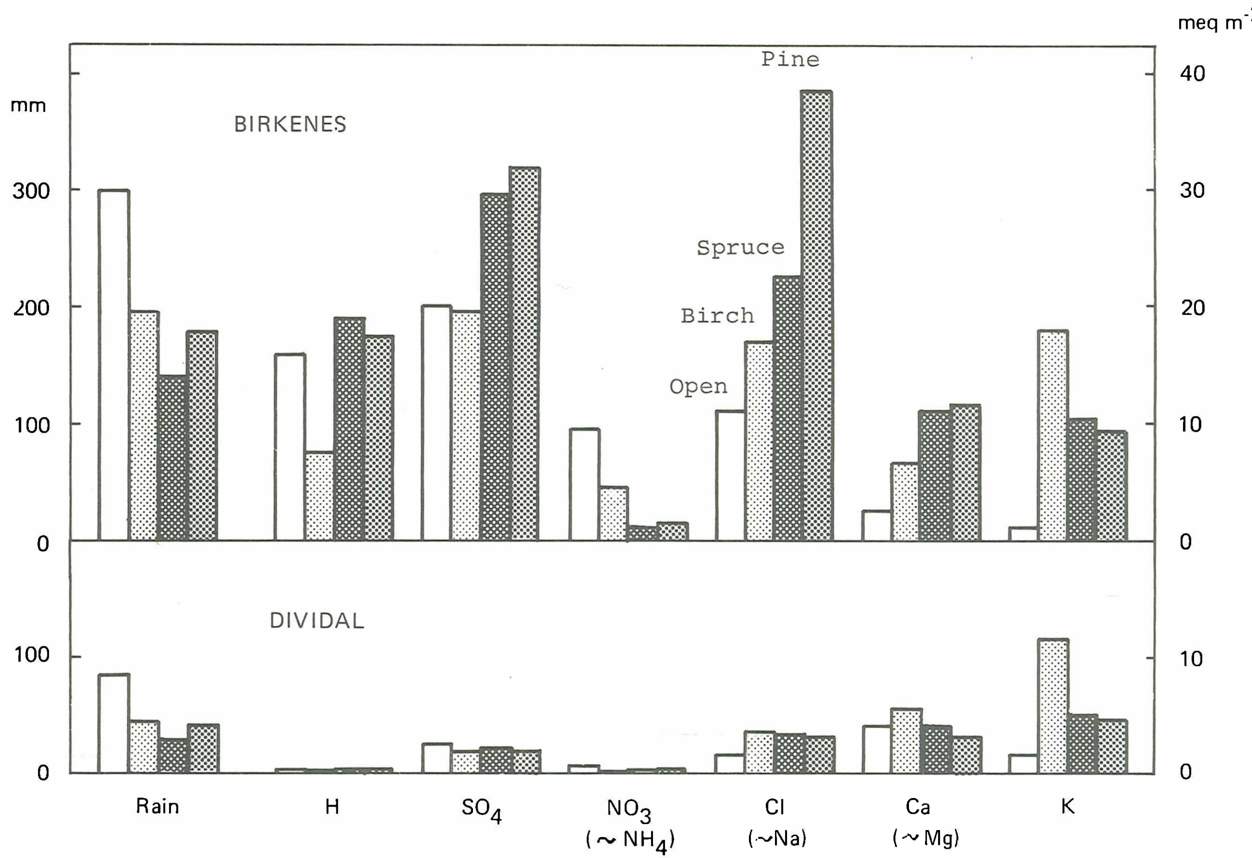

Figure 1. Chemical content of rain in Birkenes, southern Norway and Dividal, northern Norway. Data are sums of weekly contents for the period from 1 August to 13 October 1977.

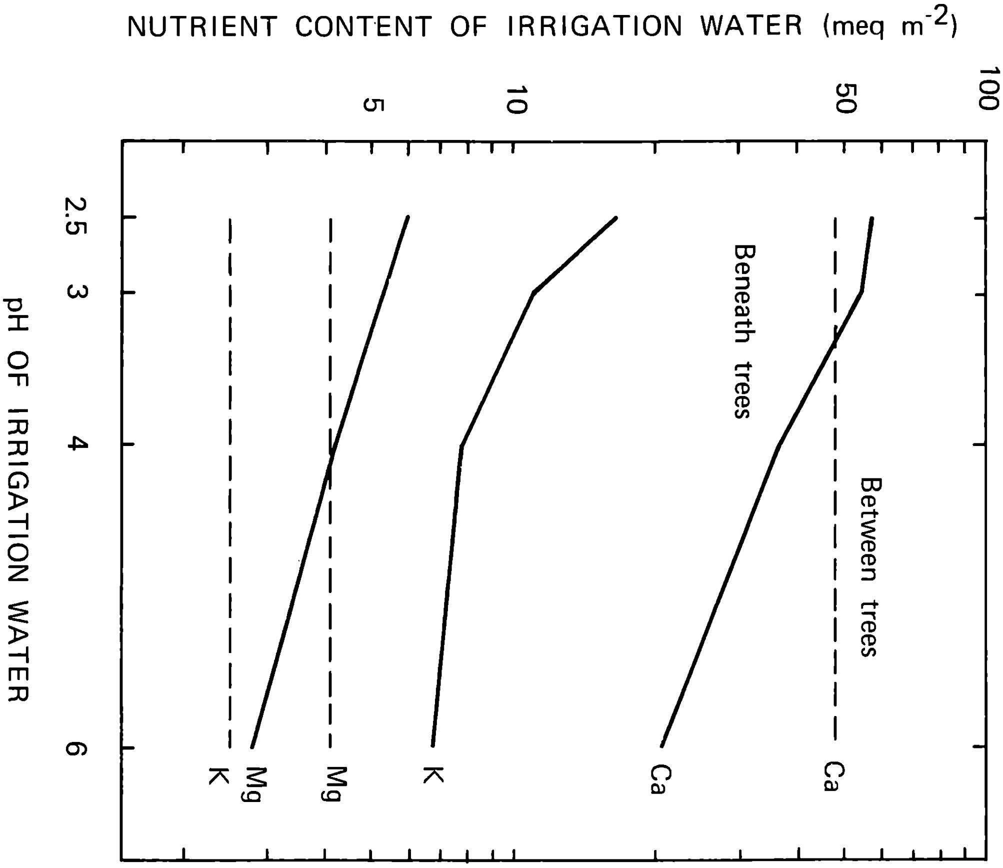

Figure 2. Effect of "rain" acidity on nutrient leaching from spruce crowns. Data are sums of four monthly values from the summer of 1976.

fects on soil chemistry and biology, on forest vegetation, and on tree growth. In this report, only forest vegetation will be considered.

The summary of results presented here is based on

- field sampling of natural precipitation above and beneath tree crowns (throughfall)
- field experiments where trees have been irrigated with acidified water (ABRAHAMSEN, BJOR and TEIGEN 1976)
- wind tunnel experiments with SO_2-deposition to tree seedlings

T H R O U G H F A L L   S A M P L I N G

Although less precipitation reaches the ground beneath trees than in open terrain, the throughfalling rain may contain both higher and lower amounts of dissolved substances. NO_3 (also NH_4 and Pb) are mostly absorbed by the tree crowns, whereas most other ions are enriched in throughfall. This enrichment is caused both by wash-off of gases and particles accumulated in the tree crowns by dry deposition, and by leaching of secreted substances from the foliage. The highest increase in throughfall content compared to that of incipient precipitation is found for K. K and H are less correlated with their contents in incipient precipitation than in the case with other ions (Na, Cl, SO_4 ...) that are enriched in throughfall.

Chemical content of rain in open terrain and beneath trees in Birkenes (high supply of Long Range Transported Air Pollutants) and Dividal (low supply of LRTAP) are shown in Fig. 1. Higher enrichment of H and SO_4 under trees in Birkenes than in Dividal may be due to dry deposition. Higher enrichment of Ca, Mg and K in Birkenes may be due to higher leaching of leaf surfaces, caused by dry and wet deposition og H (HORNTVEDT and JORANGER in prep.)

I R R I G A T I O N   E X P E R I M E N T S

In a field experiment, spruce trees 4-6 m of height have been irrigated from above the tree tops with acidified water. Chemical analysis of water collected beneath and between tree crowns reveals that leaching of most cations increases with increasing acidity of the irrigation water (Fig. 2). Except for sulphur, the nutrient status of the needles is unaffected by the treatment. Together with other evidence this indicates that the leaching nutrients are rapidly replaced.

In another field experiment, pine trees 20 m of height have been irrigated from below the crowns. Chemical analysis of rain collected inside and outside the stand reveals no effect of irrigation water acidity on the nutrient content of throughfall.

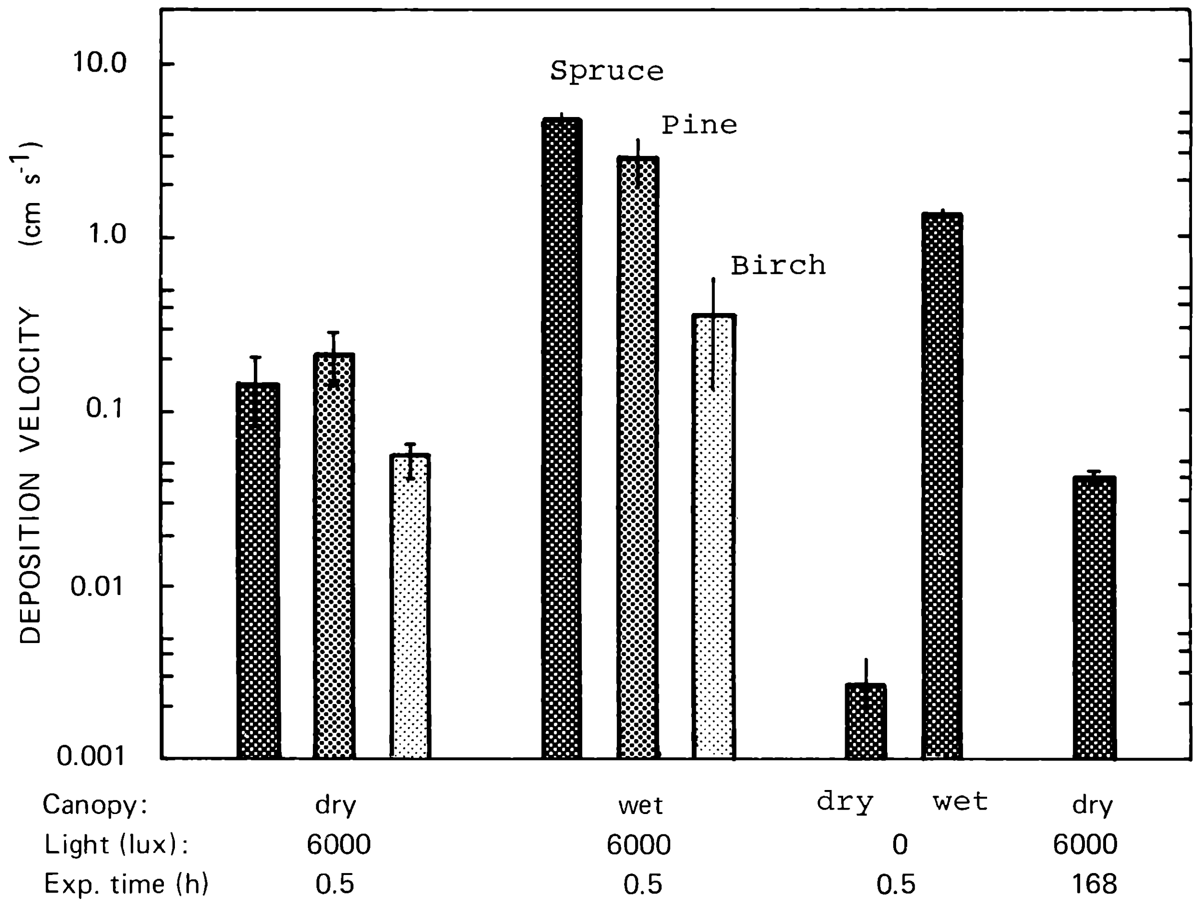

Figure 3. Summary of SO_2-exposure experiments.

This means that the acidified water, when spread beneath the tree crowns, does not effect the site or trees to an extent that is reflected in the rain passing through the tree crowns (HORNTVEDT 1979).

EFFECTS ON FOLIAGE

In irrigation experiments with field plots and lysimeters necrotic spots on some herbs and on birch (slight) have been observed at pH < 3. There have been no visible effects in conifers. The cover of the field and moss layers and also species diversity were reduced at pH < 3.

The surface of conifer needles (and of most leaves in general) is covered by waxes. Especially in the antestomatal cavities these waxes have a delicate structure. No effects of irrigation water acidified down to pH 2.5 on wax structure could be detected by scanning electron microscopy.

The amount of wax on spruce and lodgepole pine needles in field irrigation experiments was determined by extraction with chloroform, evaporation and weighing. No systematic effects of the various pH-treatments could be detected (HORNTVEDT in prep.).

WIND TUNNEL EXPERIMENTS

The dry deposition of SO_2 has been studied in specially designed wind tunnels. In short term experiments (½ h) $^{35}SO_2$ has been used and in long term experiments (168 h) untagged SO_2 (HORNTVEDT 1977; DOLLARD 1979).

The results are expressed as a deposition "velocity" v_d, defined by $F = v_d C$, where F is flux of SO_2 to a unit of leaf or ground area pr. unit of time, and C is the SO_2 concentration of the air.

In short term experiments the deposition velocity was not significantly affected by SO_2 concentration (range 50-400 μm^{-3}) or wind speed (range 0.6-2.5 $m\ s^{-1}$). Based on leaf areas, the deposition velocity was lower for birch than for spruce and pine. SO_2 was absorbed far more rapidly when the leaves were wet than when dry. When exposed in the dark, unwetted leaves absorbed SO_2 much more slowly than in light. With wetted leaves this difference was small (Fig. 3).

The deposition velocity in long term experiments was lower than in short term experiments (Fig. 3). Reasons for this could be depressed photosynthesis and gas exchange in long exposures, translocation of absorbed SO_2 to roots, among others.

The proportion of SO_2 removable by washing was much higher in short term experiments (plants washed within 10 minutes after exposure), than in long term experiments. A reason for this could be that a higher proportion of absorbed SO_2 is fixed and metabolized during the long term experiments.

ZUSAMMENFASSUNG

Das norwegische Forschungsprojekt "Saure Niederschläge - Wirkungen auf Wälder und Fisch" ist in den Jahren 1972-1980 durchgeführt worden. Das Projekt hat viele Teilprojekte umfasst; an der forstlichen Seite z.B. über Bodenchemie und -biologie, Wirkungen auf die oberirdische Waldvegetation, sowie Zuwachsuntersuchungen.

Die Untersuchungen die hier kurz besprochen werden, umfassen Analysen des Regens und des künstlich versauerten Irrigationswassers vor und nach der Passierung durch die Baumkronen, Analysen der Menge und der Struktur des Epikutikularwachses, und Begasungsversuche mit SO_2.

Wenn eine höhere Anreicherung vom Schwefel in den Kronentropfen in Süd-Norwegen als in Nord-Norwegen gefunden wird, so hängt dieses wahrscheinlich mit der größeren Absorption von SO_2 und H_2SO_2 in Süd-Norwegen zusammen. Die Absorption von SO_2 ist vielmals höher wenn die Kronen naß sind als wenn trocken. Ein bedeutender Anteil von dem absorbierten SO_2 kann mit Regen ausgewaschen werden. Mit zunehmenden Mengen von H^+-Ionen im Regen werden zunehmende Mengen von anderen Kationen (K, Mg, Ca ...) von den Baumkronen ausgewaschen. Diese Kationen werden aber schnell ersetzt. Die Epikutikularwachse in Koniferen sind ziemlich resistent gegen den sauren Regen.

LITERATURE

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