INFLUENCE OF OZONE AND SULPHUR DIOXIDE ON DEFOLIATION AND GROWTH OF POPLARS

By

MOOI J.

Research Institute for Plant Protection

Wageningen

SUMMARY

During growing season poplars often loose part of their leaves without obvious reason. Recent fumigation experiments showed that low levels of SO_2 and O_3, single and in combination could cause a severe leafdrop and a decrease in dry matter production of leaves and stems. Especially the combination $SO_2 + O_3$ gave the most severe effects. In nine fumigation experiments of two till six weeks, air pollution concentrations ranged from 35 to 70 $\mu g/m^3$ ozone and 150 to 440 $\mu g/m^3$ SO_2. During one of these experiments young plants of Populus x euramericana 'Dorskamp' and Populus maximowiczii 'Geneva' were fumigated with 158 $\mu g/m^3$ SO_2 and/or 68 $\mu g/m^3$ O_3 during four weeks. Pop. 'Dorskamp' and 'Geneva' treated with $SO_2 + O_3$ gave a maximum decrease in dry matter production of stem of 40%. This effect was mainly caused by O_3.

INTRODUCTION

During growing season poplars often loose part of their leaves without obvious reason. Premature defoliation can occur by bad soil conditions, but symptoms specific for drought or salt could not be observed. Fumigation experiments at our institute showed that low levels of ozone could cause leafdrop and a decrease in dry matter production of leaves and stems (Mooi, 1980).

The possible increase in SO_2-emission in the near future, due to a change in used fuels by power plants, and the occurrence of ozone throughout the Netherlands in concentrations which injure sensitive plants, make it more important to study the influence of $SO_2 + O_3$ combinations. From literature it is known that poplars are sensitive to O_3. However, most experiments were done at high levels of ozone with or without SO_2 during short periods (some hours, up to some days) (Karnosky, 1976, 1977). Recent long term fumigation experiments showed that low levels of SO_2, O_3 and $SO_2 + O_3$ can cause leafdrop and a decrease in dry matter production of leaves and stems. Symptoms produced in long term fumigation experiments with low levels of ozone are different from symptoms found in short term experiments with high levels of ozone (Jensen, 1974). In the period from December 1978 till February 1980 three experiments of six weeks, four of two weeks and two experiments of four weeks were carried out. In this report only some results are given, obtained in two fumigation experiments each of four weeks in January and February 1980.

MATERIAL AND METHODS

Plant Material and Plant Growing

Six weeks before the start of a fumigation, cuttings of 10 cm length of Populus x euramericana 'Dorskamp' and Populus maximowiczii 'Geneva' were put in a solution of 800 ppm indole-acetic-acid. After 12 hours they were placed in 1 liter pots containing a mixture of peat sand, 17 3 (v/v). Plants were grown in a charcoal-filtered greenhouse at a temperature of 18 - 20°C and a light intensity of at least 20 Klux during 16 hrs/day. After two weeks 3 grams Fe-EDDHA (Sequestrene 138 Fe) were given per m^2 (ca. 50 plants). After three weeks of growth 0,5 gram fertilizer (16-18-12-5) per plant was added every week. Just before fumigation identical plants of each species were selected, and devided into four equal groups with 17 to 21 plants per treatment.

Fumigation Experiment

All experiments were carried out in four fumigation greenhouses located within one big greenhouse, which were ventilated with charcoal-filtered air. This filtered air was used for the control treatment and was necessary to produce stable concentrations of SO_2, O_3 and $SO_2 + O_3$. The greenhouses had a ground area of 12 m^2, a volume of 30 m^3 and were ventilated with an air exchange rate of 80 m^3/min. SO_2 was injected 24 hrs/day from a SO_2-cylinder through Brooks thermic mass flow meters, delivering a known and very constant gas stream. The SO_2-concentration (158 $\pm$ 14 $\mu g/m^3$) was measured continuously by means of a Philips coulometric SO_2-monitor (PW 9700). O_3 was produced with oxygen supply by a Fischer ozone generator (model 501) from 8.00 a.m. till 8.00 p.m.

The concentrations of O_3 (68 $\pm$ 14 $\mu g/m^3$ during injection period and 6 $\pm$ 3 $\mu g/m^3$ without injection) were measured by a Mc.Millan 1100-3B chemiluminescence analyzer and a Dasibi UV-absorption analyzer 1003-AH.

Temperature in the fumigation greenhouses was 18 $\pm$ 2°C. Relative air humidity and light intensity varied more, depending on wheather conditions outside and were respectively 50 $\pm$ 7% and 40 $\pm$ 20 W/m^2. There was some additional illumination from 5.00 a.m. till 9.00 p.m. with six 400 W high pressure mercury lamps in each greenhouse which gave at least 25 W/m^2 without light from outside. Because of differences in climatic conditions between the fumigation greenhouses, plants were changed from chamber every week. To study air pollution combination effects, dry matter weight of leaves and stems, leaf area and number of fallen leaves, of all plants were determined at the end of each experiment.

R E S U L T S

After 7 - 10 days of exposure (dependent on plant species and concentration) plants treated with SO_2 + O_3 showed a very slight chlorosis, changing with time into a slight necrosis and followed by leafdrop. SO_2 alone caused necrosis between the veins, and also resulted in leafdrop after about 15 days of exposure. O_3 alone produced similar symptoms as SO_2 + O_3 but leafdrop was observed only after 10-15 days of exposure.

As shown in fig. 1 Populus x euramericana 'Dorskamp' treated with SO_2 showed a decrease in dry matter production of the whole plant of 2-5%, O_3 resulted in 9-13% reduction, and the combination in 12-25% as compared to the control. Dry matter production of the stem decreased with 5-8%, 21-26 and 27-40% respectively.

Populus maximowiczii 'Geneva' showed a decrease in dry matter production of the whole plant of -1 to 4% (SO_2), 7-9% (O_3) and 15-27% (SO_2 + O_3) as compared to the control. Dry matter production of the stem decreased with -1 to 2%, 11-13% and 29-39% respectively.

It may be concluded that SO_2 was much less harmful than O_3, which gave significant negative effects. The decrease in dry matter production was intended with an increased leafdrop due to O_3 and SO_2 + O_3 (fig. 1), while the combination effect was mainly caused by O_3.

Not all results will be discussed here because they came to the same conclusion.

D I S C U S S I O N

In unpolluted areas ozone concentrations do not exceed 80-130 ug/m^3. These ozone concentrations may have a natural source and are only present during short periods. It can also be produced by a reaction between hydrocarbons, oxygen and nitrogen oxides in the presence of ultraviolet light (Guicherit). Motor exhaust gases seem to be responsible for the often very high ozone levels in out atmosphere.

In table 1 some data are given concerning the air pollution situation in the Netherlands in the period April - October 1979.

Table 1.
Percentiles and average values (µg/m^3) of some components in the period from April till October 1979 in the Netherlands (hourly averages)**.

Component	Number of measuring points	P50*	P98	Average
SO_2	206	19,2	61,5	22,2
O_3	28	63,7	113,7	65,3
NO_2	88	28,3	62,8	30,4

* P50 = 50% of the number of measurements are below the given value

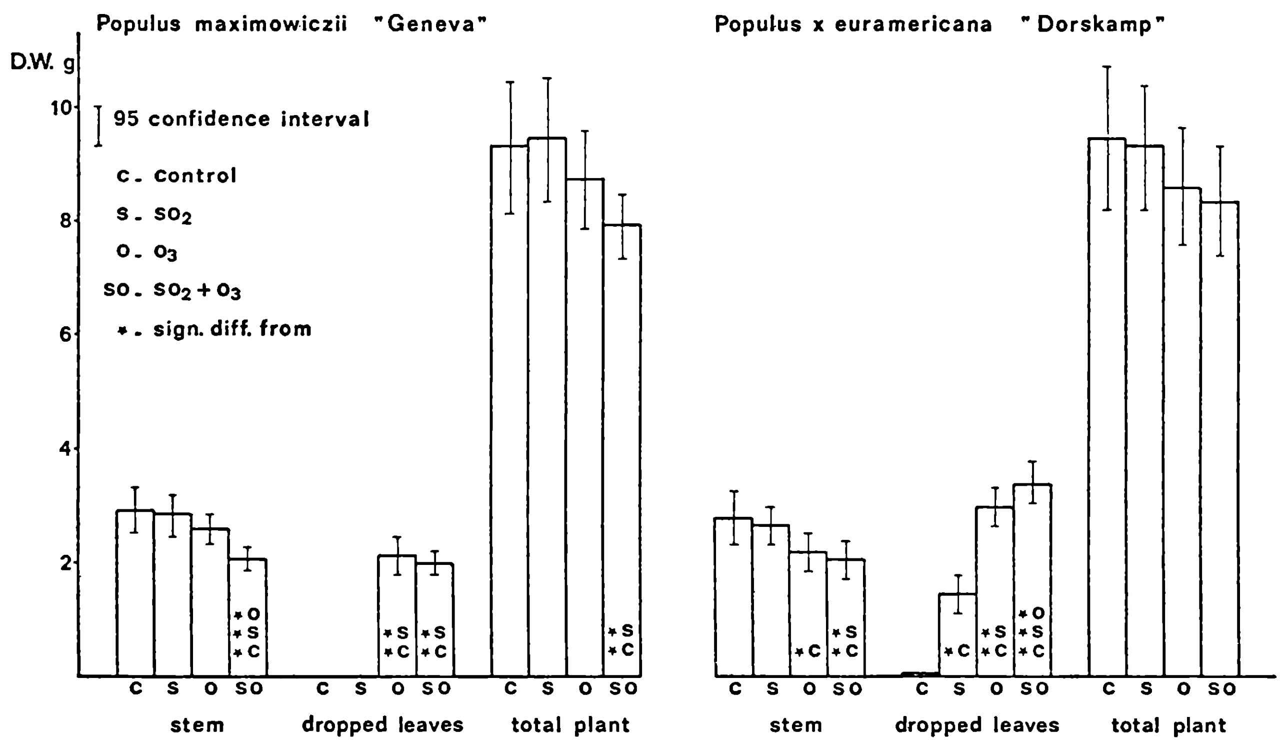
** National Air Pollution Monitoring Network (NAMN), R.I.V. report 236/79, 1979.

According to the measurements of the NAMN ozone concentrations used in our fumigation experiments were measured nearly every day during growing

Figure 1

Dry matter weight of two poplar species fumigated during four weeks (2/1–30/1–1980) with

O_3 (70 µg/m³) SO_2 (158 µg/m³) and $SO_2 + O_3$



season. SO_2 concentrations are rather high (150 µg/m^3) but, as mentioned already, SO_2 concentrations will increase from ca. 22 µg/m^3 in 1979 till ca. 75 µg/m^3 in 1985 because of the need to replace clean natural gas by coal as fuel for power plants. The recognition of ozone induced symptoms in the field is very difficult, similar symptoms may also be produced by nutrient deficiencies, herbicides, insects, etc. Whereever possible, symptoms on plants exposed to ambient ozone should be compared with those on plants exposed to known levels of ozone in chambers and to unexposed control plants.

Another important air pollution component to produce negative effects is NO_2, especially when other components are present. Fumigations experiments carried out from March till June 1980 showed that NO_2 + SO_2 gave less effects than NO_2 + O_3 and NO_2 + SO_2 + O_3 caused the strongest effect.

In five fumigation experiments concentrations were:

SO_2	60-100 µg/m^3, 24 hrs/day
O_3	50- 75 µg/m^3, 12 hrs/day (8.00 a.m. - 8.00 p.m.)
NO_2	20- 30 µg/m^3, 12 hrs/day (8.00 p.m. - 8.00 a.m.)
	60-100 µg/m^3, 12 hrs/day (8.00 a.m. - 8.00 p.m.)

By additive or synergistic action, concentration levels above which single components can cause damage, could be lowered drastically. So ambient air pollution concentrations can possibly cause damage to plants. Also Jensen (1974) found a growth reduction of 50% on Hybrid poplars fumigated with 300 ug/m^3 ozone during six weeks. Investigations of Kress, 1978, showed a growth reduction of one week old seedlings when exposed to O_3 (100 µg/m^3), NO_2 (190 µg/m^3) and SO_2 (370 µg/m^3) single and in combination. Pinus taeda showed 26% growth reduction by O_3 + NO_2 + SO_2 and Platanus occidentalis gave a maximum reduction of 45%.

Although the investigation on effects of air pollution on poplars in field conditions is not yet finished, it does not seem impossible that these effects of ozone in combination with other components will occur in large areas of the Netherlands.

L I T E R A T U R E

Guicherit, R.: Fotochemische smogvorming in Nederland. Rapport G646, Instituut voor Milieuhygiëne en Gezondheidstechniek T.N.O. te Delft.

Jensen, K.F. and L.S. Dochinger, 1974: Responses of hybrid poplar cuttings to chronic and acute levels of ozone. Environmental Pollution (6): 289-295.

Karnosky, D.F., 1976: Threshold levels for foliar injury to Populus tremuloides by sulfur dioxide and ozone. Canadian Journal of For. Res. (6): 166-169.

Karnosky, D.F., 1977: Evidence for genetic control of response to sulfur dioxide and ozone in Populus tremuloides. Canadian Journal of Forest Research (7): 437-440.

Kress, L.W., 1978: Growth impact of O_3, NO_2 and SO_2 single and in combination on two hybrid lines of loblolly pine. Proceedings of the American Phytopathological Society, 1977 (4): 120.

Kress, L.W., 1978: Growth impact of O_3, NO_2 and SO_2 single and in combination on two maternal lines of American sycamore. Proceedings of the American Phytopathological Society, 1977 (4): 120.

Mooi, J., 1980: Influence of ozone on growth of two poplar cultivars. Plant Disease 64 (accepted for publication 10-1-1980).