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Effects of sulfur dioxide, ozone, and their interactions on 'Golden Delicious' apple trees

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Comparatively little research has been directed at the identification of symptoms of air pollution injury to fruit trees. This study was conducted to gather more data about the effects of sulfur dioxide, ozone and combinations of the two gases on 'Golden Delicious' apple trees.

Uniform two-year-old potted 'Golden Delicious' apple trees consisting of single shoots (85–95 cm in length) from buds on M 9 rootstocks, were grown outdoors in 25 l containers filled with a sand-peat mixture and placed in a greenhouse 2 days before fumigation. Between July 15 and July 25, 1974 the trees were fumigated with SO_2, O_3 or combinations of the 2 gases at various concentrations (Table 1). Fourteen to 18 youngest leaves on each tree were retained for treatment and all older leaves were removed immediately prior to fumigation. Groups of 6 trees were exposed for 6 hour fumigations in 2 greenhouse chambers described previously (Spierings, 1971).

During the fumigations the temperature was 20–25 °C and the relative humidity 60–70 %. SO_2 was introduced from a cylinder of 100 % SO_2 through ducts, mixed by turbulence with filtered air at a rate of 5 m^3/min to attain the desired concentration. SO_2 was continuously measured in the fumigation chamber by a Philips (PW9700) SO_2 monitor. O_3 was generated by an ozonisator with oxygen supply and was recorded continuously by a TNO (G373) Ozonmeter. The measuring principle of both meters was the galvanic detection method with platina gauze electrodes in a solution containing a mixture of HBr and Br_2, SO_2 or O_3 passing the solution. SO_2 and O_3 were independently measured in the chambers.

After the fumigations the trees were taken to a smaller compartment of the greenhouse with the same temperature and air humidity range as during the fumigations.

'Bel W_3' tobacco plants with 5 to 6 leaves were placed in the chambers as indicators of O_3 injury.

Symptom development, abscission rate and shoot growth were compared with unexposed trees in the same greenhouse.

SO_2 injury caused mild bronzing and stippling on the upper surface of the oldest 4 to 5 leaves of some trees or on other trees bifacial rust coloured necrotic lesions occurring between the veins near the margins. A combination of both symptoms also appeared. At 2.5 ppm SO_2 necrotic lesions, chlorosis, burning, and abscission of leaves occurred.

Table 1. Effects of SO_2 and O_3 alone and in combination on shoot growth, leaf injury and abscission of 'Golden Delicious' apple trees after 6 hour fumigations.

Treatment	ppm	Shoot growth[1] (cm)	Mean % leaf surface injured of all leaves[2]	% Leaf abscission[3]
Control		23.0	0.0	0.0
Ozone	0.3	23.1	0.0	0.0
Sulfur dioxide	0.4	23.5	1.8	2.0
	0.6	24.3	7.3	5.0
	2.5	18.7	72.9	62.3
Sulfur dioxide + Ozone	0.4 + 0.2	17.5	2.8	5.7
	0.8 + 0.4	14.8	5.9	16.8
	1.5 + 0.4	14.8	17.2	28.8

[1] 21 days after fumigation.
[2] 3 to 5 days after fumigation.
[3] 10 days after fumigation.

Tabel 1. Uitwerkingen van SO_2 en O_3 afzonderlijk en in combinatie op scheutgroei, bladbeschadiging en bladval bij 'Golden Delicious' appelbomen na 6 uur durende begassingen.

O_3 injury was not detected when trees were fumigated at 0.3 ppm O_3. 'Bel W_3' tobacco indicator plants exhibited acute O_3 injury symptoms when exposed simultaneously. Since other woody plant species can be injured at the same and lower concentrations of O_3 (Hill et al., 1970), it is apparent that the apple is insensitive to O_3.

Injury from the SO_2/O_3 mixtures in this study partially resembled the rust coloured necrotic interveinal lesions near the margins caused by SO_2. Tingey et al. (1973) comparing SO_2/O_3 injury symptoms in 11 species found O_3 type symptoms on some species and SO_2 type symptoms on others. The interactions of SO_2 and O_3 resulted also in a synergistic effect on shoot growth reduction, leaf injury and abscission. The predominant synergistic effect, however, was the appearance of large greyish-green water-soaked areas on the mid shoot leaves. These areas, 0.8 tot 9.0 cm^2 in size, developed very suddenly after exposure, primarily (but not always) along the leaf margins, and were characterized by a distinct dark brown border. This symtom did not develop further prior to abscission. Such watersoaking did not occur when the trees were exposed to either pollutant alone. This symptom was present on trees fumigated at all SO_2/O_3 combinations but was less severe as SO_2 concentrations decreased (Table 1). Leaves dropped gradually after the development of the water-soaked areas.

These fumigation experiments indicate that the two year old 'Golden Delicious' apple trees were relatively sensitive to SO_2 and insensitive to O_3. The interaction of SO_2 and O_3 resulted in a synergistic effect especially on shoot growth reduction (and in a synergistic effect especially on shoot growth reduction) and in producing greyish-green water-soaked areas on the mid shoot leaves.

Samenvatting

Resultaten van begassingen met zwaveldioxyde, ozon en hun interacties op 'Golden Delicious' appelbomen

Twee jaar oude 'Golden Delicious' appelbomen bleken betrekkelijk gevoelig voor SO_2 te zijn en niet gevoelig voor O_3 als gevolg van een inwerking van deze gassen gedurende 6 uur. SO_2-beschadiging nam toe van een lichte bronsverkleuring en stippeling van de oudere bladeren bij 0,4 dpm SO_2 tot necrotische plekken, chlorose, bladverbranding en val van de bladeren bij 2,5 dpm SO_2.

O_3-beschadiging werd niet waargenomen na begassing van de bomen met 0,3 dpm O_3 gedurende 6 uur.

Begassingen met mengsels van SO_2 en O_3 hadden een synergistisch effect op scheutgroeivermindering en bladval (Tabel 1). Na alle combinaties van SO_2- en O_3-begassingen ontstonden grote, grijsgroen gekleurde, waterige plekken zowel op de onderste als op de middelste bladeren van de bomen. Deze symptomen traden niet op na toediening van beide gassen afzonderlijk.

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