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Influence of fumigations with NO_2 on growth and yield of tomato plants

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Abstract

Prolonged and short-lasting fumigations with NO_2 were carried out with tomato plants. Very young plants showed increase in length as a consequence of fumigations with 0.5 ppm for ten days. A concentration of 0.4–0.5 ppm applied during a period of 21 to 45 days also resulted in an increase in length and gave rise to the development of smaller leaves and shorter leaf petioles. Fumigations with a concentration of 0.25 ppm during the entire growth period caused a decrease in crop yield of 22%.

Introduction

It is known from literature that in nature concentrations of NO_2 may occur which can be harmful to plants. Taylor (1968) reports that concentrations of 1–2 ppm in the atmosphere are often measured in California during certain periods. Taylor and Eaton (1966) had earlier investigated the toxic influence of NO_2 on plants. They found that a continuous exposure during 10–22 days to low concentrations of NO_2 (0.15–0.21 ppm) caused growth depression, intensification of the green colour and distortion of leaves of tomato plants. In Western Germany van Haut and Stratmann (1967) investigated the sensitivity to this gas of a great many plant species. They distinguished three groups, highly sensitive, sensitive and slightly sensitive plants.

In each group were tree species as well as agricultural and horticultural crop plants and ornamental plants. In the western part of the Netherlands where vegetables and ornamentals are grown under glass over a large area, the number of industries and the road traffic are rapidly increasing. This made it desirable to investigate the toxic influence of NO_2 on plants because it may be expected that this gas is emitted in increasing quantities in the atmosphere. The tomato is the most important glasshouse crop in this part of the country; therefore this plant was chosen for the fumigation experiments with NO_2.

Material and methods

The investigation was started with short-lasting fumigations and later a more prolonged fumigation was carried out. For all the experimens the tomato variety 'Moneymaker' was used. Two small glass chambers were used for the short-lasting fumigations and two larger transparent plastic chambers for the prolonged fumigation. For short-term fumigations the plants were grown in pots or boxes and – for the fumigation over

a longer period – in the soil of the fumigation chambers. In order to eliminate the influence of strong wind and rain on the air-sampling apparatuses, which were installed around the fumigation chambers, a large enclosing glasshouse was built. The small glass chambers have a capacity of 8 m^3, a base area of 2 by 2 m and are ventilated at a rate of 8 m^3/min (Fig. 1). The large plastic chambers, used for the prolonged fumigation, have a capacity of 30 m^3, a base area of 3 by 4 m and are ventilated with 90 m^3 of air per min (Fig. 2).

To obtain the NO_2 for these experiments a cylinder is filled with liquid N_2O_4 and placed in a waterbath maintained at 30 °C. The tube connecting the cylinder with the place where the gas is injected into the air stream is kept at 90 °C. At this temperature most of the N_2O_4 is converted into NO_2. A flow meter is built at the end of the injection tube to register the amount of gas that is released. It takes about 2 to 3 sec for the NO_2 to reach the fumigation chambers from the place where the gas enters into the air stream. This period is long enough to convert remaining traces in the air stream into NO_2 by dilution of the N_2O_4.

The concentration of NO_2 in the fumigation chambers was determined according to the modified 'Saltzman' method (Stratmann and Buck, 1966). The temperature and humidity in the four chambers were measured with a thermohygrograph. Each fumigation experiment was carried out together with a control experiment with NO_2-free air. The temperature and relative humidity in both chambers were always almost identical and showed no differences in the maximum and minimum values. Watering of the plants in the large chambers was carried out by means of a trickle irrigation system connected to the water main, in which a filter was installed to prevent the tubes from being blocked. A watering period of 4 h per day was usually sufficient. The

Fig. 1. Glass chambers for short-lasting fumigation of plants grown in pots or boxes.

Fig. 1. Kasjes voor kortdurende begassingen van planten opgekweekt in potten of kisten.

Fig. 2. Plastic chambers for fumigation during the entire growth period of plants grown in the soil of the chambers.

Fig. 2. Kasjes voor begassingen gedurende de gehele groeiperiode van planten opgekweekt in de grond van de kasjes.

fresh air was cooled by sucking it through a wet filter. This filter with a surface 5.80 × 4.40 m in size consisted of a 3-cm thick layer of wood shavings kept in place by wire netting. A metal pipe with 1-mm openings placed at every 5 cm was fixed horizontally above this filter to wet it during passing of the air. A contact thermometer in one of the chambers gave a signal to a magnet valve in the water main to open as soon as the temperature reached 22 °C.

In the small chambers three fumigations were carried out during three to six weeks (short fumigations) with a concentration of 0.4–0.5 ppm on ten, twelve and thirteen plants.

To eliminate a possible influence of differences in light intensity in the third case the fumigation chamber of the former experiments served as a control chamber and vice versa. Thereupon a fumigation experiment during the total growth period of the plants took place in the large chambers to observe the gradually developing chronic injury and to determine total reduction of fruit yield. The NO_2-concentration applied was 0.25 ppm.

Results

The results of measurements of plant lengths of the three short lasting fumigations are given in Table 1.

In the first two fumigations there is a marked increase in plant height after NO_2-treatment. The same holds for the third experiment, where the fumigation was carried out in the control chamber of the former experiments and vice versa.

An additional experiment with a concentration of 0.5 ppm NO_2 was carried out with very young plants to investigate if they would perhaps react differently in a very early stage of development. In each chamber thirteen plants were used. Data on plant lengths and weights of leaves and petioles as well as total weights are given in Table 2.

For these young plants only ten days of fumigation were apparently sufficient to show increase in length. Although the fumigated plants were longer, they weighed considerably less than the control plants. This is in agreement with results of Taylor and Eaton (1966). The leaf margins of the fumigated plants curled downwards and the leaves formed during the experiment were smaller than those of the control plants (Fig. 3).

A prolonged fumigation was carried out larger in the fumigation chambers. Twenty-

Table 1. Differences in length of tomato plants in three experiments due to NO_2-fumigation 0.4 to 0.5 ppm (figures are average lengths in cm of ten plants).

Experiment	I		II		III	
Date	12–2	28–3	27–3	23–4	9–5	29–5
Fumigation period	45 days		28 days		21 days	
Control plants	26.5	64.7	25.7	68.0	22.6	72.5
Fumigated plants	28.9	76.7	25.0	79.0	22.7	83.7
Difference	+2.4	+12.0	−0.7	+11.0	+0.1	+11.2

Tabel 1. Verschil in lengtegroei van tomateplanten als gevolg van begassing met 0,4–0,5 ppm NO_2 (weergegeven zijn de gemiddelde lengten in cm van telkens 10 planten).

Fig. 3. Leaves of tomato plants. Right: after 10 days of treatment with 0.5 ppm NO_2. Left: control.

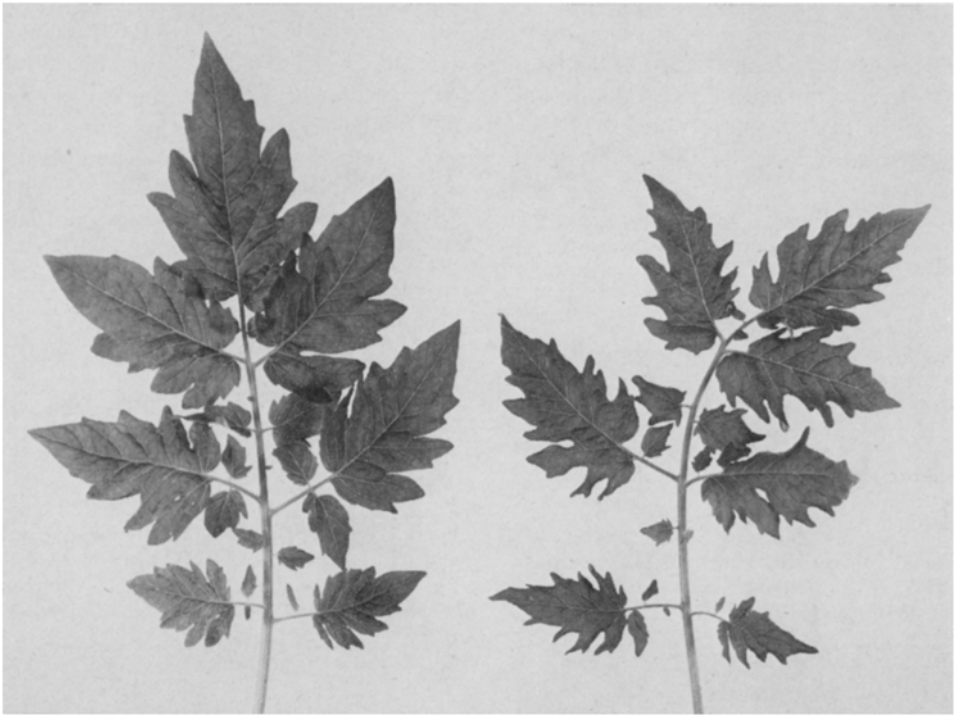

Fig. 3. Bladeren van tomateplanten. Rechts: na 10 dagen begassing met 0,5 dpm NO_2. Links: controle.

six tomato plants were treated with a concentration of 0.25 ppm NO_2 and the same number of plants served as control. The fumigation lasted from 22 July until 27 November, but had to be interrupted several times in order to tie up the plants, to pollinate the flowers, to apply some fertilizer and to harvest the fruits.

On 28 August the fumigated plants showed the following differences when compared with the non-fumigated ones. The lower leaves were yellowing, all leaves had margins curled downwards, were smaller and resembled those of a nettle.

The leaf petioles were also shorter than normal, giving the plants together a less dense appearance. On 9 September the fumigated plants had an average length of

Table 2. Average difference in weight (in g) and length (in cm) between treated and non-treated young tomato plants after a NO_2-fumigation (0.5 ppm) from 7–7 to 17–7.

	Control	NO_2
Leaf weight	134.9	94.8
Petiole weight	196.3	162.9
Total weight	331.2	257.7
Length at the start of the experiment	9.5	9.5
Length at the end of the experiment	29.8	31.5

Tabel 2. Gemiddeld verschil in gewicht (g) en lengte (cm) tussen behandelde en niet behandelde jonge tomateplanten na begassing met 0,5 dpm NO_2 van 7 tot 17 juli.

205.6 cm and the control plants measured 195.8 cm. The stems were smaller in diameter than those of the controls.

On 28 August the tops of all plants were removed just above the sixth inflorescence. The fruits were picked from 23 September onwards. The total weight of the first three harvests from the fumigated plants was higher than that of the control plants. However, the total weight of the last nine crops (30 October–27 November) of the control plants was higher than the weight of the corresponding crops of the fumigated plants.

Table 3. Total yield, number of fruits, average fruit and plant weight of tomato plants fumigated with NO_2 and non-fumigated tomatoplants.

	Treated	Control
Total yield (in %)	78	100
Number of fruits	821	919
Average fruit weight (in g)	54.4	62.2
Average plant weight (in kg)	12	20.5

Tabel 3. Opbrengst, aantal vruchten, gemiddeld vrucht- en plantgewicht van met NO_2 begaste en niet begaste tomateplanten.

Fig. 4. Tomato plants at the end of the growth period (14-11-69) almost continuously fumigated with NO_2 (0.25 ppm).

Fig. 4. Tomateplanten aan het einde van de groeiperiode (14-11-69) bijna continu begast met NO_2 (0,25 dpm).

Fig. 5. Tomato plants grown in the same period and under the same conditions as indicated in Fig. 4, but not fumigated with NO_2 (photographed 14-11-69).

Fig. 5. Tomateplanten opgekweekt in dezelfde periode en onder dezelfde omstandigheden als aangegeven in Fig. 4, maar niet begast met NO_2 (opname 14-11-69).

The results of the total yield, number of fruits, average fruit and plant weight, are given in Table 3.

The great difference in weight between fumigated and control plants is mainly caused by the loss of the lower leaves of the treated plants which began six to eight weeks after planting (Fig. 4 and 5).

Leaf samples and soil samples of the top layer of 30 cm were collected and dried for determination of the nitrate and total nitrogen content. In the compressed juice of the fresh leaf material no nitrite was found. The results are given in Table 4.

Table 4. Results of nitrogen analyses of tomato leaves and soil samples after NO_2 fumigation (0.25 ppm) from 22–7 to 27–11.

	Treated	Control
N (g N/100 g dry leaves)	3.54	3.06
NO_3 (g NO_3/100 g of dry leaves)	1.14	1.61
NO_3 (mg. NO_3/100 g dry soil)	109.7	62.1
NH_3 (mg. N/100 g dry soil)	0.2	0.1
Water soluble N (mg. N/100 g dry soil)	24	14
Total N (%)	0.52	0.49

Tabel 4. Resultaten van de stikstof analyses van tomatebladeren en grondmonsters na een NO_2 begassing (0,25 dpm) van 22–7 tot 27–11.

Discussion

In the prolonged fumigation experiment the growth conditions of glasshouses, where tomatoes are commercially grown, were as carefully imitated as possible. The plants were therefore fumigated during the whole period in rather large transparent plastic chambers and grown directly in the soil.

The results of the short-lasting fumigation experiments (0.5 ppm during ten days) are to a certain degree in accordance with those of Taylor and Eaton (1966). They reported fumigation experiments with plants of Pearson improved tomato seedling during ten to 22 days with 0.15–0.21 ppm NO_2 (0.31–0.42 mg/m^3) which resulted in a marked decrease in both fresh and dry weights of the fumigated plants. In longer lasting experiments the leaves also became distorted. In our very prolonged experiment the leaves started yellowing from the base of the plants onwards and finally dropped. The decrease in weight of the crop (22%), in the number of fruits (98) and of the average fruit weight in g (7.8) of the fumigated plants in comparison with the control, also point to a chronic toxic influence of NO_2. The results of the analyses for NO_3 of plants and soil samples in the fumigation and the control chamber show that the NO_3 content is lower in the plants and higher in the soil in the fumigation chamber. This higher NO_3 content of the soil may be the cause of the initial intensification of the green colour of the plants.

In conclusion we can say that fumigation with a low concentration of NO_2 (0.25 ppm) during the whole growth period of the tomato cv 'Moneymaker' results in an increasing injury with the following symptoms: growth retardation of leaves, petioles and stems, gradual yellowing of the older leaves, early leaf dropping and a slightly earlier but smaller crop.

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Samenvatting

Invloed van begassing met NO_2 op groei en opbrengst van tomateplanten

Met NO_2 werden begassingen van betrekkelijk korte en van lange duur op tomateplanten uitgevoerd. Concentraties van 0,4–0,5 dpm (delen per miljoen delen lucht), gedurende 20–37 dagen toegepast, hadden enerzijds een afname van het bladoppervlak en verkorting van de bladstelen, en anderzijds een toename in lengtegroei van de planten tot gevolg (Tabel 1). Een begassing met 0,5 dpm gedurende 10 dagen veroorzaakte een gewichtsvermindering van bladeren en bladstelen en wederom een toename in lengtegroei van de planten vergeleken met de controle (Tabel 2). Door begassing met een concentratie van 0,25 dpm gedurende de gehele teelt verminderde de opbrengst met 22% (Tabel 3). Het nitraatgehalte van de bladeren bleek na deze langdurige begassingen te zijn afgenomen, terwijl dat van de bovenste 30 cm van de grond hoger was geworden (Tabel 4).

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