# EFFECTS OF CHRONIC AND ACUTE EXPOSURE TO SULPHUR DIOXIDE ON THE GROWTH OF HYBRID POPLAR CUTTINGS

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*ABSTRACT*

*Hybrid poplar clones were fumigated in controlled-environment chambers with either 5 ppm sulphur dioxide for 1½, 3, and 6 h or with 0·25 ppm sulphur dioxide for six weeks. Multivariate analyses were made from shoot-growth data before and after treatment and on the foliar injury induced by $SO_2$. Both short- and long-term fumigation produced similar plant-behaviour responses to the two $SO_2$ concentrations.*

## INTRODUCTION

Most of the field research about chronic pollution effects on forest tree species has been limited to the nature of foliar symptoms on injured vegetation. Laboratory studies of plant behaviour in response to gaseous pollutants have used higher concentrations than are encountered in the forest. Such divergent approaches of investigation have left serious gaps in our knowledge about the interrelation of long- and short-term pollution exposures.

Incidences of acute injury should lessen as air-quality standards are established and control technology is improved for abating air pollutants at their sources. Chronic pollution will not, however, be influenced by these measures. These sub-lethal conditions will continue and their debilitating effects on forest plantings will probably intensify.

The data on chronic exposures and their lack of identification with acute fumigations under controlled conditions make it important to establish a relationship between the two. The purpose of this initial investigation involved defining: (1) the responses of shoot growth and foliar symptoms of hybrid poplar clones to chronic and acute concentrations of $SO_2$ and (2) the correlation of suggestive patterns of similar plant behaviour to the two fumigation treatments.



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## MATERIALS AND METHODS

Preliminary fumigation had indicated differences in susceptibility to $SO_2$ among cultivars of hybrid poplars of the parentage *Populus deltoides* Bartr. × *P. trichocarpa* Torr. and Gray (Dochinger *et al.*, 1972). Accordingly, cuttings were obtained from a tolerant clone (clone 207) and a moderately sensitive clone (clone 211). Ten one-year-old whips were removed from each of five trees of each clone. Two 20 cm cuttings were taken from each whip and designated as either a terminal or a basal cutting.

All cuttings were weighed to 1/100th g, labelled for treatment, and inserted into a 15 cm plastic pot containing a peat–sand–soil mixture (1:1:1). Pots were placed randomly on greenhouse benches. Temperature was maintained at about 20°C at night and 30°C during daylight hours. Cuttings were kept well watered and were fertilised biweekly with a complete nutrient solution, after they had broken dormancy.

When new growth was initiated, 20 plants were set in each of four flow-through fumigation chambers. Excess buds were pinched, and each ramet contained only a single shoot. The air, filtered through a particle and a charcoal filter, was pulled through the chamber at the rate of one change every 2 min. Relative humidity was maintained at 60% and the temperature ranged between 25 and 30°C. Each chamber contained a terminal cutting and a basal cutting from each of the 10 parent trees.

Two of the chambers were used for untreated controls, and two were fumigated with 0·25 ppm $SO_2$ for 8 h a day, five days a week. Fumigant concentrations were monitored in each chamber every 15 min with a Melpar flame-photometric analyser and were corrected manually by means of a flowmeter and needle valve. Accuracies were kept within $\pm 0{\cdot}05$ ppm of the desired concentration.

Height of the cuttings was measured weekly during the six-week chronic fumigation treatment. After exposure, the plants were rated for symptom development by assessing each leaf on the basis of no injury, less than 50% injury, and over 50% injury. The leaves, stems, and roots were then separated and their fresh weights recorded.

At the completion of the chronic fumigation experiment, cuttings rooted in the greenhouse at the same time as in the chronic study were placed in the chambers and fumigated with 5 ppm $SO_2$ for either $1\frac{1}{2}$, 3, or 6 h.

Each fumigation chamber had five terminal cuttings and five basal rooted cuttings from each of the two hybrid poplar clones. A similar number served as controls in a clean-air chamber. Each treatment group was replicated four times. Height growth of these cuttings was recorded at weekly intervals, beginning five weeks before fumigation.

After exposure, all plants were returned to the greenhouse. Height growth for all cuttings was measured 24 and 48 h after $SO_2$ treatment and weekly for a period of

five weeks. Foliar responses were subjectively rated 48 h after fumigation, as in the chronic study.

## RESULTS

Multivariate analysis of covariance (Morrison, 1967) was used to determine the statistical significance of the responses of the two hybrid poplar clones to acute and chronic $SO_2$ fumigation. Initial weights of the cuttings served as the covariate, and their values were regressed against subsequent shoot growth and foliar-injury measurements. Because the covariance structure of analysis was assumed to be different, and because of the wide variation in fresh weight of stems, separate analyses were computed for both the terminal and the basal cuttings. Growth curves showed that both poplar clones were growing rapidly before fumigation.

*Chronic fumigation* (0·25 *ppm*)

In the study of chronic fumigation, a significant difference in height growth was found between the two clones for both the terminal and basal group of cuttings (Fig. 1). In all comparisons, clone 207 grew more than clone 211. Basal cuttings in the control treatment grew significantly more than those in the fumigation treatment, but no significant differences were observed among the terminal cuttings (Fig. 2).

Chronic levels of $SO_2$ also caused a significant increase in the percentage of injured leaves (Fig. 3). Clone 211 displayed more foliar sensitivity (Table 1).

TABLE 1

PERCENTAGE OF LEAVES FROM TERMINAL (T) AND BASAL (B) SHOOTS OF HYBRID POPLAR 207 AND 211 IN EACH OF THREE INJURY CATEGORIES AFTER FUMIGATION WITH EITHER 0·25 OR 5 PPM OF $SO_2$

| *$SO_2$ concentration and treatment time* | *Shoot position* | *Clone* 207 | | | *Clone* 211 | | |
|---|---|---|---|---|---|---|---|
| | | *None* | <50% | >50% | *None* | <50% | >50% |
| 0·25 ppm | T | 47 | 52 | 1 | 33 | 51 | 16 |
| | B | 45 | 52 | 3 | 31 | 56 | 13 |
| 5 ppm (*Hours of fumigation*) | | | | | | | |
| 0 | T | 100 | 0 | 0 | 100 | 0 | 0 |
| | B | 100 | 0 | 0 | 100 | 0 | 0 |
| 1½ | T | 13 | 20 | 67 | 15 | 15 | 70 |
| | B | 25 | 21 | 54 | 38 | 11 | 51 |
| 3 | T | 5 | 27 | 68 | 1 | 20 | 79 |
| | B | 18 | 29 | 53 | 22 | 22 | 58 |
| 6 | T | 7 | 15 | 78 | 0 | 16 | 84 |
| | B | 13 | 20 | 67 | 5 | 21 | 74 |

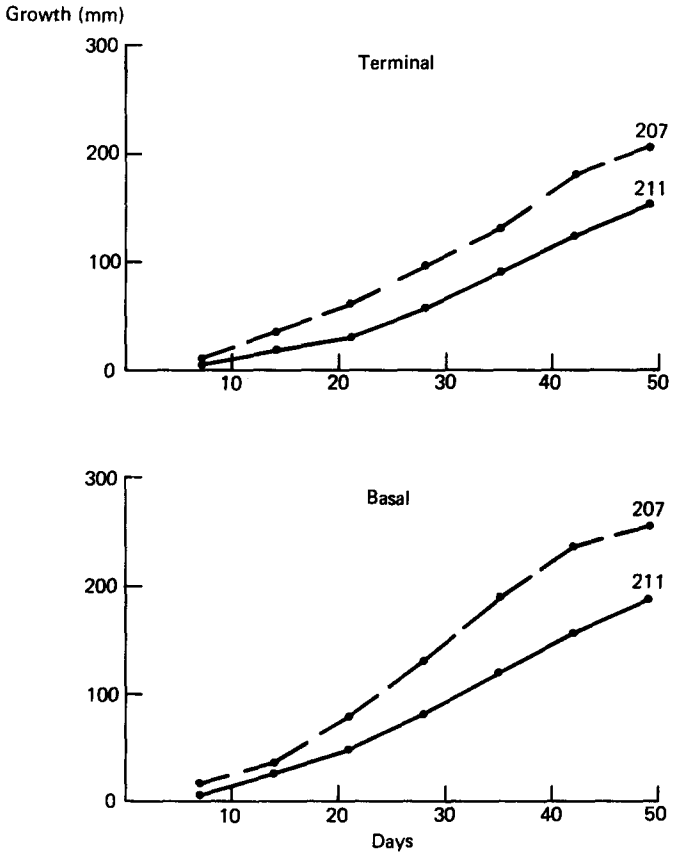


Fig. 1. Growth of terminal and basal cuttings of hybrid poplar clones 207 and 211 after chronic exposure to 0·25 ppm $SO_2$ for 30 days.

There were about 15% more symptomatic leaves, and about 10% of these were injured more than 50%. No clonal variation was associated with the number of uninjured leaves and the amount of foliar necrosis when comparing basal and terminal cuttings.

*Acute fumigation* (*5 ppm*)

Thirty-five days after exposure, height growth of the fumigated hybrid poplar cuttings was significantly curtailed for both terminal and basal cuttings (Table 2). These decreases were observed between the control treatment and the three fumigation treatments. Lengthening the time of exposure did not influence shoot growth until 14 days after $SO_2$ fumigation (Fig. 4).

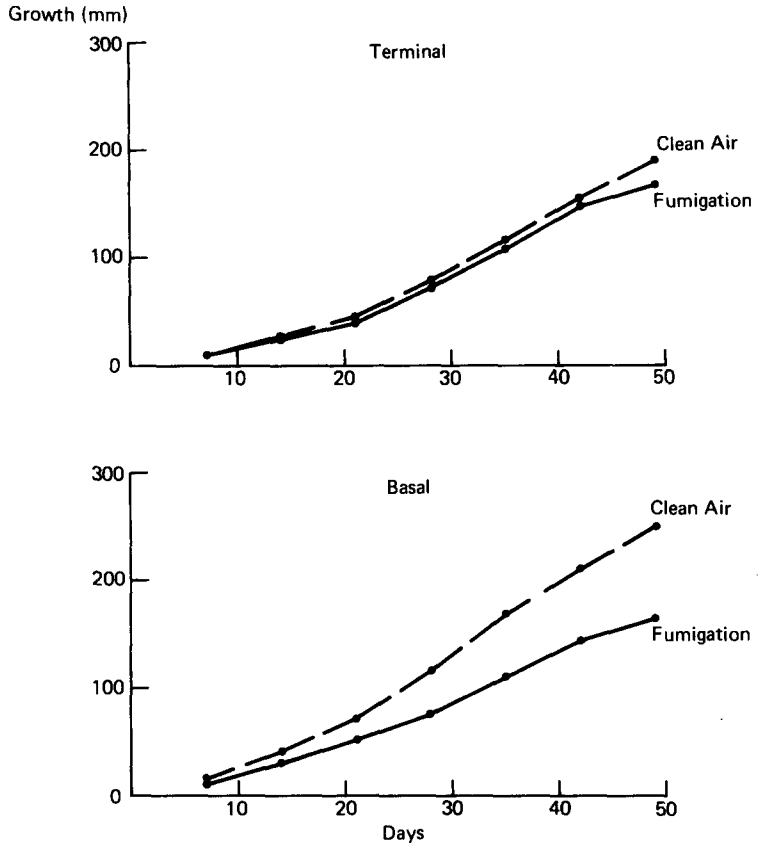


Fig. 2. Growth of terminal and basal cuttings of two hybrid poplar clones grown in clean air and fumigated with 0·25 ppm $SO_2$ for 30 days.

TABLE 2

AVERAGE HEIGHT (MM) OF TERMINAL AND BASAL HYBRID POPLAR CUTTINGS 24 H BEFORE FUMIGATION (<) AND 35 DAYS AFTER EXPOSURE (>) TO 5 PPM $SO_2$

| *Hours of fumigation* | *Terminal cuttings* | | *Basal cuttings* | |
|---|---|---|---|---|
| | < | > | < | > |
| 0 | 143* | 493 | 202 | 606 |
| 1½ | 150 | 348 | 198 | 458 |
| 3 | 145 | 360 | 180 | 435 |
| 6 | 157 | 363 | 189 | 427 |

* Average shoot growth based on 10 cuttings.

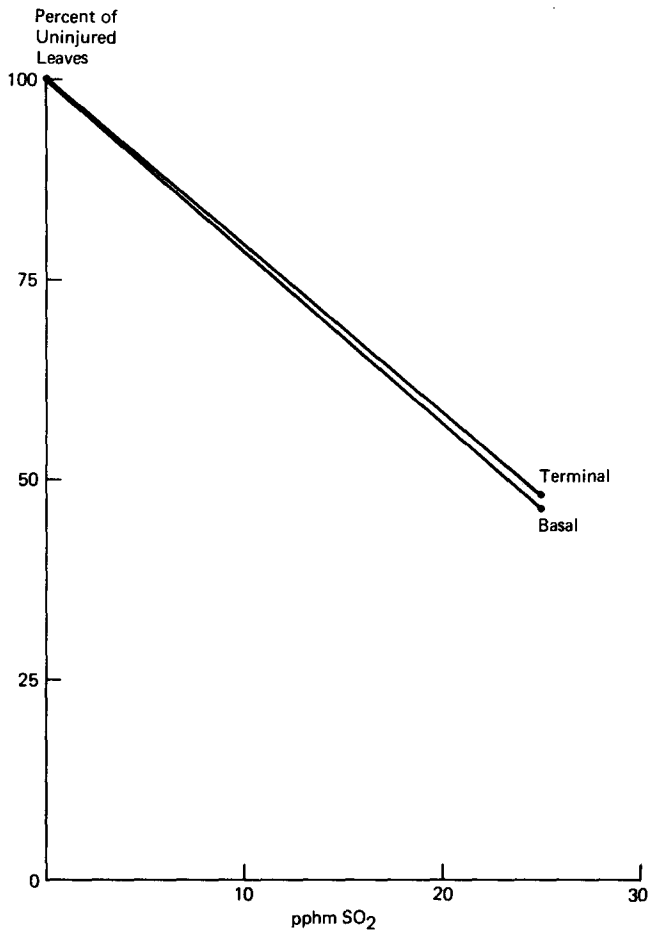


Fig. 3. Relative percentage leaf injury to shoots of hybrid poplar clones after exposure to 0·25 ppm $SO_2$.

In the responses of both clones, significant differences in shoot growth were associated at all measurement times for terminal and basal cuttings (Fig. 5). Clone 207 produced more shoot growth than clone 211 before and after fumigation, but the influence of basal cutting–shoot growth was not the overriding factor, as it was in the chronic fumigation treatment (Fig. 6). Shoot growth was significantly better for all cuttings in clean air than for those that received 5 ppm $SO_2$ 14 days after acute fumigation.

The 5 ppm $SO_2$ fumigation injured a significant number of leaves (Table 1). Exposing poplars to extended periods of fumigation did not significantly increase

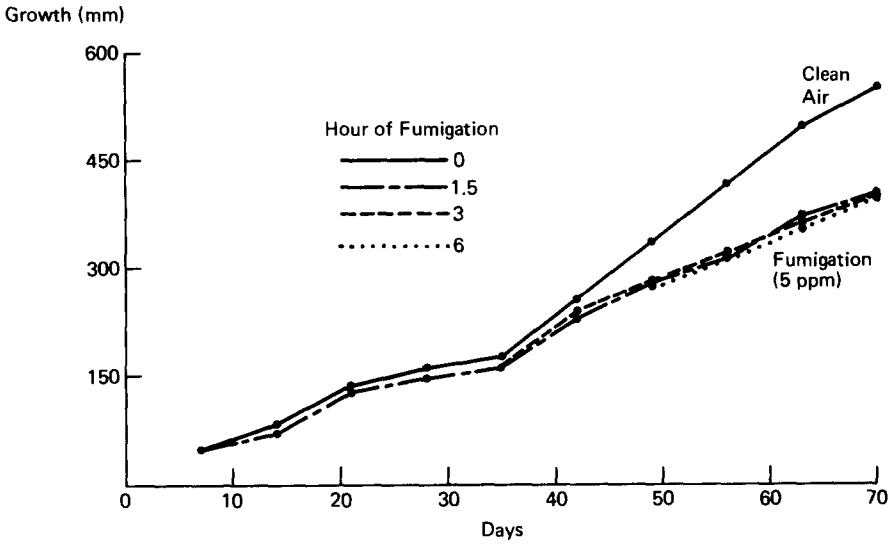


Fig. 4. Shoot growth of hybrid poplar clones grown in clean air and fumigated with 5 ppm $SO_2$. Data combined for all cuttings.

the number of injured leaves nor the amount of foliar necrosis (Fig. 7). As in the chronic fumigation treatment, clone 211 displayed more foliar sensitivity to a high level of fumigation, except for its response to $1\frac{1}{2}$ h of $SO_2$ exposure (Table 1).

There seemed to be a relationship between initial stem weights and subsequent shoot growth, but not with final foliage condition. More significant growth was made by the basal, than by the terminal, cuttings.

## DISCUSSION

In the acute $SO_2$ treatments and the chronic treatment of basal cuttings, the reduction in height growth was positively correlated with foliage injury. However, foliar impairment from the two treatments was possibly the result of different processes. In the chronic treatment, the foliage responses were determined at the end of the study. Therefore, with continued exposure of the poplars to $SO_2$, tissue necrosis may have occurred from the accumulation of sulphate, sublethal concentrations of sulphite, or both (Jacobson & Hill, 1970). Such a gradual degradation of foliage would curtail photosynthesis and finally affect shoot growth.

In the acute treatment, foliage readings were determined 48 h after the fumigation period and before any cessation in plant growth. Foliage injury probably resulted from the accumulation of lethal concentrations of sulphite, which then caused

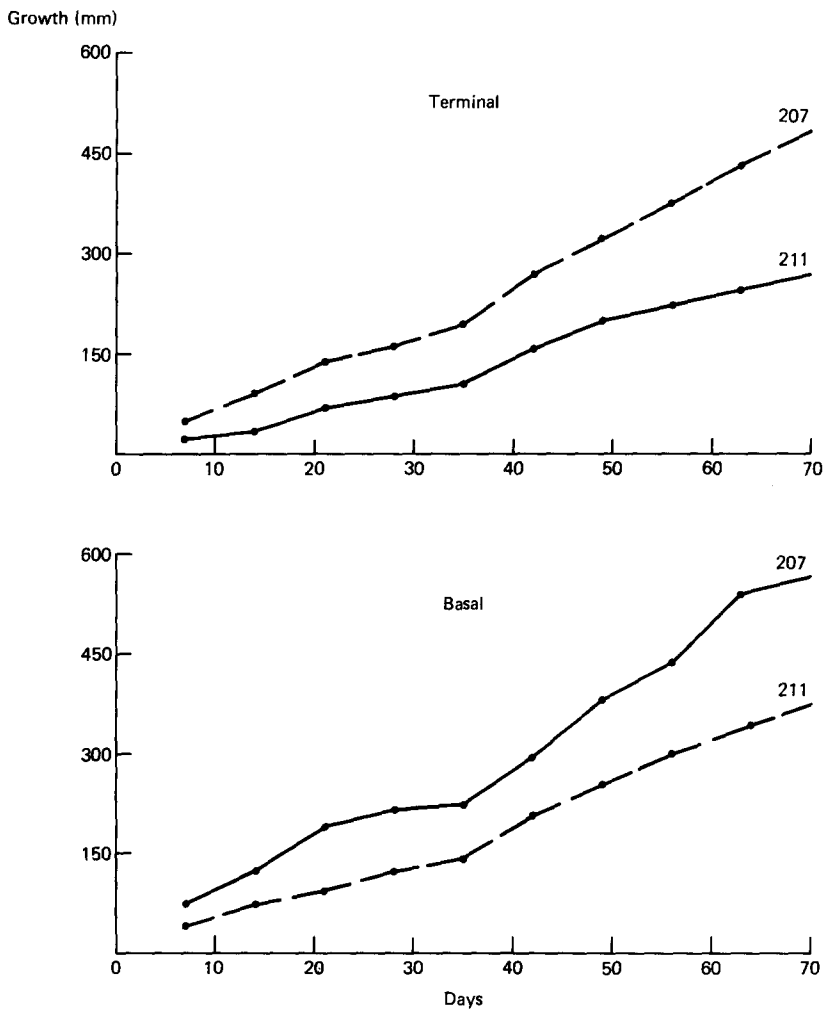


Fig. 5. Growth of terminal and basal cuttings of hybrid poplar clones 207 and 211 after acute exposure to 5 ppm $SO_2$. Data combined for all hours of fumigation.

foliar necrosis. A reduction in growth was not manifested until 14 days after fumigation. This lag in shoot response was probably tied in with the stored carbohydrates used in growth. After these stored reserves were exhausted, growth rate decreased because the photosynthesising tissue of the leaf was destroyed by the $SO_2$ treatment.

We do not know why the 0·25 ppm $SO_2$ fumigation influenced the growth of basal cuttings and not terminal cuttings. The amount of foliar injury in both groups

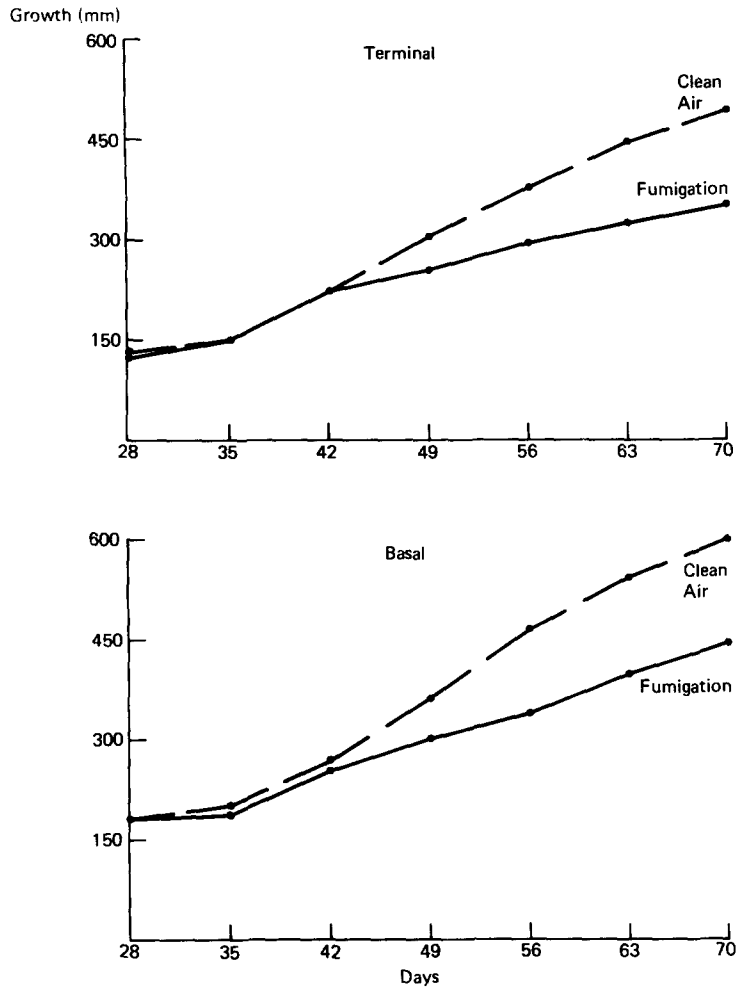


Fig. 6. Growth of terminal and basal cuttings of two hybrid poplar clones grown in clean air and fumigated with 5 ppm $SO_2$. Data combined for all hours of exposure.

of cuttings was identical. Perhaps the larger size of cuttings in the basal group provided more food reserves for maintaining growth.

The significant difference in susceptibility between the two clones to $SO_2$ fumigation corroborates earlier investigations (Dochinger *et al.*, 1972; Temple, 1972), in which interclonal and tree-species differences were reported. Clone 211 was more sensitive than clone 207 to both the chronic and acute fumigation. Because shoot growth reduction and foliar injury were similar with both exposures

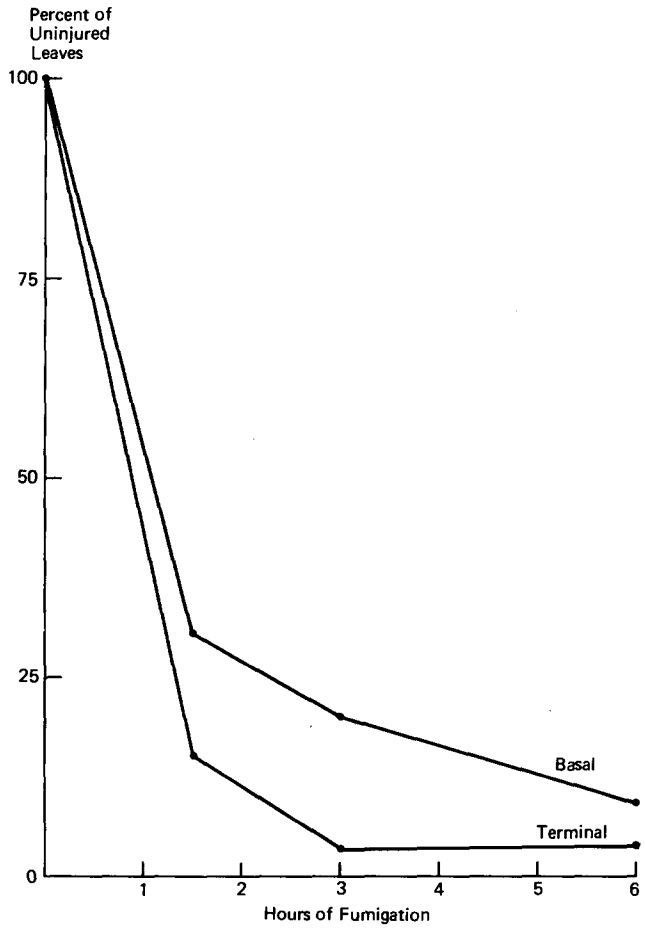


Fig. 7. Relative percentage leaf injury to shoots of hybrid poplar clones after exposure to 5 ppm $SO_2$.

to $SO_2$, and the treatment–clone interactions were not significant, acute exposures to $SO_2$ might be useful in predicting plant susceptibility.

Determining the susceptibility of plants to $SO_2$ by short exposures to a high concentration of the pollutant would shorten the time required to select genetically-resistant stock. However, this relationship between levels of pollutant must be investigated for each pollutant and tree species. In an allied study, Jensen & Dochinger (1974) reported that chronic levels of ozone reduced shoot growth of these hybrid poplar clones, whereas acute fumigation had no effect. More studies,

using wider ranges of tree susceptibility and levels of $SO_2$ fumigation, will be required to clarify dose/plant-response interactions completely.

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