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GROWTH RESPONSES OF *AILANTHUS ALTISSIMA* SEEDLINGS TO SO_2

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ABSTRACT

Growth of Ailanthus altissima *(Mill.) Swingle seedlings exposed to various levels of sulphur dioxide (SO_2) was observed. Exposure for 1 or 2 weeks at 260 $\mu g\, m^{-3}$ (0·1 ppm) or 520 $\mu g\, m^{-3}$ (0·2 ppm) of SO_2 significantly ($p \leq 0{\cdot}05$) reduced extension growth and biomass accumulation of 2- and 3-week-old seedlings. Root growth was inhibited more than shoot growth, and reduction of growth was more severe at the higher SO_2 concentration.*

INTRODUCTION

The establishment and survival of recently germinated tree seedlings is severely limited by a number of environmental factors (Kozlowski, 1979). In this study the effects of one such factor, atmospheric SO_2 pollution, on growth of *Ailanthus altissima* (Mill.) Swingle seedlings were investigated. Ailanthus, a tree native to Asia and first planted in North America in the late 1700s, frequently out-competes native vegetation. Its success is particularly evident in urban environments and is due, in part, to a lack of natural enemies, rapid growth rates, and very large reproductive capacity. In addition, ailanthus has been described as being able to flourish in poor, hard-packed soils and in smoky atmospheres (Illick & Brouse, 1926; Vines, 1960; Harlow & Harrar, 1968). However, little evidence has been presented to show that ailanthus is really resistant to air pollutants (Ranft & Dässler, 1970).

Very few studies have examined the effects of SO_2 on recently germinated woody plants (Berry, 1971, 1974; Constantinadou *et al.*, 1976; Suwannapinunt &

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Kozlowski, 1980). We felt it was important to learn more about the effects of physiological stresses on very young seedlings since previous studies have indicated that epigeously germinating woody plants may be very susceptible to stresses during the cotyledon stage of growth (Marshall & Kozlowski, 1974, 1976). With these considerations in mind, we conducted this study to determine the effect of two relatively low concentrations of SO_2 on growth of recently germinated ailanthus seedlings.

METHODS

Ailanthus seeds were collected in southeastern Michigan in the fall of 1977. Unstratified seeds were germinated in moist vermiculite on a greenhouse bench. When seedlings were about 2 cm tall (14–18 days after sowing and 5–7 days after radicle emergence), four seedlings were transplanted into each of 36 cylindrical plastic pots (600 ml) containing loam, sand, and perlite (2:1:1 v/v). Twelve pots were placed in each of three identical growth chambers which were maintained as follows: 25 °C days, 20 °C nights, 70–80 % RH, and a 16-h photoperiod with fluorescent and incandescent lights providing about 320 $\mu E\, m^{-2}\, s^{-1}$ at the tops of the seedlings. Chamber 1 received charcoal-filtered air (control), Chamber 2 was maintained at 260 $\mu g\, m^{-3}$ SO_2 (0·1 ppm), and Chamber 3 was maintained at 520 $\mu g\, m^{-3}$ SO_2 (0·2 ppm). SO_2 concentrations were monitored with a Beckman 906A which was calibrated with a permeation tube. Plants were harvested after 1 or 2 weeks of exposure in the chambers. Great care was taken to maintain intact root systems during the harvest. Measurements included lengths and dry weights of roots and shoots. Equality of variances among treatments was not a valid assumption, so data were analysed with a median test (Dixon & Massey, 1969).

RESULTS

After 1 week of exposure to the treatments no visible injury was apparent and shoot elongation was not affected. However, root elongation was significantly inhibited by exposure to either SO_2 concentration (Table 1). SO_2 had no apparent effect on root biomass accumulation after 1 week, but it caused a significant reduction in shoot biomass (Table 1).

After 2 weeks, plants exposed to the lower SO_2 concentrations were not significantly different from controls with respect to root and shoot lengths or root biomass, though shoot biomass accumulation was decreased (Table 1). Two weeks of exposure to the higher SO_2 concentration caused some foliar yellowing and severe reductions of all growth parameters (root length—58 % of controls, shoot length—79 % of controls, root dry weight—58 % of controls, and shoot dry weight—77 % of controls, Table 1).

TABLE 1
EFFECTS OF SO_2 ON AILANTHUS SEEDLING GROWTH

Condition	*Exposure (days)*	*Root length*[a] *(cm)*	*Shoot length (cm)*	*Root dry wt (mg seedling*$^{-1}$*)*	*Shoot dry wt (mg seedling*$^{-1}$*)*
Control	7	9·3 (0·7)	4·4 (0·6)	4·4 (0·7)	14·9 (1·6)
	14	12·8 (1·4)	5·7 (0·5)	12·9 (1·2)	48·5 (4·2)
260 $\mu g\,m^{-3}\,SO_2$	7	7·8 (0·8)*	4·9 (0·7)	4·5 (0·8)	10·7 (1·2)*
	14	11·4 (1·1)	5·6 (0·6)	15·0 (2·2)	32·7 (4·0)
520 $\mu g\,m^{-3}\,SO_2$	7	6·8 (0·9)*	4·8 (0·8)	5·3 (0·6)	11·4 (1·2)*
	14	7·9 (1·1)*	4·8 (0·6)*	7·5 (2·4)*	15·7 (2·8)*

[a] Numbers are means with standard deviations in parentheses.
* Indicates that number is significantly different from that of the control ($p \leq 0{\cdot}05$).

Relative growth rates (RGR) were calculated from whole-plant biomass data to give an indication of the increase in plant weight per unit of original plant weight over a 1-week interval. Results show that the lower SO_2 concentration (260 $\mu g\,m^{-3}$) had no effect on RGR whereas the higher concentration had a severe effect (reduced the RGR to 29% of the control (Table 2)).

TABLE 2
RELATIVE GROWTH RATES OF AILANTHUS EXPOSED TO SO_2 FOR 14 DAYS

Condition	*Relative growth rate*[a]
Control	0·1652
260 $\mu g\,m^{-3}\,SO_2$	0·1632
520 $\mu g\,m^{-3}\,SO_2$	0·0472

[a] $$\mathrm{RGR} = \frac{\ln(W_2) - \ln(W_1)}{t_2 - t_1}$$

where W = weight in mg, and t = time in weeks.

DISCUSSION

Chronic exposure of very small ailanthus seedlings to moderate concentrations of SO_2 appeared to inhibit root growth more than shoot growth. Suwannapinunt & Kozlowski (1980) reported similar results with very young black locust and American elm seedlings, but they had used much higher SO_2 concentrations and much shorter exposure times. The reduction of root growth in very young woody seedlings could have serious implications in seedling establishment and early seedling growth since inhibited root growth could limit water uptake.

Others have reported that brief exposures to high SO_2 concentrations can also increase transpirational water losses from foliage of young woody seedlings (Suwannapinunt & Kozlowski, 1980). Sulphur dioxide pollution appears to increase woody seedlings' susceptibility to drought stress which, for very young seedlings, can greatly impair seedling development and growth and may be responsible for considerable seedling mortality (Kozlowski, 1979). Impaired root growth could also affect mineral nutrient relations and growth regulator balances in small seedlings.

Growth reductions in woody angiosperms following chronic exposures to moderate concentrations of SO_2 have been reported by many (Katz *et al.*, 1939; Dochinger & Jensen, 1975; Jensen & Dochinger, 1979), but few studies have included recently germinated seedlings. Growth reductions in response to SO_2 in very young conifers have been reported (Berry, 1971, 1974; Constantinadou *et al.*, 1976) but these have involved acute exposures to relatively high concentrations.

Growth reductions caused by SO_2 have generally been attributed to decreased photosynthesis (Bennett & Hill, 1974; Mudd, 1975; Barton *et al.*, 1980). If photosynthesis was decreased in the fumigated ailanthus seedlings then one might expect root growth to be more inhibited than shoot growth since shoots of small woody angiosperm seedlings are strong carbohydrate sinks (Marshall & Kozlowski, 1974) and may outcompete roots for current photosynthates.

Photosynthesis impacts may be more serious for species with epigeal germination, that is, with cotyledons exposed above ground. Previous study has shown that small seedling development is closely linked to cotyledon photosynthesis (Marshall & Kozlowski, 1976). Species with large cotyledons kept below ground (hypogeal germination) generally have rapid root elongation that is somewhat independent of current photosynthesis; thus such species may be more resistant to SO_2-induced damage in very early stages of growth.

We have concluded from this study that during the first 3 weeks after emergence, ailanthus seedlings are not particularly resistant to chronic SO_2 exposure with respect to growth inhibition. Such seedlings may become more or less tolerant of SO_2 as they become older, but small seedling susceptibility to SO_2 may limit seedling establishment. Further work which links pollution-caused growth reductions in very small seedlings to susceptibility to other environmental stresses is needed.

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