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GROWTH RESPONSES OF WOODY SPECIES TO LONG- AND SHORT-TERM FUMIGATION WITH SULFUR DIOXIDE

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Abstract

Height growth of silver maple, white ash, yellow-poplar, sycamore, eastern cottonwood, and white spruce seedlings was not significantly influenced by 0.15 ppm SO_2 for 8 hours/day, 5 days/week. A fumigation treatment of 0.25 ppm SO_2 for 8 hours/day, 5 days/week did not significantly affect height growth of black alder, yellow-poplar and white spruce seedlings but significantly reduced the height growth of eastern cottonwood, green ash, and sycamore seedlings. Exposure to toxic concentrations of SO_2 (1 to 4 ppm) for 2 to 8 hours significantly affected the height growth and caused leaf injury in silver maple and yellow-poplar seedlings. Growth was only suppressed for 14 days after the toxic fumigation because by that time new leaves had formed and normal growth had resumed.

DESPITE the increase in air pollution research in recent years, the impact of air pollutants on growth and productivity of forest and agricultural crops is still largely unknown. Information is available for some agricultural crops: soybean (Heagle et al. 1974), sweet corn (Heagle et al. 1972), radish (Tingey et al. 1971a), tomato (Oshima et al. 1975), and tobacco (Tingey and Reinert 1975), but little or no data are available for most tree species.

To fill this information void, we are conducting studies to determine what effects ambient or near-ambient levels of pollutants have on growth of tree seedlings. To date these studies have shown that the growth of sycamore, sugar maple, and silver maple seedlings were significantly reduced by either 0.25 ppm or 0.30 ppm ozone (Jensen 1973, Jensen and Masters 1975). Growth of hybrid poplar clones was slowed by both 0.15 ppm ozone and 0.25 ppm sulfur dioxide (Jensen and Dochinger 1974, Dochinger and Jensen 1975).

The objectives of this study are: 1) to evaluate the influence of low or near-ambient levels of sulfur dioxide on growth of tree seedlings and 2) to compare the responses of tree species to low levels of SO_2 with the responses of seedlings exposed to toxic levels of the same pollutant.

MATERIALS AND METHODS

In the first experiment, twenty-four 1-year-old seedlings each of black alder (*Alnus glutinosa* (L.) Gaertn.), green ash (*Fraxinus pennsylvanica* Marsh.), yellow-poplar (*Liriodendron tulipifera* L.), sycamore (*Platanus occidentalis* L.), and eastern cottonwood (*Populus deltoides* Bartr.) and 2-year-old seedlings of white spruce (*Picea glauca* (Moench) Voss) were potted in a 1:1 sand-soil potting mixture in 15-cm plastic pots. The seedlings of each species were randomly assigned to either a control group or fumigation treatment with 0.25 ppm SO_2 for 8 hours/day, 5 days/week. Treatments were applied to the seedlings in two 8x8x8-foot polyethylene-covered chambers inside a greenhouse. (Heagle et al. 1972).

Height was measured when the seedlings were placed in the chambers in mid-June and remeasured every two weeks for 14 weeks. Leaf counts were made on September 9 and leaf width and length measurements were made on September 3. All data were statistically analyzed by species using a completely randomized design.

In the second experiment twenty-four 1-year-old seedlings each of silver maple (*Acer saccharium* L.), white ash (*Fraxinus americana* L.), yellow-poplar, sycamore, and eastern cottonwood and 2-year-old seedlings of white spruce were potted in late May as in the first experiment. Seedlings of each species were randomly assigned to either fumigation with 0.15 ppm SO_2 for 8 hours/day, 5 days/week, or the control group. The treatments were applied in the same chambers used in the first experiment.

Height was measured as in the first experiment. Leaves were counted and their area measured with an electronic area meter on July 18. All data were statistically analyzed by species, using a completely randomized design.

In the third experiment, 1-year-old seedlings of silver maple, yellow-poplar, and eastern cottonwood were potted as above and placed on a greenhouse bench in mid-July. After the seedlings had produced an average of 15 leaves, 80 seedlings of each species were selected and 8 randomly assigned to each of the following treatments: 1) 1 ppm SO_2 for 2 hours, 2) 1 ppm SO_2 for 5 hours, 3) 1 ppm SO_2 for 8 hours, 4) 2.5 ppm SO_2 for 2 hours, 5) 2.5 SO_2 for 5 hours, 6) 2.5 ppm for 8 hours, 7) 4 ppm SO_2 for 2 hours, 8) 4 ppm SO_2 for 5 hours, 9) 4 ppm SO_2 for 8 hours, and 10) control.

The fumigation treatments were applied to the seedlings in a 2×3×4-foot polyethylene covered chamber located inside an environmental control unit. The chamber had a closed circulation system. The light intensity at plant height inside the chamber was 2000 foot-candles. The temperature was 26±2°C and relative humidity 60±15 percent. The seedlings were returned to the greenhouse immediately after fumigation.

Seedling height was measured 1 week before fumigation, on the day of fumigation, and 2 and 4 weeks after fumigation. Leaf injury was assayed 2 days after fumigation by separating the leaves into three classes, 1) no injury, 2) less than 50 percent injured, and 3) more than 50 percent injured. Height, determined 4 weeks after fumigation, and leaf injury were statistically analyzed by species in a completely randomized design.

The SO_2 concentrations in the treatment chambers in all three experiments were continually monitored with a Beckman 906A[1] SO_2 analyzer. Sulfur dioxide was added to the chambers from either tanks of SO_2 or SO_2 and nitrogen combined.

RESULTS

No significant change in height growth was found for any species fumigated with 0.15 ppm SO_2. However, the final heights of eastern cottonwood, green ash, and sycamore seedlings fumigated with 0.25 ppm were significantly less than the heights of the corresponding unfumigated seedlings (Fig. 1). No air pollution injury was observed on the leaves of any of the seedlings in the fumigation treatment.

No significant differences were found in either number of leaves or leaf area between the seedlings in the control treatment and the seedlings fumigated with 0.15 ppm SO_2. With the 0.25 ppm treatment no significant change was found in either leaf length or width, but the number of leaves on eastern cottonwood and black alder seedlings was significantly less in the fumigated treatment than in the control treatment (Table 1). Conversely, yellow-poplar seedlings in the fumigated treatment had more leaves than seedlings in the control treatment.

Table 1. The effect of 0.25 ppm SO_2 on leaf number.

Species	Number of leaves per seedling	
	Control	Fumigated
Green ash	18	15
Cottonwood	29	16**
Sycamore	16	12
Yellow-poplar	20	27*
Black alder	29	18*

*Significant at the 5 percent level.
**Significant at the 1 percent level.

Fumigating with toxic levels of SO_2 significantly affected the height of silver maple and yellow poplar (Fig. 2). Significant differences were found both among fumigations and lengths of exposure. Growth reductions were the greatest after 8 hours of treatment for both species and with 4 ppm SO_2 for yellow-poplar and 1 ppm SO_2 for silver maple.

Growth was suppressed for only 14 days following fumigation. Growth rate between 14 days and 28 days after fumigation was similar to the growth rate before fumigation (Fig. 3).

Figures 4 to 6 show the leaf injury caused by the high doses of fumigation. Injury increased significantly for all species with an increase in SO_2 concentration, in length of exposure, and in dose (concentration × time).

In general, growth reduction was inversely correlated with an increase in leaf injury. For example, with yellow-poplar, as the concentration of SO_2 increased from 1 to 4 ppm, leaf injury increased from 0 to 47 percent and growth was reduced from 171 mm to 122 mm. Similar relationships were observed with eastern cottonwood and silver maple.

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Figure 1. Height growth response of six woody species fumigated with 0.25 ppm sulfur dioxide. C—control, F—fumigated.

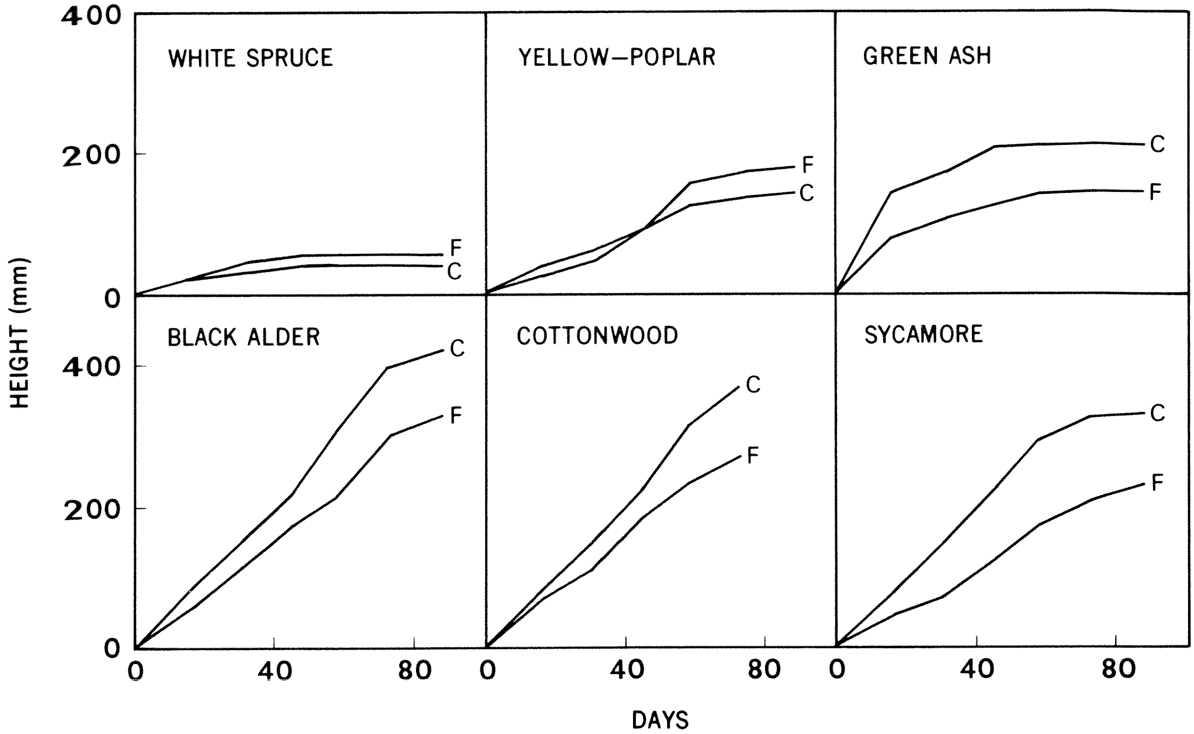
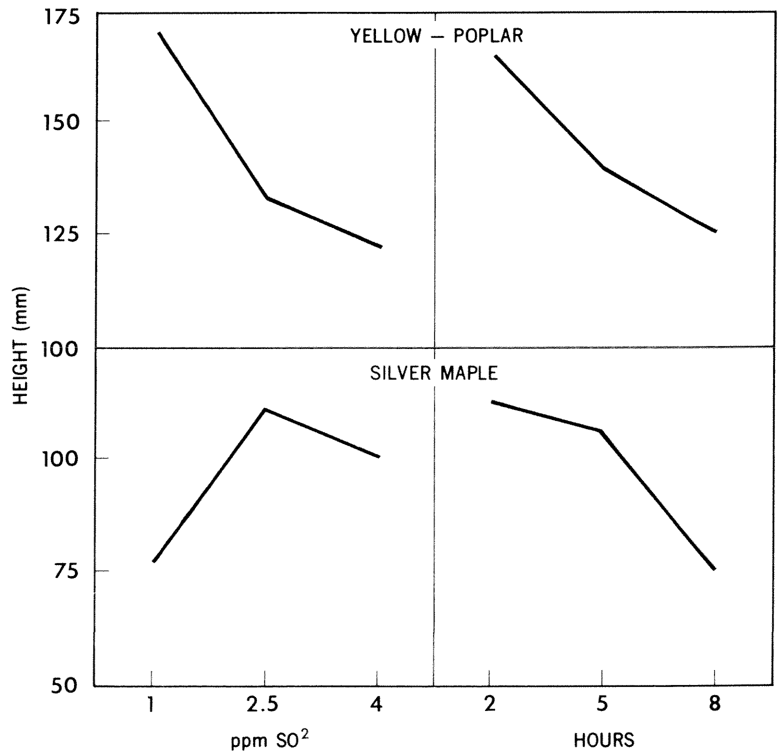


Figure 2. Height growth of silver maple and yellow-poplar seedlings fumigated with toxic doses of SO_2.



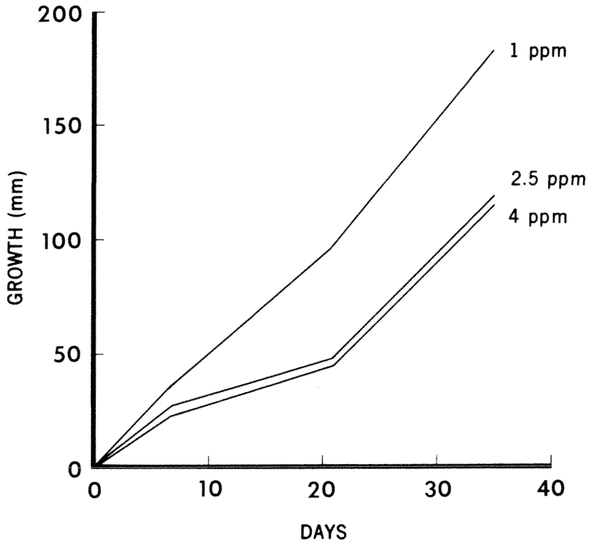


Figure 3. Growth pattern of yellow-poplar seedlings fumigated for 5 hours with toxic levels of SO_2. Fumigation treatments were applied on the seventh day.

Figure 4. Effect of SO_2 fumigation dose on leaf injury of cottonwood seedlings. Graph is a plot of the percentage of leaves with over 50 percent of the surface injured. Each horizontal line represents 10 percent.

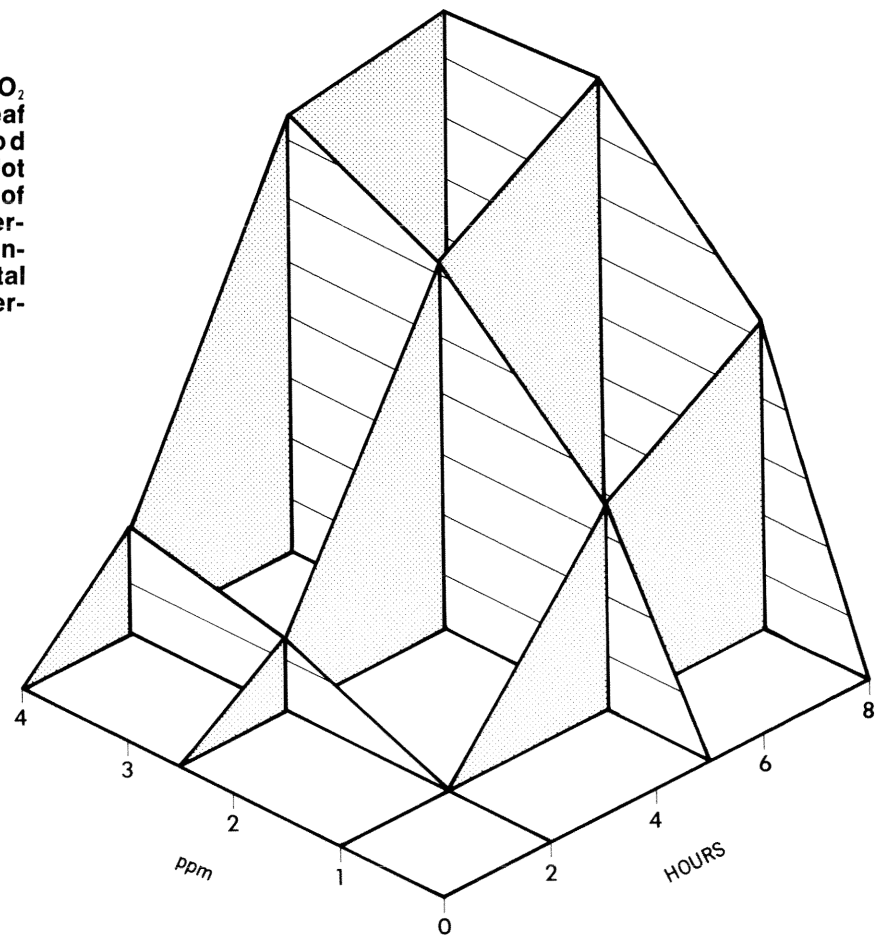
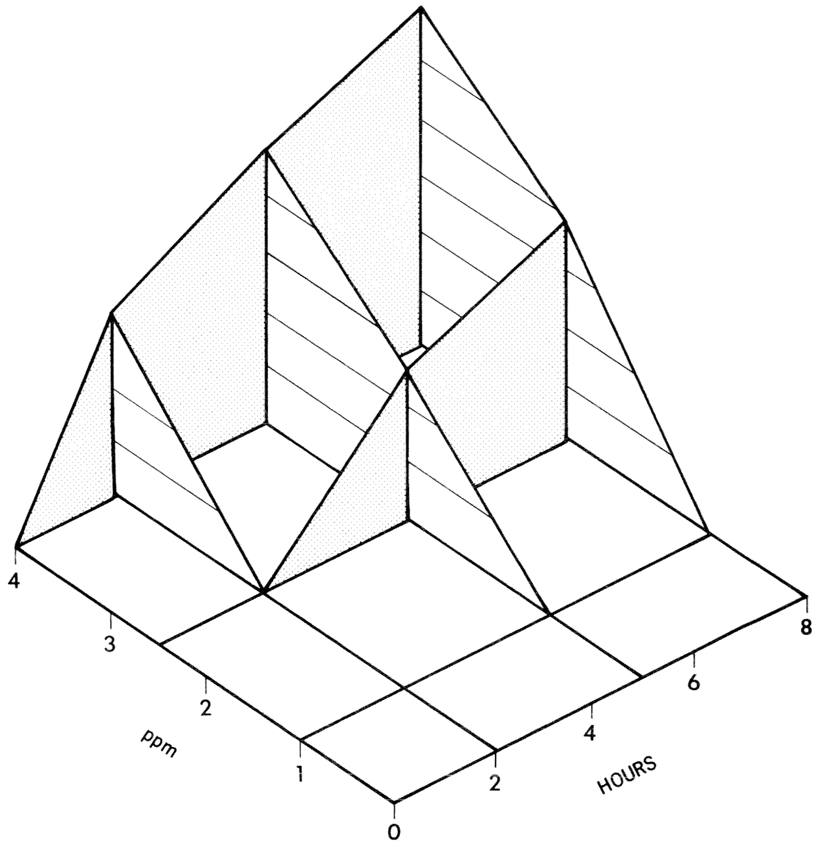


Figure 5. Effect of SO_2 fumigation dose on leaf injury of yellow-poplar seedlings. Plotted in the same way as Figure 4.



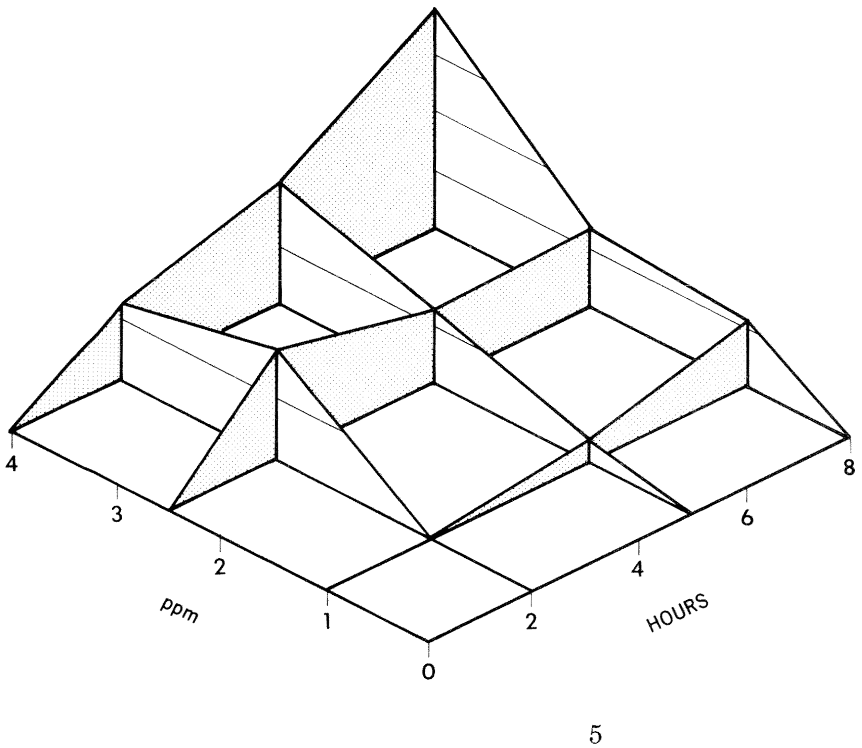


Figure 6. Effect of SO_2 fumigation dose on leaf injury of silver maple seedlings. Plotted in the same way as Figure 4.

DISCUSSION

The nonsignificant change in height of seedlings fumigated with 0.15 ppm SO_2 and of white spruce, yellow-poplar, and black alder fumigated with 0.25 ppm SO_2 suggest that many woody species are tolerant to present-day levels of this pollutant. However, caution must be exercised in making such general conclusions. In the natural environment the average concentration of SO_2 is lower than that used in these experiments and the range of concentration is wider. Also, we used only one pollutant, whereas in the natural environment several, pollutants or chemicals may be present, which in combination with even low levels of SO_2 may be harmful to plant growth (Dochinger et al. 1970, Tingey et al. 1971b, Costonis 1973, Houston 1974). Another consideration is the condition of the seedlings. In these experiments the seedlings were grown under good environmental conditions, whereas under field conditions, light, water, or some other factor may be limiting. Limiting environmental factors can modify the response of plants to pollutants (Heck and Dunning 1967, Menser et al. 1963).

The pollutants may also initiate secondary problems that would not develop in chamber experiments. The pollutants may act as a stress factor and weaken the host just as drought or frost would. After several years in this condition, the vigor of the trees may decline and the trees may become susceptible to insect or disease attack (Cobb and Stark 1970).

The reduction in height of seedlings fumigated with 0.25 ppm SO_2 was due to a reduced growth rate. The average growth rate for green ash, eastern cottonwood, and sycamore seedlings dropped from 3.6 mm/day in the control chamber to 2.5 mm/day in the fumigated chamber. These reductions in height were associated with a reduction in number of leaves. It was significant only for eastern cottonwood, but the trend of fewer leaves with less growth must certainly be considered. With more leaves, more photosynthate should be available for growth. Additionally, the pollutant may suppress the photosynthesis rate (Bennett and Hill 1973, Sij and Swanson 1974). This may explain why no significant differences were found between treatments in height of yellow-poplar seedlings even though the seedlings in the fumigated treatment had a significantly higher number of leaves.

The high levels of SO_2, 1, 2.5, and 4 ppm, had no influence on height growth until the exposure time exceeded 2 hours. After 5 and 8 hours, growth of silver maple and yellow-poplar was statistically reduced. A reduced growth rate was observed only for 2 weeks after fumigation as by the 4th week the growth rate was again comparable to the rate before fumigation. New leaf tissue had been formed to replace the leaf tissue destroyed by fumigation.

The analysis of leaf injury using response surfaces was suggested by Temple (1972). This approach allows an analysis of exposure and concentration both independently and jointly. With eastern cottonwood, injury tended to increase as the length of fumigation increased, whereas with yellow-poplar and silver maple, injury tended to increase with increased pollutant concentration. Foliar injury of all three species increased as dose increased.

To compare SO_2 susceptibility ratings at high and low fumigation levels, silver maple, eastern cottonwood, and yellow-poplar were ranked according to sensitivity, from their response in experiment 1, 0.25 ppm, and experiment 3, toxic levels. In experiment 3, eastern cottonwood and yellow-poplar were classified as more sensitive than silver maple on the basis of foliar injury, and eastern cottonwood more sensitive than yellow-poplar on the basis of height growth. In experiment 1, eastern cottonwood was again classified as more sensitive than yellow-poplar on the basis of height growth. No comparison can be made with silver maple as no differences were found with the 0.15 ppm fumigation and no seedlings were available when the 0.25 ppm SO_2 fumigation experiment was established. These results are encouraging in that classification schemes for low levels of SO_2 can be developed from experiments that use toxic levels of pollutants, but many more studies are needed before definite relationships can be established.

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