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Sensitivity and Growth of Five Elatior Begonia Cultivars to SO_2 and O_3, Alone and in Combination[1]

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Abstract. **The effect of SO_2 (0.5 ppm) and O_3 (0.25 ppm) were tested alone and in combination using 5 cultivars of Elatior begonia (*Begonia* X *hiemalis* Fotsch). 'Schwabenland Red' and 'Whisper '0' Pink' were the most sensitive to O_3 based on foliage and flower weight. 'Fantasy' was the most sensitive to SO_2 and flower production was significantly reduced without visible injury at 0.5 ppm SO_2. The only significant ($SO_2 \times O_3$) interaction occurred with flower weight of 'Schwabenland Red', where the combined effect of the 2 pollutants was less than expected from the linear additive model.**

Begonias are sensitive to ozone and sulfur dioxide and are considered among the more pollutant-sensitive floricultural bedding crops (1). Variation in O_3-sensitivity has been reported in cultivars of the annual begonia (*Begonia semperflorens* Link & Otto) (1, 4, 5) and in Elatior begonia cultivars (7). Elatior begonia were grouped in 3 sensitivity classes; high, moderate, and low. The 'Schwabenland' types and 'Whisper 'O' Pink', and 'Improved Krefeld Orange' were highly sensitive to O_3. 'Renaissance', 'Heirloom', 'Nixe', and 'Fantasy' were moderately sensitive and 'Ballerina', 'Mikkell Limelight' and 'Turo' were the least sensitive.

There are 2 reports concerning the sensitivity of Elatior begonia 'Schwabenland Red' to SO_2 and O_3, alone and in combination (2, 9). In both reports total leaf injury from the SO_2 and O_3 combination treatment was greater than the sum of the injury of the single pollutant treatments. Effects of SO_2 and O_3 on growth of 'Schwabenland Red' were undetected if exposures were given when begonia was in the early vegetative stage; however, plants treated in the prefloral stage were more sensitive in terms of inhibition of foliage growth (2).

No research has been reported concerning the effects of SO_2 and O_3 on the flowering of Elatior begonia. Thus, this study will 1) determine if SO_2 affects foliage and flower growth of begonia or modifies the effect of O_3 on begonia, and 2) evaluate SO_2 effects using a series of cultivars with differing sensitivities to O_3.

Materials and Methods

Five Elatior begonias were selected based on their sensitivity to O_3: 'Schwabenland Red' and 'Whisper 'O' Pink,' (sensitive); 'Renaissance' and 'Fantasy' (moderately sensitive); and 'Turo' (insensitive). Rooted cuttings of each cultivar were planted in 15 cm plastic pots containing 45% sphagnum peat moss, 45% perlite and 10% soil on a volume basis and amended with 7 g dolomitic limestone and 3.5 g of 20% superphosphate per dm^3 of mix. A single application of a trace element mixture (STEM, 0.6 g/liter of water) was given 2 weeks after potting. The root medium in each pot was saturated weekly to container capacity with a fertilizer solution consisting of 3.2 mM KNO_3, 4.5 mM NH_4NO_3 and 4.5 mM $Ca(NO_3)_2$ (250 ppm N and 125 ppm K; 25% ammoniacal N). All plants were sprayed with chlorothalonil, at 3 and 5 weeks to protect them from powdery mildew infection. Plants were grown at $26^o \pm 3^oC$ (day) and $18^o \pm 3^o$ (night) temperatures. All plants received 5 weeks of long days involving a period of incandescent light (minimum intensity of 100 lux) between the hours of 2200 and 0200 each night followed by 3 weeks of natural short days (13-14 hr dark period) before exposure. During long days plants were grown in a greenhouse without charcoal filtered air, and during short days plants were grown in a greenhouse receiving charcoal filtered air from the beginning of natural short days until harvest.

Eight weeks after planting, 30 plants of each cultivar were selected for uniformity and divided into 2 replications. Twelve plants (3 plants per treatment) from each replicate were exposed to either charcoal filtered air, 0.25 ppm O_3, 0.5 ppm SO_2, or 0.25 ppm O_3 + 0.5 ppm SO_2. All plants were exposed 4 times, once every 6 days for 4 hr using CSTR chambers (3) placed in the greenhouse. Control plants were exposed to charcoal filtered air which passed through the chamber for the duration of the exposure time. Ozone was generated by a Welsbach O_3 generator and monitored during exposure by a chemiluminescence O_3 analyzer. Sulfer dioxide was dispensed from a tank containing 1% SO_2. A flame photometric SO_2 analyzer was used to monitor the concentration of SO_2 during exposure. Foliar injury estimates 0-100% of the whole plants were determined 2 and 4 weeks after initial exposure. Foliage (leaves plus stems) and flower (flowers including peduncles) parts were harvested about 2 weeks following the last exposure.

The experimental design was a split-plot with pollutant treatments as the whole plot and cultivars as the sub-plot. The design consisted of 2 replications, 20 treatment combinations (5 cultivars and 4 air pollutant treatments), and 3 plants per experimental unit. The sum of squares were partitioned by factorial analysis into SO_2, O_3 and cultivar main and interaction effects (8). The pollutant treatment effects were assessed in the following way. The main effect of O_3 was the average difference (g) of the means for the O_3 treatments at the low $[(O_3\text{-Control})]$ and high $[(SO_2 + O_3)\text{-}(SO_2)]$ levels of SO_2. A similar relationship was determined for SO_2 (8). The interaction effect was determined as ½ the difference (g) of the simple effects of O_3, $\frac{1}{2}[\{(SO_2 + O_3)-(SO_2)\}-\{(O_3\text{-Control})\}]$ or of SO_2, and measured the failure of the effect of one pollutant to be consistent at different concentrations of the second pollutant (8).

Results

Effects on foliar injury. The amount of foliar injury from O_3 (Table 1) was similar to that previously reported for each

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Table 1. Foliar injury of 5 Elatior begonia cultivars exposed to SO_2 and/or O_3.[z]

Pollutant treatment	Concn (ppm)	Total plant injury (%)[y]				
		Schwabenland Red	Whisper 'O' Pink	Fantasy	Renaissance	Turo
Control	0	0	0	0	0	0
SO_2	0.5	2	1	0	0	0
O_3	0.25	54	25	2	15	8
SO_2+O_3	0.5+0.25	67	58	13	18	15

[z]Plants were exposed 4 times, once every 6 days for 4 hr.

[y]Each value is a mean of 6 plants from 2 replications.

Elatior begonia cultivar (7). Traces of injury were found on 'Schwabenland Red' and 'Whisper 'O' Pink' after exposure to 0.5 ppm SO_2 (Table 1). 'Whisper 'O' Pink' and 'Schwabenland Red' were the most sensitive to O_3, although 'Schwabenland Red' was the most severely injured by the SO_2 + O_3 mixture. The difference in foliar injury between SO_2 + O_3 and O_3 was greater on the 'Whisper 'O' Pink' than on the other Elatior begonia cultivars. This suggested that 'Whisper 'O' Pink' is more sensitive to the pollutant mixture. The symptoms of foliar injury from SO_2 + O_3 were similar to foliar injury from O_3 (Table 1). Also, the symptom types were similar among the 5 begonia cultivars.

Effects on foliage and flower weight. The SO_2, O_3, and cultivar main and interaction mean square values and error mean square values are given in Table 2. There were significant $SO_2 \times O_3 \times$ cultivar (flower weight), and $O_3 \times$ cultivar (flower and plant weight) interactions. There was also a significant O_3 main effect. There were no significant SO_2 or $SO_2 \times O_3$ effects. There were also significant differences among the 5 begonia cultivars.

Further partitioning of the $SO_2 \times O_3 \times$ cultivar interaction involving changes in the mean dry weight of foliage, flowers and total plant are summarized in Table 3. The cultivars varied in their response to SO_2 and to O_3. There were no significant interaction effects of $SO_2 \times O_3$ on the foliage or total plant growth of the 5 Elatior begonia cultivars (Table 3). In 'Schwabenland Red' the combined effects of the 2 pollutants on flower growth were significant (P = 5%). The effect of the combined pollutants on flower weight was antagonistic since it was less than expected from the additive model with respect to both pollutants. In the other 4 cultivars the effect of the combined pollutants were only additive, since the total inhibition of flower growth from the 2 pollutants combined did not differ significantly from the sum of the single effects on flower growth.

Table 2. Mean square values of partitioned sum of squares for SO_2, O_3 and cultivars, and their interactions.[z]

Source	df	Foliage	Flower	Plant
Replication	1	.05	.13	.33
Air pollutants (A)	3	5.38	2.77*	14.50
SO_2	1	.03	1.45	1.91
O_3	1	12.96	6.87*	38.70*
$SO_2 \times O_3$	1	3.15	.01	2.89
Error A				
Rep (SO_2, O_3)	3	1.49	.18	2.44
Cultivar (Cv)	4	184.8**	33.91**	276.8**
Cv x A	12	1.16	.49*	2.37
$SO_2 \times$ Cv	4	.92	.43	1.35
$O_3 \times$ Cv	4	1.97	.55*	4.17*
$SO_2 \times O_3 \times$ Cv	4	.58	.49*	1.58
Error B				
Rep x Cv (SO_2, O_3)	16	1.28	.16	1.38
Residual	80	2.95	.42	4.66
Corrected Total	119			

[z]The experimental design consisted of 2 replications, 5 cultivars, 4 air pollutant treatments and 3 plants per experimental unit to equal 120 plants.

There were no significant pollutant effects on the cultivar 'Turo' from either SO_2 or O_3, which was shown in a previous experiment to be insensitive to O_3 (7). However, flower weight of the cultivar 'Fantasy' was reduced significantly (P = 1%) by treatments containing SO_2 compared with treatments without SO_2 (Table 3). The mean flower weight of all cultivars except 'Turo' was significantly reduced (P = 5%) by treatments containing O_3 compared with treatments that did not contain O_3. These differences are expressed in g per plant with a minus sign representing a weight loss and a plus sign representing a weight gain (Table 3).

Discussion

Studies involving the effects of SO_2 and O_3, alone and in combination, on crop plants have been summarized (6). In most of the studies the SO_2 + O_3 treatment has been evaluated by some standard treatment means comparison test. This approach does not statistically evaluate the $SO_2 \times O_3$ interaction; the failure of one pollutant to be consistent at different concentrations of the second pollutant (8). In our study the interaction effects of $SO_2 \times O_3$ were tested for each cultivar and the reduction in flower weight of 'Schwabenland Red' due to O_3 was modified by SO_2. Gardner and Ormrod (3) demonstrated a significant inhibition of fresh weight of 'Schwabenland Red' foliage by the SO_2 + O_3 treatment compared to the control, but they did not determine if there was an interaction of the 2 pollutants to influence the foliage weight change. Furthermore, they did not measure changes in flower weight. In our study both foliage and flower weight changes were determined.

The 5 cultivars used in this study were chosen because of their different sensitivity to O_3. The magnitude of flower weight reduction due to O_3 in the present study related to the sensitivity of each cultivar described earlier (7). 'Turo' was insensitive to O_3 while 'Schwabenland Red' and 'Whisper 'O' Pink' were sensitive. 'Fantasy', described as moderately sensitive in the earlier study (7), was also highly sensitive to SO_2 based on changes in flower weight. The close similarity in response to O_3 of the Elatior begonia cultivars in the present as well as the early study is an important observation. It strongly suggests that different sensitivities among cultivars within a species can be consistent from experiment to experiment even though the environments in which each experiment is run may differ.

Gardner and Ormrod did not demonstrate inhibition of growth of 'Schwabenland Red' by SO_2 at 0.6 ppm (2). In other studies, Adedipe et al. (1) reported that SO_2 did not inhibit the growth of 3 *B. semperflorens* cultivars until the concentration

Table 3. Mean dry weight of foliage and flowers of 5 Elatior begonia cultivars and the significant factorial effects after exposure to SO_2 and/or O_3.[z]

	Mean weight (g)[y]			Weight change (g) in main and interaction effects[x]			
Treatment[z]	Foliage	Flower	Plant	Effect	Foliage	Flower	Plant
			Schwabenland Red				
Control	11.08	2.89	13.97				
SO_2	11.56	2.26	13.82	SO_2	+ .64	− .29	+ .35
O_3	10.05	1.75	11.80	O_3	− .87	− .81**	−1.67**
$SO_2 + O_3$	10.85	1.80	12.65	S × O	+ .16	+ .34*	+ .50
			Whisper 'O' Pink				
Control	11.64	2.19	13.83				
SO_2	11.70	2.53	14.20	SO_2	− .13	+ .10	− .02
O_3	10.27	1.71	11.99	O_3	−1.55**	− .71**	−2.27**
$SO_2 + O_3$	9.97	1.58	11.54	S × O	− .18	− .24	− .42
			Fantasy				
Control	9.04	4.54	13.58				
SO_2	9.25	4.06	13.31	SO_2	− .35	− .59**	− .94
O_3	9.14	4.28	13.42	O_3	− .46	− .38*	− .83
$SO_2 + O_3$	8.24	3.57	11.80	S × O	− .56	− .12	− .68
			Renaissance				
Control	6.11	1.38	7.49				
SO_2	6.53	0.79	7.32	SO_2	− .06	− .29	− .34
O_3	6.28	0.62	6.90	O_3	− .30	− .46*	− .76
$SO_2 + O_3$	5.76	0.64	6.39	S × O	− .47	− .30	− .17
			Turo				
Control	4.69	1.73	6.42				
SO_2	4.99	1.92	6.90	SO_2	− .27	− .03	− .30
O_3	5.14	1.91	7.06	O_3	− .11	− .04	− .15
$SO_2 + O_3$	4.31	1.66	5.97	S × O	− .57	− .22	− .79

[z]Plants were exposed 4 times, once every 6 days for 4 hrs to charcoal filtered air (Control), 0.25 ppm O_3, 0.5 ppm SO_2 and 0.5 ppm SO_2 + 0.25 ppm O_3.

[y]Each value is a mean of 6 plants from 2 replications.

[x]The linear additive model used to evaluate these effects assumes that fixed treatments sum to zero. The main and interaction effect differences represent the g weight change per plant from zero. Levels of significance equal P = 5% (*) and P = 1% (**).

reached 2.0 ppm after one 2 hr exposure. In our study 'Fantasy' was sensitive to 0.5 ppm SO_2 based on changes in flower weight averaged over the presence and absence of O_3. This effect of SO_2 on 'Fantasy' occurred in the absence of visible injury from SO_2 alone. In conclusion, several concepts concerning SO_2 on 'Fantasy' occurred in the absence of visible injury from SO_2 alone. In conclusion, several concepts concerning to SO_2 based on foliage and flower weight changes was different from cultivar sensitivity to O_3; and 3) SO_2 reduced flower weight in the absence of visible injury from SO_2 alone. Our study provides one of the few instances which strongly support this last observation.

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