The Ozone Sensitivity of *Petunia hybrida* Vilm. as Related to Physiological Age

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Abstract. Sets of 6 multiflora Petunia F₁ hybrids representing 8 different age groups were simultaneously fumigated with 0.2 ppm ozone for 8 hours. The more sensitive hybrids acquired a marked ozone tolerance upon visible differentiation of a floral bud. The acquired tolerance was manifested several nodes beneath the lowest flowering node. The more tolerant hybrids developed a greater tolerance (greater percentage of nodes whose leaves exhibited no ozone injury) and acquired it prior to the visible differentiation of a floral bud. Also, the oldest uninjured leaves on tolerant hybrids had a significantly higher leaf plastochron index than did the oldest uninjured leaves of the sensitive hybrids, suggesting that the tolerant hybrids had some mechanism which protected leaves of an older physiological age.

In spite of the relative sensitivity of petunias to air pollutants, especially photochemical oxidants, this ornamental continues to be one of the most commonly used urban bedding plants. In the Los Angeles area, plants placed on retail sales counters often develop characteristic photochemical oxidant (ozone and peroxyacetyl nitrate) symptoms which were not evident at the time of arrival from the grower. The smog damage to the leaves not only makes the plants less saleable but also reduces their subsequent growth rate. Any procedure by which a less severely damaged plant can be marketed will result in a more vigorous and attractive plant for the purchaser and increased sales for the grower.

Many factors have been shown to influence the sensitivity of a plant species to damage from ozone exposure. Heggestad and Heck's recent review (6) describes the effect of genetic, climatic, edaphic, and other factors upon the air pollutant sensitivity of a given species, and notes that the physiological age of leaf tissue is also important. Cracker and Starbuck (4) suggest that the differential sensitivity of different aged tissue correlates with the rate of pollutant absorption. With the possible exception of Berry's recent study of pine seedlings (2), little information is available concerning the effect of the physiological age of the entire plant at the time of ozone exposure. We report a correlation between plant age, associated with flower bud initiation, and ozone tolerance in petunias.

Materials and Methods

Six F₁ hybrid multiflora petunias were selected from among the 49 possible combinations of 7 inbred lines on the basis of their widely differing response to ozone (O₃). The inbred lines (arbitrarily assigned letters A through G) were extracted from inbreds obtained from Bodger Seeds, Ltd., El Monte, California and Harris Seeds, Rochester, New York. The inbreds were further selected by us for individual uniformity of response to ozone fumigation. In order of increasing O₃ tolerance, the inbreds response was: D, A, C, E, B, F, and G. Preliminary tests indicated the order of increasing O₃ tolerance of the F₁ hybrids chosen for these experiments was D × A, D × C, C × A, C × F, B × G, and E × F.

Quantities of each hybrid seed were prepared and bulked. Then, for 8 weekly intervals commencing June 13, 1973, sufficient seed of each hybrid was planted to provide 20 uniform seedlings when transplanted into 5-cm square plastic pots. The seedlings were grown in a charcoal-filtered, positive-pressure unshaded greenhouse under normal summer sunshine at Arcadia, California. The soil mixture was UC Mix C11 (UCD II) (1) to which P K solution containing Fe chelate was added twice a month.

Fumigation was performed in a growth chamber at approximately 0.2 ppm ozone for 8 hours at 27°C and light intensity of 1250 ft.-c from a multiple source composed of tungsten filament, cool white fluorescent, and Sylvania Gro-Lux lamps. The plants were transferred from the greenhouse to the growth chamber and left to adjust for 1 hour prior to fumigation which began at 9:00 am. After fumigation the plants were returned to a filtered-air greenhouse and scored for ozone injury the next day.

The 48 plants, which constituted a set, were inserted in a randomized pattern into the growth chamber and ozonated. Each set consisted of 1 plant of each hybrid at each of the various age levels (6 hybrids × 8 age levels). A total of 9 such sets was analyzed over a 2-wk period with ozonation occurring on the first 4 days of the work week (allowing for scoring on Friday). At the time of first ozonation, the seedlings ranged in age from 5 to 12 weeks. This ozonation procedure resulted in an array of plants of continuous chronological age, with all but the youngest 2 groups of plants showing evidence of flower bud initiation.

The plants were individually scored for ozone injury as follows. The seedlings were removed from the soil mixture and the status of the leaves at each node was recorded. In all instances where the leaves were not showing evidence of senescence prior to fumigation each leaf (1 cm long or longer) was scored on a scale ranging from 1 through 12.

Ratings:
1 = no visible injury to leaf tissue
2 = 5% of leaf tissue injured
3 = 10% of leaf tissue injured
4 = 20% of leaf tissue injured
5 = 30% of leaf tissue injured
6 = 40% of leaf tissue injured
7 = 50% of leaf tissue injured
8 = 60% of leaf tissue injured
9 = 70% of leaf tissue injured
10 = 80% of leaf tissue injured
11 = 90% of leaf tissue injured
12 = 100% of leaf tissue injured

Where leaves were paired at a node (the leaves of petunias are alternate until the basal floral node at which the leaves become decussate), both leaves were scored and an average value was recorded for the node. In addition, the presence of floral bud, flower, or fruit at each node was recorded.

Results

There are various ways to rate entire plants for ozone injury. By utilizing the individual leaf score data, 4 different rating systems...
yielded similar conclusions (Table 1, rows 1–4). Proceeding downward from the top of a blooming or flowering-induced plant, the average number of nodes with uninjured leaves was significantly greater for hybrids E × F and B × G than for hybrids D × C and D × A (row 1). Also, the percentage of nodes which bore leaves exhibiting no ozone symptoms was significantly greater with hybrids E × F and B × G than with hybrids D × C and D × A (row 2). Similarly, the total leaf score of the apical 10 nodes (row 3) or nodes 11–15 from the apex (row 4).

### Table 1. Varietal differences between six petunia hybrids with respect to node of first flowering and ozone injury.

<table>
<thead>
<tr>
<th>Row</th>
<th>Measurement</th>
<th>Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Σ # of nodes, apex to injury</td>
<td>E × F</td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>14.1a</td>
</tr>
<tr>
<td>2</td>
<td>% of nodes without injury</td>
<td>53.5a</td>
</tr>
<tr>
<td>3</td>
<td>Total ozone score (nodes 1–10)</td>
<td>10.8a</td>
</tr>
<tr>
<td>4</td>
<td>Total ozone score (nodes 11–15)</td>
<td>8.2a</td>
</tr>
<tr>
<td>5</td>
<td>Σ flowering node (from base)</td>
<td>24.1a</td>
</tr>
<tr>
<td>6</td>
<td>Node production rate (nodes/day)</td>
<td>.356a</td>
</tr>
<tr>
<td>7</td>
<td>(uninjured nodes: total nodes)</td>
<td>.07 ± .16</td>
</tr>
</tbody>
</table>

* Mean separation, within rows by Duncan's multiple range test at the 5% level.

x This value is approximately the same as the leaf plastochron index of the youngest injured leaf.

y The regression of the number of ozone-tolerant nodes upon the total number of nodes possessed by the plant.

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**Fig. 1** The response of six petunia hybrids to ozone fumigation as a function of the developmental state of the plant (abscissa) and the physiological age of the leaf (ordinate). White bars represent missing plants.
Our observations suggest that reproductive buds produce a substance which diffuses downward and causes leaves to become more ozone tolerant. This substance is apparently not synthesized by vegetative buds, at least not in quantities sufficient to protect leaves which are several nodes below the bud. It is possible that more of this substance is produced in the “tolerant” hybrids than in the sensitive ones; this might allow it to move farther down the stem and have a greater influence before dilution to an ineffective concentration. It is also possible that the substance is produced at an earlier physiological age by the tolerant hybrids.

Our data also demonstrate that response of petunia plants to ozone fumigation should be compared only after they have reached a specific physiological age closely associated with flowering. At that time petunia plants acquire increased ozone tolerance. Tentative results from other experiments suggest that a similar effect of physiological age on ozone tolerance holds with pansy (Viola tricolor L. hortensis) and viola (Viola cornuta L.) but not with sweet alyssum (Lobularia maritima Desv.) and dimorphotheca (Dimorphotheca sinuata D.C.). Haas (5) has evidence which suggests that white beans (Phaseolus vulgaris L.) lose O₃ tolerance shortly after flowering. Thus, whatever occurs in petunias to provide some protection from ozone damage at the time of flowering may not be a universal phenomenon in the plant kingdom.

Our observations suggest that it is important to understand ozone tolerance as a function of the development and physiology of individual cultivars and hybrids in order to select efficiently for genetic tolerance.

**Discussion**