produced on the same tree is useful for this type of study because seedlessness is neither confounded with treatment effects nor imposed by seed abortion.

Literature Cited


Ozone Induced Foliar Injury in Lettuce and Radish Cultivars

Richard A. Reiner, David T. Tingey, and Hershell B. Carter

Abstract. Eight lettuce and 9 radish cvs. were exposed for 1.5 hr to 70 and 35 ppm ozone, respectively, and ranked according to their sensitivity. 'Dark Green Boston' was the most sensitive while 'Great Lakes' and 'Black-Seeded Simpson' were the least sensitive of the lettuce cvs. tested. 'Cherry Belle' was the most sensitive and 'Icecide' was the least sensitive of the radish cvs.

Ozone, a product of photochemical reactions in the atmosphere, is responsible for injury to a wide range of plant species (8). Recently, cvs. within various crop species were compared and ranked with respect to their susceptibility to ozone (2, 3, 4, 10, 11, 13, 16, 17, 20). In these studies, foliar injury was evaluated as an initial step to an understanding of the genetic variability among cvs. within a species. Foliar injury has been a useful criterion in studies that suggest good correlation of tolerance and susceptibility in cvs. exposed to ozone in ambient air compared with cvs. exposed experimentally to ozone (21). Foliar injury may also be important in determining decreased yield and productivity of crops grown in ambient ozone stress.

There are several reports concerning the exposure of lettuce, Lactuca sativa L. and radish, Raphanus sativus L. to ozone and other phytotoxic gases (1, 5, 6, 9, 12). Romaine lettuce was resistant to 40 ppm ozone after a 2 hr exposure (9), whereas a concent of 100 ppm ozone for 2 hr injured 'Black-seeded Simpson' lettuce (12). 'White Tip Sparkler' radish developed some of the data in this paper have previously appeared as abstracts (14, 15). Cultivars were chosen to ozone and other pollutants.

The objectives of this study were: (a) to determine the sensitivity and ranking of selected cvs. of lettuce and radish to ozone, and (b) to describe the symptoms of ozone induced foliar injury on both crops. Some of the data in this paper have previously appeared as abstracts (14, 15). Cultivars were chosen to ozone and other pollutants.

with respect to (a) economic importance, (b) use in home and market gardening, and (c) importance to the plant breeder for further crop improvement.

Materials and Methods

Lettuce and radish, purchased from Burpee and Joseph Harris5 seed companies, were seeded directly in 10-cm-diam plastic pots containing a 1:1 peat:perlite mixture. Plants were grown at 27 ± 3°C day and 21 ± 1°C night temp in a greenhouse equipped with charcoal filters and were watered daily with half-strength Hoagland's solution containing chelated iron. Seven days after germination cvs. of both plant species were thinned to one plant per pot. Supplemental fluorescent lighting ensured a minimum of 11,000 lux and a 12-hr photoperiod. Relative humidity varied from 50 to 70%.

Three-week old lettuce and radish plants were exposed to ozone in greenhouse exposure chambers (7). The exposure temp was 27 ± 3°C, and the average relative humidity was 60%. Ozone was generated by silent electrical discharge in dry O2 and was measured coulometrically with a Mast oxidant (ozone) meter5 and monitored continuously on an Esterline Angus recorder5. Mast meter readings were corrected to a 2% neutral buffered KI standard, because the efficiencies of Mast meters in the measurement of ozone vary from approximately 60-90%, depending on the individual meter. The factors considered in the correction were: (a) the flow rate of the meter (sec/50 cc.), (b) a flow factor (0.0467) to adjust air flow to the recommended flow rate of 140 cc/min, (c) the apparent ozone concn as indicated by the meter (in pphm), and (d) the Mast efficiency factor, which was determined by standardizing the meter to a known ozone concn as determined by the neutral buffered KI method (18). The actual ozone concn was the product of all the above factors.

In determining relative cv. sensitivity, one plant from each of 8 lettuce cvs. was placed in each of 9 exposure chambers and exposed to 70 ± 2 pphm ozone for 1.5 hr6. A similar design was used for 9 radish cvs. which were exposed to 35 ± 1 pphm ozone. Exposures were made from 10 - 11:30 AM. Different plants were exposed on each of 4 successive days. Thus, 36 plants from each cv. were used to evaluate relative sensitivity.

Injury to lettuce and radish was evaluated by visually determining the percentage of chlorosis or necrosis on the upper leaf surface for each individual plant and leaf, respectively. Injury was determined in 5% increments (0-100% scale) 3 days following exposure. The percent plant injury value (lettuce) and the average percent of the 3 most severely injured leaves (radish) were used to develop plant injury means for each of the cvs. A 3 leaf average was used with radish even when only 1 or 2 of the leaves showed injury.

An analysis of variance was performed on the injury data of

Fig. 1. 'Grand Rapids Forcing', lettuce leaf showing ozone induced chlorosis or a cell clearing. Most visible with back lighting.

Fig. 2. 'Crimson Giant', radish leaf showing ozone induced small fleck lesions, chlorotic in appearance, and some larger bifacial necrosis.

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both species and differences between cv. injury means were illustrated by Duncan's Multiple Range Test.

**Results**

Foliar injury to lettuce generally appeared first as a chlorotic and necrotic upper surface fleck and became bifacial as injury increased. In other instances a chlorosis and cell clearing occurred. Injury to the lower leaf surface occasionally appeared independently of the upper surface injury, however, no attempts were made to measure the amount of this injury. The first evidence of injury to the lower leaf surface appeared to be a cell collapse, followed by a glazing or browning and necrosis. Occasionally, visible injury to the lower surface developed first and was finally expressed as a bifacial necrosis. Cell clearing was an important symptom in several lettuce cvs. (Fig. 1). The apparent chlorophyll destruction associated with these injured cells was not observed unless the leaves of the cvs. were held up to the light. This symptom was observed in 'Grand Rapids Forcing', 'Imperial #456', and to some extent in 'Butter Crunch'. 'Big Boston' developed a purplish-brown pigmentation and frequent bifacial necrosis. Some of the pigmentation was related only to the upper leaf surface.

Injury symptoms among radish cvs. were similar, but there was some variation in the symptom type within cvs. In the less ozone sensitive cvs., small chlorotic fleck-like lesions were frequently observed, and occasionally these areas became necrotic (Fig. 2). On some leaves large fleck areas developed between veins and frequently appeared to coalesce, forming chlorotic or necrotic areas. A form of interveinal bleaching developing, which suggests that chlorophyll has been destroyed. In the sensitive radish cvs. there was more necrotic fleck and bifacial necrosis than chlorosis.

The mean squares from the analysis of variance of both the lettuce and radish experiments are given in Table 1. The main effects of days, chambers, and cvs. were significant for both radish and lettuce. The interaction of day with chamber was also significant for both species. The day by chamber interaction showed that different amounts of foliar injury developed in the chambers on different days. The lack of significant day by cv. and chamber by cv. interactions indicated that the cvs. maintained their same relative sensitivity ranking in all chambers over all days.

Lettuce and radish cvs. were ranked according to injury means (Table 2). 'Dark Green Boston' was the most ozone sensitive lettuce cv. followed by 'Grand Rapids Forcing'. The least sensitive cvs. were 'Black-Seeded Simpson' and 'Great Lakes'. 'Cherry Belle' was the most ozone sensitive radish cv. and 'Icicle' was the least sensitive. The radish cvs. could be divided into 2 groups with 'Cherry Belle', 'Crimson Giant', 'Comet', and 'Champion' more sensitive to ozone than other cvs.

**Discussion**

The ozone conncs used in this and other studies (16, 19, 20) were corrected, as described earlier, due to the varying efficiencies of the Mast oxidant meters. For example, if the ozone concn desired was 70 pphm as in the lettuce experiment, and if a flow rate of 21.4 sec/50 cc. and a Mast efficiency factor of 1.5 were assumed, the apparent ozone concn indicated by the Mast meter would equal 46 pphm. The ozone levels and the duration of exposure in this study were chosen to cause approximately 50% foliar injury to the most sensitive cvs. In previous studies (16, 20) ozone concns above average ambient ozone levels for short time durations produced enough injury in selected cvs. so that differences in sensitivity between cvs. were established. In this manner, rapid screening of cvs. within plant species is possible over short time periods. Additional studies are needed to determine whether screening cvs. at ozone concn that exceed ambient levels can be correlated with screening at ambient levels of ozone. Unpublished data concerning soybean cvs. showed similarities between relative sensitivity rankings at ambient ozone levels and elevated experimental exposure levels.

The difference in mean injury between radish cvs. Cherry Belle and Icicle was approximately 18%; the difference for tomato cvs. was 63% (16). Since the concn of ozone used in both studies were similar, these differences indicate the degree of sensitivity to ozone between species, as well as the variation between cvs. within species. Similarly, the difference in mean injury between the most sensitive and most tolerant soybean cvs. exposed to 70 pphm ozone was 42% (20) and was greater than that for lettuce, which was 36%. Thus, the variation between cvs. within soybean appeared to be more pronounced than within lettuce.

**Table 1. Mean squares for lettuce and radish cv. study.**

<table>
<thead>
<tr>
<th>Source</th>
<th>Lettuce</th>
<th>Radish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Day</td>
<td>M.S. d.f.</td>
<td>M.S. d.f.</td>
</tr>
<tr>
<td>Chamber</td>
<td>8 1191.4** 8</td>
<td>1875.7**</td>
</tr>
<tr>
<td>Cv.</td>
<td>7 4593.0** 24</td>
<td>1298.2**</td>
</tr>
<tr>
<td>Day x Chamber</td>
<td>24 315.3** 24</td>
<td>1181.6**</td>
</tr>
<tr>
<td>Day x Cv.</td>
<td>21 55.2 24</td>
<td>444.3</td>
</tr>
<tr>
<td>Chamber x Cv.</td>
<td>56 49.5 64</td>
<td>295.7</td>
</tr>
<tr>
<td>Error</td>
<td>168 42.1 192</td>
<td>313.6</td>
</tr>
</tbody>
</table>

**Table 2. Cultivar response of lettuce and radish to 70 pphm and 35 pphm ozone, respectively, for 1.5 hr.**

<table>
<thead>
<tr>
<th>cvs</th>
<th>Mean plant injury</th>
<th>Mean plant injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dark Green Boston</td>
<td>45.7a</td>
<td>Cherry Belle 34.7a</td>
</tr>
<tr>
<td>Grand Rapids Forcing</td>
<td>30.3b</td>
<td>Crimson Giant 33.9a</td>
</tr>
<tr>
<td>Imperial #456</td>
<td>24.1c</td>
<td>Comet 32.4ab</td>
</tr>
<tr>
<td>Butter Crunch</td>
<td>23.7c</td>
<td>Champion 30.7abc</td>
</tr>
<tr>
<td>Big Boston</td>
<td>23.6c</td>
<td>Red Boy 24.7bcd</td>
</tr>
<tr>
<td>Romaine</td>
<td>19.3d</td>
<td>Calvarondo 23.7cd</td>
</tr>
<tr>
<td>Black Seeded Simpson</td>
<td>11.2e</td>
<td>Early Scarlet Globe 23.6cd</td>
</tr>
<tr>
<td>Great Lakes</td>
<td>9.9e</td>
<td>French Breakfast 23.4cd</td>
</tr>
</tbody>
</table>

**Significant at 1%.

2Average percent injury of the whole lettuce plant based on 36 plants. Cultivar means followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

3Average percent injury of the 3 most severely injured leaves on each of 36 plants. Cultivar means followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

20) were exposed to ozone in chambers placed in a greenhouse. These exposures were nearly always made on successive days. In data reported previously (16, 20), it was demonstrated that, even though the average injury of all cvs. within a chamber varied among chambers and among days, the conditions of experimental design did not influence the cvs. ranking and relative sensitivity to ozone of the species studied.

Lettuce is an economically important vegetable crop in California, but the only published information regarding sensitivity of lettuce to ozone and other oxidants was concerned with the cvs. Romaine and Black-seeded Simpson (9, 12). Relative sensitivity of these 2 cvs. in our study agreed with these 2 reports. Ozone sensitivity information on the other lettuce cvs. used in this study should be useful to plant breeders in the development of cvs. tolerant to oxidant air pollutants. Since size and wt of radish was reduced by ozone (19), the data reported in this study should be useful in selecting cvs. for commercial production.

Literature Cited


Mass Selection for Low Oxidation in Sweetpotato

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Abstract. Mass selection for low oxidation of root flesh was initiated in the fourth generation of an open-pollinated sweetpotato [Ipomoea batatas (L.) Lam.] population. Two selection schemes were followed which provided different selection pressures by varying effective population sizes. In one (population A), selected plants were randomly intercrossed by insects each cycle. In the other (population D), approximately 10% of the randomly intercrossing population were selected each cycle and their true seed used to plant the next generation. After 2 cycles of selection in A and 3 in D, they were compared to appropriate generations of the base population. Results were in agreement with selection theory and closely paralleled those obtained with other crops. More rapid advance was made with A, which requires 2 seasons per cycle for any trait not measured in the seedling stage. Good advance was made with D, which allows 1 cycle per season. Study of 21 other traits indicated more changes in unselected traits in A than in D, thus favoring the method of D in early generations of mass selection in sweetpotato. The rapid increase of low oxidizing plants in this study suggests that selection for low oxidizing cvs. may reduce associated processing problems.

In 1963, meiotic data were collected from 40 sweetpotato [Ipomoea batatas (L.) Lam.] breeding lines and first year seedlings (3). Nineteen of the best flowering lines were used to initiate a population suitable for quantitative genetic studies. Ultimate objectives were to develop improved breeding procedures for sweetpotatoes (2) and to provide plant materials suitable for use in such procedures, i.e. free flowering types. Studies to date have presented cytological and fertility data of the originating plants (3), reported the morphological variability of early generations (4, 9, 11), characterized the phenotypic, genotypic, and environmental variances and correlations displayed in the base population (5, 6, 7, 8, 10), documented the additive and non-additive genetic effects of 21 traits (5, 6, 10), and observed the fertility and morphological changes of the first 7 open-pollinated generations (9, 11). This report deals with the next phase of these exploratory studies of sweetpotato genetics, the effects of controlled selection. Two mass selection schemes of practical interest to breeders were considered. Although previous reports (2, 3, 4, 5, 6, 7, 8, 9, 10, 11) have indicated the suitability of mass selection for sweetpotato improvement, no information from actual selection experiments is available.

Materials and Methods
Selection for low oxidation was based on the reaction of cut roots to the oxidizing agent catechol. After dipping the cut roots to the oxidizing agent catechol. After dipping the cut...