Response of Sugarbeet Cultivars to Ozone

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Received for publication February 4, 1974

For almost 30 years, photochemical air pollution, produced chiefly by the action of sunlight on motor-vehicle exhaust gases and comprised mostly of ozone (O_3), oxides of nitrogen (NO_x), and peroxyacyl nitrates (PAN's), has damaged many crop species, but has apparently affected sugarbeet production very little. Haagen-Smit et al. (2)[2] exposed sugarbeets to the reaction products of ozone and olefins and reproduced symptoms similar to injury observed in the Los Angeles Basin. Several crops, including sugarbeets, were considered to be sensitive to the synthetic smog mixture. Brewer et al. (1) used stock beet as a test species to assess nutritional aspects of oxidant responses. Hill and Littlefield (4) chose sugarbeet as a tolerant crop species to study the effects of ozone on apparent photosynthesis.

In the United States, commercial sugarbeets are grown from monogerm hybrid seed produced from disease-resistant, close-bred, and inbred lines. We tested the response to ozone of three monogerm hybrids; one open-pollinated, mass-selected cultivar; and one close-bred cultivar. The purpose of the experiments was to determine the relative ozone resistance of a diverse selection of sugarbeet germplasm, and to depict accurately the symptoms of ozone injury.

Materials and Methods

Sugarbeet (*Beta vulgaris L.*) seeds of monogerm hybrids 'USH6,' 'USH9B,' 'USH20,' close-bred 'SP6822-0-(P),' and open-pollinated 'US401' were grown in 7.5-cm clay pots containing a sterilized mixture of loam:compost greenhouse soil. The plants grew for several weeks under natural lighting and general care in a greenhouse equipped with activated charcoal filters to exclude ozone air pollution. Fumigations were done at about the time the twelfth and thirteenth leaves were emerging. The chamber used to expose sugarbeets to ozone, described by Menser and Heggestad (5), has been used extensively for air pollution studies of tobacco (6). Provisions included controls for light, temperature, relative humidity, flow rate of carbon-filtered air, introduction of gases, and an exposure area of 2.25 m². Ozone was measured by a Mast 724-2 Ozone Meter[3] placed in the chamber and wired to a Varian G-11A strip chart recorder.

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[2]Numbers in parentheses refer to literature cited.

[3]Mention of a trademark name or proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products that may also be suitable.

Initial tests showed that the five sugarbeet cultivars were not marked visibly by a 2-hr ozone exposure at 25 pphm (parts per hundred million) by volume. Accordingly, we used concentrations of 40, 55, and 70 pphm to inflict ozone symptoms. Five plants each of USH6, USH9B, US401, and SP6822-0-(P) were exposed to 40 pphm ozone in tests repeated three times. The same cultivars were fumigated at 55 pphm in four experiments that totaled 18 plants of each. USH20 was added to the list in a third group of tests consisting of 14 plants of each cultivar exposed at 70 pphm. Plants used in each test had not been exposed previously to ozone. Exposures were done for 2 hr at 28°C, 60 to 70% relative humidity, and 22.2 K-lux lighting from VHO fluorescent lamps. Estimates of ozone injury were made by critical examination of both surfaces of all leaves. Scores from 0 to 10, based on the relative severity of symptoms, were given to each leaf, and the data were totaled for a percent-injury score for each plant.

Results

Ozone injury to all of the sugarbeet cultivars increased as the ozone dosage increased from 40 to 70 pphm (Table 1). USH6 and USH9B showed less injury than US401 and SP6822-0-(P). Cultivars differed significantly (1% level) at the 40-pphm rate, but not at 55 and 70 pphm. The synthetic SP6822-0-(P) was the most ozone-susceptible cultivar at the lowest and highest ozone rate. Hybrids USH6 and USH9B tended to be more tolerant to ozone.

Table 1.—Estimated ozone injury (%) to sugarbeet cultivars fumigated for 2 hr at various ozone concentrations.

	O_3, pphm		
Cultivar	40[1]	55[2]	70[3]
USH6	6	17	41
USH9B	3	22	45
USH20	–	–	62
USH401	9	43	54
6822-0-(P)	23	30	69
$L.S.D._{0.01}$	8	N.S.	N.S.

[1]Mean injury to 15 plants.
[2]Mean injury to 14 plants.
[3]Mean injury to 18 plants.

The relationship between ozone symptoms and leaf maturity showed that mid-plant leaves were more sensitive to ozone when plants were exposed at 40 pphm (Fig. 1). At 55 pphm ozone, the 3 oldest leaves of SP6822-0-(P) displayed a pronounced increase in necrotic tissue as compared to the same three leaves of the other varieties. This disparity diminished at 70 pphm, but the youngest leaves of all cultivars tended to remain more ozone-tolerant. The illustration of injury in relation to leaf age clearly shows the breakdown of

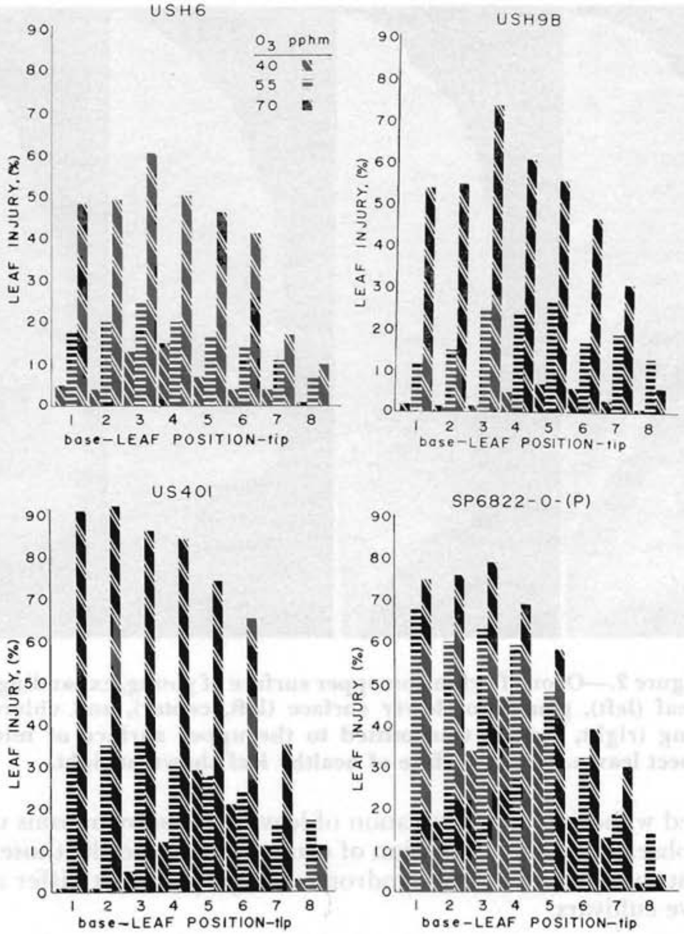

Figure 1.—Relationship between ozone concentration and injury to sugarbeet leaves at various stages of development.

ozone tolerance of the two hybrids and US401 at 55 and 70 pphm. Symptoms on US401 were more severe than those shown by USH6 and USH9B at these rates.

Ozone symptoms on the oldest leaves consisted of bleached punctate flecks scattered over the upper surfaces (Fig. 2). Mid-plant leaves displayed a glazing or silvering of the lower surface, which led to a chlorotic, mottled appearance on the upper surface (Fig. 2). No necrosis of the upper surface was evident, unless symptoms were very severe. Symptoms on youngest leaves appeared as flecks on the upper surface near the leaf tips. A waxy, shiny appearance often developed on leaves that a day later became flecked or glazed or sometimes remained visibly unmarked. Severe, bifacial necrosis was preceded by a very

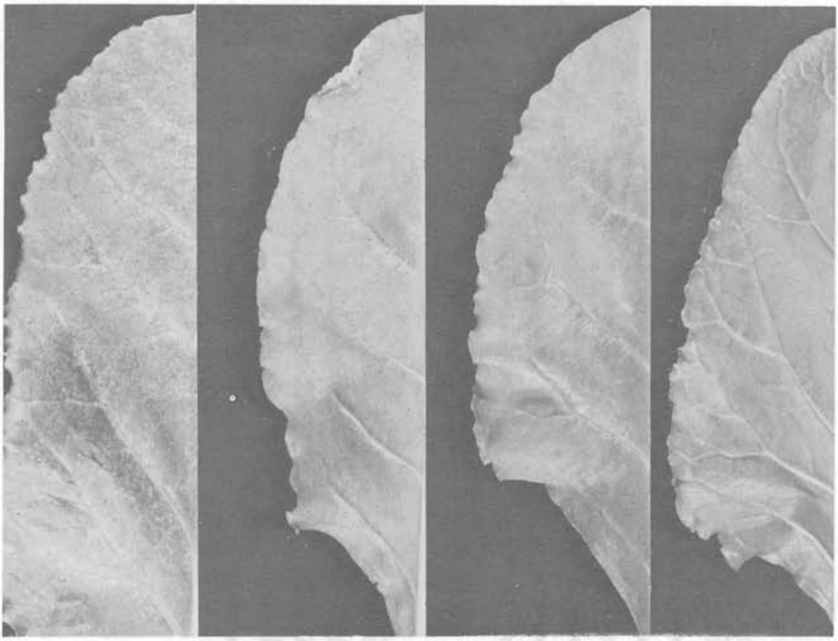

Figure 2.—Ozone flecking on upper surface of young, expanding sugarbeet leaf (left), glazing of lower surface (left, center), and chlorosis or mottling (right, center) transmitted to the upper surface of mid-plant sugarbeet leaves. Lower surface of healthy leaf shown at right.

marked withering and dessication of leaves. These symptoms usually were observed at the conclusion of ozone tests, especially those at the highest concentration. The syndrome of injury did not differ among the five cultivars.

Open stomata are essential for the uptake of ozone. Silicone rubber imprints of upper and lower leaf surfaces of four cultivars taken at the beginning of one experiment revealed that the stomata were open. Subsequent observations showed that stomata had closed at the end of the 2-hr exposure interval of 55 pphm ozone.

Discussion

This is the first recorded account of the effects of controlled ozone dosages on diverse sugarbeet cultivars. The lack of information about the response of sugarbeets to photochemical smog seems to reflect the general view that oxidants, including ozone, have no adverse effect on sugarbeet production. Personal communications from J. S. McFarlane, A. O. Paulus, and O. C. Taylor noted occasional unpublished accounts of photochemical smog damage to sugarbeets in the South Coast Basin of Southern California. Paulus felt that PAN or ozone had done no damage economically to sugarbeets, and that most of the crop was grown outside the air-pollution areas of the state. Taylor's many field observations led to his conclusion that sugarbeets were quite susceptible to PAN, but he was never sure that ozone caused much leaf injury. Anatomical differences and light dependency are reasons cited for the distinction between plant tissues shown by PAN and ozone (7).

Our tests show that the varietal responses of sugarbeets to various ozone concentrations are similar to the varietal characteristics of several other crop species tested for ozone resistance. Ozone usually is more injurious to physiologically mature leaves than to developing, expanding leaves. Ting and Mukerji (8) attributed this sensitivity of ozone to the existence of relatively low levels of soluble constituents in mature leaves. Reducing substances such as ascorbic acid, glutathione, and sulfhydryl groups, in sufficient amounts, presumably counter the oxidizing action of ozone. Photosynthetically active tissues usually contain more of these substances. Occasional ozone-pollution episodes with concentrations as high as 50 pphm for 2 hr may temporarily slow the growth processes of sensitive sugarbeet varieties by killing large numbers of cells or by inducing momentary closure of stomata. Hill and Littlefield (4) observed a temporary closure of sugarbeet stomata and a reduced rate of photosynthesis of plants exposed to 65 pphm ozone.

The hybrids USH6 and USH9B originated in California several years ago. Their more tolerant ozone response in our tests probably is a coincidence, although some selection toward ozone-tolerance may have been practiced because of the presence of photochemical air pollution in many areas of the state. The "synthetic" cultivar SP-6822-0-(P), developed by G. E. Coe at Beltsville, was bred for resistance to leaf spot (*Cercospora beticola Sacc.*) and black root (*Aphanomyces cochlioides Drechs.*). Tolerance to smog was not a factor in the breeding of SP6822-0-(P), because we have witnessed only one event toxic to sugarbeets at Beltsville in the past 15 years. The hybrid USH20 contains the synthetic SP6322-0, a close relative of SP6822-0-(P), as one of its progenitors. This sibling relationship may partially explain why USH20 was not one of the more ozone-tolerant hybrids.

Ozone generally injures the upper surfaces of leaves, while PAN and ozonated-hydrocarbons (HC) damage lower surfaces. The principal action sites for PAN are found in young, developing leaves (7), but ozonated-HC, like ozone, injures the mature and somewhat older leaves (3). We observed ozone injury on lower surfaces of mature leaves and typical flecking on other leaves. The field diagnosis of smog injury to sugarbeets perhaps would be easier if PAN were the only pollutant, but to distinguish between ozone and ozonated-HC injury is not possible, because both toxicants cause similar syndromes.

Summary

Five sugarbeet cultivars exposed to controlled ozone rates of 40, 55, and 70 pphm showed various degrees of leaf injury. Two-hour fumigations disclosed that the synthetic variety 'SP6822-0-(P)' was more ozone-susceptible at 40 pphm than the monogerm hybrids 'USH6,' 'USH9B,' and multigerm, open pollinated 'US401'; and at 70 pphm, SP6822-0-(P) also showed the most extensive ozone injury. Hybrids USH6 and USH9B were a little more ozone-tolerant than the other cultivars. The average injury to all cultivars increased from about 10% at 40 pphm to 55% at 70 pphm ozone. Basal and mid-plant leaves were much more sensitive to ozone than young, developing leaves. Ozone caused flecking on the youngest leaves, and glazing or silvering of the lower surfaces of mid-plant leaves. The silver-leaf appearance resembled the injury syndrome associated with ozonated-hydrocarbons and peroxyacetyl nitrate (PAN).

Acknowledgment

I thank Dr. G. E. Coe for his technical assistance and advice in conducting this study, and Dr. J. S. McFarlane for his criticisms and suggestions in preparing the manuscript.

Literature Cited

(1) BREWER, R. F., F. B. GUILLEMET, and R. K. CREVELING. 1961. Influence of N-P-K fertilization on incidence and severity of oxidant injury to mangels and spinach. Soil Sci. 92:298-301.

(2) HAAGEN-SMIT, A. J., E. F. DARLEY, M. ZAITLIN, H. HULL, and W. NOBLE. 1952. Investigation of injury to plants from air pollution in the Los Angeles area. Plant Physiol. 27:18-34.

(3) HEGGESTAD, H. E., F. R. BURLESON, J. T. MIDDLETON, and E. F. DARLEY. 1964. Leaf injury on tobacco varieties resulting from ozone, ozonated hexene-1, and ambient air of metropolitan areas. Intern. J. Air Water Poll. 3:1-10.

(4) HILL, A. C. and N. LITTLEFIELD. 1969. Ozone. Effect on apparent photosynthesis, rate of transpiration, and stomatal closure in plants. Env. Sci. and Tech. 3:52-56.

(5) MENSER, H. A., and H. E. HEGGESTAD. 1964. A facility for ozone fumigation of plant materials. Crop Sci. 4:103-105.

(6) MENSER, H. A., G. H. HODGES, and C. G. MCKEE. 1973. Effects of air pollution on Maryland (Type 32) tobacco. J. Environ. Qual. 2:253-258.

(7) TAYLOR, O. C. 1969. Importance of peroxyacetyl nitrate (PAN) as a phytotoxic air pollutant. J. Air Poll. Contr. Assoc. 19:347-351.

(8) TING, I. P., and S. K. MUKERJI. 1971. Leaf ontogeny as a factor in susceptibility to ozone : amino acid and carbohydrate changes during expansion. Amer. J. Bot. 58:497-504.