

Ozone Air Pollution Increases Petroleum Spray Oil Phytotoxicity

W.A. Retzlaff¹, W.W. Barnett², and L.E. Williams³

Kearney Agricultural Center, 9240 South Riverbend Avenue, Parlier, CA 93648

T.M. DeJong⁴

Department of Pomology, University of California, Davis, CA 95616

Additional index words. *Prunus salicina*, 'Casselman' plum, *Tetranychus* spp., spider mite

Abstract. Japanese plum (*Prunus salicina* Lindl. 'Casselman') trees exposed to three atmospheric ozone partial pressure treatments were sprayed with a summer application of Volck Supreme oil (1% aqueous solution) to control an outbreak of spider mites (*Tetranychus* spp.). Phytotoxic effects were observed on the foliage of trees in the plots exposed to ambient or higher atmospheric ozone partial pressures 5 days following spray application. Foliage on trees exposed to 0.044 and 0.081 $\mu\text{Pa}\cdot\text{Pa}^{-1}$ ozone [12-h mean (8 Apr. to 12 June 1992)] partial pressures developed water spotting and more foliage abscission than trees exposed to charcoal-filtered air (0.024 $\mu\text{Pa}\cdot\text{Pa}^{-1}$ ozone). Thus, ozone air-pollution stress may predispose plants to increased phytotoxicity from summer oils.

Petroleum oil sprays have been used for pest control for more than 100 years (Davidson et al., 1991). Used properly, summer oil application can effectively control spider mites. However, when heavy grades, high rates, or impure oil sprays are deposited on some foliage, they may penetrate and block stomata, kill cells, and lead to yellowing or chronic foliar injury. Riehl et al. (1958) found that transpiration of 'Beams' lime (*Citrus latifolia* Tan.), 'Eureka' lemon [*C. limon* (L.) Burro. f], and 'Valencia' oranges [*C. sinensis* (L.) Osbeck] was depressed for up to 5 weeks following application of a California medium-grade oil. The recommendation for the application of spray oils in the summer is to avoid high temperatures or low relative humidity and trees suffering from water stress or any other stress when spraying (Davidson et al., 1991).

During the 1992 growing season, a moderate to severe outbreak of spider mites (*Tetranychus* spp.) occurred on field-grown 'Casselman' plum trees exposed to three atmospheric ozone partial-pressure treatments in open-top chambers. Visual observations indicated mite levels were uniform throughout all chambers. To control the outbreak, a single application of a commercially available oil was "made on 12 June 1992. The conditions of the plum air pollution study and the phytotoxic effects that developed as a result of the spray treatment are discussed.

Materials and Methods

Plant materials and ozone treatments. Nursery stock of 'Casselman' plum on 'Citation' (*Prunus* hybrid) rootstock were planted 1 Apr. 1988 in an experimental orchard at the Univ. of California Kearney Agricultural Center, near Fresno, Calif. (lat. 36°36'N, long. 119°30'W). Tree and row spacing were 1.83 and 4.27 m, respectively. Trees were trained to an open-vase shape, with other cultural practices similar to those used for the commercial production of plums.

Ozone treatments imposed in this study were charcoal-filtered air (CF), ambient air (AA), and ambient air + ozone (AO). Treatments were assigned randomly to an open-top chamber (Retzlaff et al., 1992) containing four plum trees; there were five replications containing one chamber of each treatment. Ozone partial pressures in the treatment plots were monitored using a computer-controlled monitoring system described by Retzlaff et al. (1991). Ozone treatments were maintained in the chambers from 8 Apr. to 1 Nov. 1992.

Air for the AA and AO treatments was blown directly into each chamber. Air for CF was first drawn through activated charcoal filters before delivery into the chambers. Additional ozone for the AO chambers was generated from dry ambient air with a Griffin

(Lodi, N. J.) model GTC-2A ozone generator and delivered via Teflon tubing to the delivery air stream of these chambers. Supply air for the ozone generator was dried by a General Cable Corp. (Westminster, Colo.) Puregas heatless air drier (model F200A109-132). The ozone generator was computer-automated to adjust the ozone output from 0800 to 2000 HR Pacific Daylight Time (PDT), depending on the ambient atmospheric ozone partial pressure. This system resulted in ozone partial pressures ≈ 1.9 times ambient in the AO chambers during the ozone exposure period.

Final ozone partial-pressure data analysis was conducted by use of the means procedure (PROC MEANS) of the statistical analysis system (SAS) (SAS Institute, 1988). Ozone 12-h means (0800-2000 HR PDT) were calculated for each treatment during the exposure period (preceding the spray date) between 8 Apr. and 12 June 1992. These 1992 ozone partial pressures were used to determine the relationship between spray oil phytotoxicity and ozone partial pressure.

Spray application. Volck Supreme oil (viscosity: 150 SUS @38C) (VALENT USA Corp., Walnut Creek, Calif.) was tank-mixed (as a 1% aqueous solution) in an AIR-O-FAN (Gilroy, Calif.) model GB34 sprayer. The spray mix was applied by hand-held sprayer until runoff. The spray application was made between 0930 to 1030 HR PDT on 12 June 1992.

Meteorological data. Temperature and humidity at the time of spray application were obtained from a California Irrigation Management Information System (CIMIS) weather station located 0.5 km southeast of the plum orchard.

Leaf abscission. Leaf abscission was quantified by collecting leaves that had fallen to the ground-below the trees in each of the treatment chambers on 19 and 23 June 1992. Collected leaves were dried in a forced-air oven at 70C until no further weight change occurred. Leaf fall data were collected at regular intervals throughout the remainder of the growing season to determine final foliage biomass. The percentage of foliage remaining on the trees was calculated after phytotoxic leaf abscission ceased on 23 June.

Statistical design and analysis. The design used was a randomized complete block with three ozone partial-pressure treatments and five replications. Spray oil phytotoxicity data were analyzed by analysis of variance (ANOVA) using the SAS program (SAS Institute, 1988). Linear contrast with 12-h mean ozone partial pressure was used for a *priori* comparisons among treatment means ($\alpha \leq 0.05$).

Results and Discussion

Phytotoxic effects were observed on the foliage of trees in the air pollution study treatment plots 5 days (17 June 1992) following spray application. Injury first appeared as darkened spots on the adaxial leaf surface. Foliar injury was spread uniformly throughout the tree canopy, but was not evident on all foliage. Phytotoxic oil injury differs from that of foliar

Received for publication 25 June 1993. Accepted for publication 28 Sept. 1993. This study was funded in part by a grant from the California State Air Resources Board. The statements and conclusions of this report are those of the Univ. of California and not necessarily those of the California State Air Resources Board. The mention of commercial products, their source, or their use in connection reported herein is not to be construed as either an actual or implied endorsement of said products. We thank P. Biscay, W. Yang, and N. Ebisuda for technical assistance; C.G. Summers and J.E. Dibble for critical manuscript review; and J. Coviello for word-processing assistance. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

¹Postdoctoral Research Associate. Current address: Boyce Thompson Inst. for Plant Research at Cornell Univ., Tower Rd., Ithaca, NY 14853-1801.

²Area IPM Farm Advisor, Univ. of California, Cooperative Extension.

³Associate Professor, Dept. of Viticulture and Enology, Univ. of California-Davis.

⁴Professor.

injury induced by increased atmospheric ozone partial pressures. Ozone injury of 'Casselman' plum foliage consists of chlorotic spots and yellow flecking and occurs on older foliage first (Retzlaff et al., 1992). Visible spray oil injury was present on trees in all ozone treatments; however, injury was more prevalent on trees exposed to the higher atmospheric ozone partial pressures. During spray application, the AA chamber in replication two was inadvertently missed entirely, and trees in the AO chamber from replication four were sprayed on only one side of the canopy. Phytotoxic injury symptoms were absent in the missed AA chamber and injury was less (amount of foliage exhibiting visual symptoms) in the AO chamber trees sprayed only on one side than in those sprayed entirely. Consequently, replications two and four were omitted from further analysis (the final ANOVA included only three replications).

Oil-damaged foliage abscised from the trees after the appearance of visible injury. Premature leaf abscission has been documented for 'Casselman' plum trees following 2 months of exposure to atmospheric ozone partial pressures $>0.090 \mu\text{Pa}\cdot\text{Pa}^{-1}$ (Retzlaff et al., 1991, 1992). However, ozone-induced 'Casselman' plum foliage abscission has never been observed at the lower ozone partial pressures we used. In our study, more foliage abscised (dry weight collected on 19 June) from trees exposed to 0.044 and 0.081 $\mu\text{Pa}\cdot\text{Pa}^{-1}$ ozone partial pressure than from trees exposed to 0.024 $\mu\text{Pa}\cdot\text{Pa}^{-1}$ (Fig. 1). Foliage abscission was greatest across all ozone treatments during the period between 19 and 23 June. Following 23 June, foliage abscission ceased, and no additional visible spray oil injury symptoms appeared on any of the remaining plum foliage.

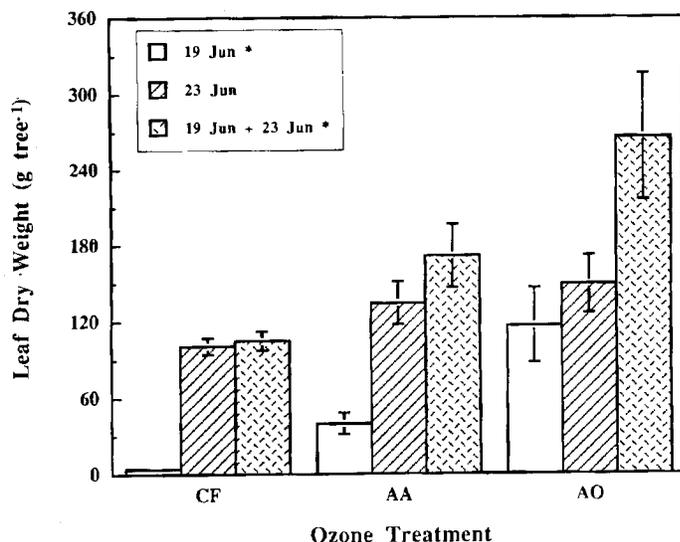


Fig. 1. Dry weight of abscised leaves on 19 and 23 June 1992, and the sum of the two dates, from 'Casselman' plum trees; exposed to three atmospheric ozone partial pressures and sprayed with Volck Supreme oil on 12 June 1992. CF = charcoal-filtered, AA = ambient air, and AO = ambient air + ozone, respectively. Vertical bars represent ± 1 SE. Asterisks (*) represent dates on which there was a significant linear treatment effect ($P \leq 0.05$), $n = 3$.

Table 1. Air temperature, relative humidity, and ozone partial pressure at the time (1000 HR PDT) of spray application and at 1600 HR PDT (time of peak daily ozone partial pressure) on 12 June 1992. Seasonal average (12-h mean) ozone partial pressures are also given for the period 8 Apr. to 12 June 1992.

Hour	Air temp (°C)	Relative humidity (%)	Ozone partial pressure ² ($\mu\text{Pa}\cdot\text{Pa}^{-1}$)		
			CF	AA	AO
1000	18.7	48	0.018	0.026	0.036
1600	23.0	39	0.025	0.041	0.095
Season			0.024	0.044	0.081

CF = charcoal-filtered, AA = ambient air, and AO = ambient air + ozone, respectively.

Final dry weight of foliage that had abscised by 23 June was higher for trees exposed to 0.044 or 0.081 $\mu\text{Pa}\cdot\text{Pa}^{-1}$ of ozone than for those exposed to 0.024 $\mu\text{Pa}\cdot\text{Pa}^{-1}$ (Fig. 1). The amount of foliage remaining on the plum trees after final abscission that had been induced by the oil spray on 23 June was reduced as atmospheric ozone partial pressure increased (i.e., 97%, 95%, and 93% of the final leaf biomass remained on the trees in the CF, AA, and AO treatments, respectively; significant linear treatment effect, $P \leq 0.05$).

Similar phytotoxicity has been described following applications of oils to foliage of fruit trees during periods of high temperatures ($> 32\text{C}$) or low relative humidity ($< 20\%$) or when trees were stressed in any way before spraying (Davidson et al., 1991). Previously, Retzlaff et al. (1991, 1992) found that leaf net CO_2 assimilation rate and trunk cross-sectional area growth of 'Casselman' plum trees was reduced following 2 months of exposure to increased atmospheric ozone partial pressures, indicating that trees growing in increased ozone, air pollution are stressed. Further, leaf net CO_2 assimilation of the 'Casselman' plum trees in the AA and AO treatment chambers was reduced compared to the CF trees when measured on 22 June 1992 (unpublished data). We do not know whether stress caused by the

spider mites or the interaction between mite feeding and ozone stress influenced the degree of oil-induced phytotoxicity.

In this study, temperature and relative humidity at the time of spraying and at 1600 HR PDT on the date of spray application (Table 1) were well within recommended limits, and the only other visible sign of stress was mites. At the time of spraying, visual estimation of mite populations indicated that mite infestation was uniform across all treatments. However, plum trees had been exposed to different atmospheric ozone partial pressure treatments for >2 months before spray application in 1992, and atmospheric ozone partial pressures differed at the time of spray application (Table 1). Therefore, increased phytotoxicity following spray oil application to plum trees exposed to increased atmospheric ozone partial pressures indicates that ozone air pollution stress can predispose plants to phytotoxicity from spray applications of summer oils. We do not know whether the reduction in foliage remaining on the trees (up to 7% in the 0.081 $\mu\text{Pa}\cdot\text{Pa}^{-1}$ ozone partial-pressure treatment) as a result of spray oil phytotoxicity was great enough to affect the productivity of these plum trees. However, there have been previous, but unexplained, episodes of spray oil phytotoxicity (W.W. Barnett and J.E. Dibble, personal communication) in the San Joaquin Valley of California that may be linked to the atmospheric ozone air pollution stress that this region has experienced.

Literature Cited

- Davidson, N. A., J.E. Dibble, M.L. Flint, P.J. Marer, and A. Guye. 1991. Managing insects and mites with spray oils. IPM Education and Publications, Statewide Integrated Pest Management Proj., Univ. of California, Div. of Agriculture and Natural Resources, Publ. 3347.
- Retzlaff, W. A., L.E. Williams, and T.M. DeJong. 1991. The effect of different atmospheric ozone partial pressures on photosynthesis and growth of nine fruit and nut tree species. *Tree Physiol.* 8:93-105.
- Retzlaff, W. A., L.E. Williams, and T.M. DeJong. 1992. Photosynthesis, growth, and yield response of 'Casselman' plum to various ozone partial pressures during orchard establishment. *J. Amer. Soc. Hort. Sci.* 117:703-710.
- Riehl, L. A., R.T. Wedding, J.P. La Due, and J.L. Rodriguez. 1958. Effect of a California spray oil on transpiration of citrus. *J. Econ. Entomol.* 51:317-320.
- SAS Institute. 1988. SAS/STAT user's guide. Release 6.03 ed. SAS Institute, Inc., Cary, N.C.