Protection of Plants Against Ozone Injury Using the Antiozonant N-(1,3-Dimethylbutyl)-N'-Phenyl-p-Phenylenediamine

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Among air pollutants which are deleterious to plants, ozone is believed to cause, by far, the most widespread injury. Visual symptoms of ozone injury to foliage are manifested by the development of translucent or yellow mottled or mosaic areas in leaves. Histologically, chlorophyll is destroyed and palisade and spongy mesophyll cells collapse following disintegration of their protoplasm (ELFVING et al., 1976). The foliar application of several agents to plants has been reported to offer varying degrees of protection against ozone injury (KENDRICK et al., 1962; JONES, 1963; SILBER, 1964; WALKER, 1967; REINERT and SPURR, 1972; SEEM et al., 1973; TOMLINSON and RICH, 1973; MANNING et al., 1974; ORMROD and ADEDIPE, 1974; GILBERT et al., 1975; ELFVING et al., 1976). Several of the compounds studied have included those used commercially as antioxidants in the formulation of rubber products for protection against ozone attack.

Santoflex 13, N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine, is used in the formulation of rubber to give protection against ozone attack. In the work reported, the compound was applied as a dust to plant foliage to evaluate its effectiveness as a protectant against ozone injury.

Experimental

Four species of plants were studied: 'Northern Spy' apple seedlings (Malus domestica Borkh.), 'Tendercrop' green snapbeans (Phaseolus vulgaris L.), 'Delicious 51' muskmelons (Cucumis melo L.) and 'Bel W-3' tobacco (Nicotiana tobacum L.). The plants were grown in plastic pots containing a 1:1 v/v mixture of peat moss and vermiculite with the necessary added fertilizer constituents (BOODLEY and SHELDRAKE, 1973). The plants were exposed to ozone for 16 hours of each 24 hour period in specially built ozone chambers as described previously (GILBERT et al., 1975). The dust formulation consisted of 1% (w/w) Santoflex 13 on 100-120 mesh Celite 545. The formulation was applied to the plant foliage using a commercial garden

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duster. Plants treated with Celite 545 alone served as controls. Untreated plants served as absolute controls. The chambers were opened each day and the plants were removed, watered, observed and replaced again randomly.

A description of the appearance of ozone injury in each plant species and the method of rating the magnitude of damage were given earlier (GILBERT et al., 1975). A rating scale of 0 to 5 was used: 0 = no visible injury; 1 = yellowing (or absence of chlorophyll) covering up to 10% of the leaf area; 2 = 10 to 50%; 3 = 50 to 75%; 4 = 75 to 90%; and 5 = over 90%. Visible foliar injury progressed with exposure time. Plants were removed from the exposure chambers and rated when injury in the control plants was well developed.

Results and Discussion

The extent of visible protection (numerical injury rating) obtained with the treatments and the operating parameters during exposure are listed in Table I. Protection was afforded by the Santoflex 13 in all treatments. SILBER (1964) and WALKER (1967) found application of the antiozonant, N,N'-diphenyl-p-phenylenediamine, to tobacco to offer protection against "weather fleck" believed to be caused by ozone. We studied two other antiozonants, Santoflex 77 (N,N'-bis(1,4-dimethylpentyl)-p'-phenylenediamine) and Goodrite 3201 (dioctyl-p-phenylenediamine) as possible protectants on tobacco but they were ineffective and phytotoxic.

The susceptibility of plants to ozone damage varies considerably and depends on genetic, edaphic and environmental factors (ORMROD and ADEDIPE, 1974). The concentrations of ozone used in this study are within the range of 2 to 69 pphm that have been reported for certain areas of California (THOMPSON et al., 1972).

A recent study using attenuated total reflectance spectroscopy indicates that the mechanism of protection of rubber by antioxidants involves their scavenging of ozone at the surface with resultant formation of a surface film of ozonized antioxidant (ANDRIES and DIEM, 1975). It may be that a similar mechanism of protection is involved when antiozonants are used on plants. This is especially true when applied as a dust which would tend to hold the active compound on the foliar surface

Table I

Effectiveness of Santoflex 13 in preventing visible ozone injury to various plants.

Species	Age at treatment (days)	Treatment	No. of replicates	Ozone[1] pphm	Exposure time days	Injury rating[2,3]
Apple	90	none	6	35	9	2.0ab
	90	Celite 545	6	35	9	2.3a
	90	5% Santoflex 13 on Celite	6	35	9	1.3b
Bean	14	none	12	35	4	3.2a
	14	Celite 545	12	35	4	2.6a
	14	1% Santoflex 13 on Celite	12	35	4	1.7b
Muskmelon	21	none	12	35	2	3.6b
	21	Celite 545	12	35	2	4.4a
	21	1% Santoflex 13 on Celite	12	35	2	1.8c
Tobacco	60	none	7	20	7	2.0a
	60	Celite 545	7	20	7	2.1a
	60	1% Santoflex 13 on Celite	7	20	7	0.5b
	60	none	12	35	10	3.3a
	60	Celite 545	12	35	10	3.3a
	60	1% Santoflex 13 on Celite	12	35	10	1.5b

1 16 hours per day

2 0 (no visible injury) to 5 (yellowing or absence of chlorophyll in over 90% of leaf area) See text for details.

3 mean separation within species and ozone levels by Duncan's multiple range test, 5% level

but out of intimate contact with reactive endogenous compounds at the leaf surface thereby preventing their reaction with and probably inactivation of the protectant. The application of antiozonants as dusts offers the most practical advantage for protection of greenhouse plants in urban areas where ozone levels are likely to be elevated and removal of the formulation by rainfall is obviated.

Summary

Santoflex 13, (N-(1,3-dimethylbutyl)-N'-phenyl-p-phenylenediamine), is an antiozonant used in the formulation of rubber products. Its application as a dust was shown to offer foliar protection against visible ozone injury when apple seedlings, bean, muskmelon and tobacco plants were exposed to ozone concentrations up to 35 pphm in a chamber.

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