Reduction Air Pollution Injury to Foliage of *Chrysanthemum morifolium* Ramat. Using Tolerant Cultivars and Chemical Protectants,[1]

Gerald L. Klingaman[2] and Conrad B. Link[3]
University of Maryland, College Park

Abstract. Forty-five chrysanthemum cultivars exposed to ozone in a controlled environment chamber exhibited a wide range of sensitivity with several showing sufficient sensitivity to be damaged by ambient oxidant concentrations. Chemical protection of foliage from ambient air pollution was tested on pollution sensitive 'King's Ransom' and pollution tolerant 'Yellow Jess Williams'. Chemical protectants included 1) benomyl, 2) thiophanate ethyl, 3) triarimol, 4) ancymidol, 5) SADH, and 6) Folicote. No visible injury was observed on unprotected 'Yellow Jess Williams', but extensive injury occurred on older foliage of 'King's Ransom'. Full season protection was observed on 'King's Ransom' receiving treatments of benomyl, thiophanate ethyl or ancymidol but ancymidol delayed anthesis and reduced flower count.

Significant differences in cultivar susceptibility to oxidant pollution have been established in poinsettias (1), petunias (2), alfalfa (5) and other horticultural and agronomic crops (4). Many cultivars possess sufficient tolerance to be uninjured by present ambient pollution levels.

Protection of pollution sensitive crops has been attempted using various fungicides, antioxidants, and growth regulators. Weather fleck of field-grown tobacco (12) was reduced with weekly 3 times normal sprays of Polyram (a mixture of zinc ammoniates of ethylenebisdithio carbamate and ethylenebisdithio carbamic acid), zineb (zinc ethylenebisdithio carbamate) and maneb (manganese ethylenebisdithio carbamate).

Benomyl [methyl 1-(butyl carbamoyl)-2-benzimidazone carbamate] has been reported to reduce oxidant damage on field-grown tobacco (12), grapes (6), and beans grown in controlled environment chambers (9). Kender et al. (6) reduced the occurrence of oxidant damage on 'Ives' and 'Concord' grapes using multiple applications of benomyl. They observed that protection was directly related to frequency of application, with 3 week intervals being most effective.

Seem et al. (10, 11) reported that the systemic fungicides, triarimol (alpha-2,4-dichlorophenyl)-alpha-phenyl-5-pyrimidinemethanol) and thiophanate ethyl [1,2-Bis (3-ethoxy carbonyl-2-thioureido) benzene], when applied as soil amendment or foliar spray, reduce oxidant damage on beans under fumigation chamber conditions. Triarimol is a close structural relative of the growth regulator ancymidol [alpha-cyclopropyl-alpha-(4-methoxy-phenyl)-5-pyrimidinemethanol] while thiophanate ethyl has the same breakdown product as benomyl, methyl-2-benzimidazole carbamate (MBC).

Much air pollution research is carried out in controlled environmental chambers using high concentrations of pollution for a short period of time. Menser and Hodges (7) observed that tobacco plants exposed to 0.3 ppm ozone for 1 hour resulted in more damage than did an exposure of 0.1 ppm for 3 hours. Feder and Campbell (3) exposed carnations to sublethal ozone for 8 weeks and observed a delay in flowering and a decrease in the number of flowers harvested.

Howell et al. (5) suggested the use of ambient pollution in greenhouses as a method of selecting pollution resistant plants. Otto and Daines (8) reported that high relative humidity, such as that found in greenhouses cooled with pad and fan cooling, predisposed plants to ozone injury.

We undertook to determine the range of chrysanthemum sensitivity to ozone pollution and to control pollution damage with chemicals. Exposure to ambient ozone levels in a pad and fan cooled greenhouse was evaluated as a method of determining effectiveness of protectant treatments in reducing oxidant damage.

Methods

Fumigation. Eighteen cultivars were planted February 24, 1972, in 1:1:1 (peat:loam:perlite) soil mix in 10-cm plastic pots. One cutting was planted per pot and all plants were topped 3 times. Nine plants per cultivar were flowered under natural day length and fumigated April 24. Six cuttings of an additional 27 cultivars were planted on July 17 and fumigated on September 15.

Plants in full bloom were fumigated for 3 hrs. with ozone from an electric arc generator in a Controlled Environment (Model PWG 36) growth chamber. Chamber conditions during fumigation consisted of 2000 ft-c of light supplied by cool white fluorescent lights with 10% supplied by incandescent lamps, temperature of 27°C and relative humidity of 78–88%.

Plants were ranked according to the method used by Cathey and Heggestad (2) for foliar damage 4–7 days after fumigation from 0 (no damage) to 10 (100% of most sensitive leaves showing damage). The most sensitive tissue of the chrysanthemum is the upper leaf surface of the older leaves.

Ambient air. 'King's Ransom', judged an ozone sensitive cultivar, and 'Yellow Jess Williams', judged ozone tolerant, were used in tests conducted from May to October, 1972 and 1973, in a greenhouse located 100 m from a 4-lane highway in College Park. The greenhouse was cooled by a conventional pad and fan cooling system with the fans operating from 6:00 AM to 10:00 PM. The air in the greenhouse was changed once a minute. Cuttings were planted in 15-cm plastic pots and grown on a bench adjacent to the pads. Plants were evaluated for oxidant damage October 13, 1972, and August 17, 1973. Plant fresh wt and flower number were determined October 13, 1972, and October 10, 1973.

In 1972 protectant treatments started June 7 and ended August 23. They were: benomyl, 250 ppm spray biweekly; ancymidol, 100 ml of 4 ppm concentrated single soil drench; SADH (succinic acid 2,2-dimethyl hydrazide) 1500 ppm spray June 7 and July 7; and Folicote a multi-molecular film type antitranspirant, 5% spray biweekly. The 5 treatments were arranged by cultivar as 5 x 5 Latin squares, each repeated 4 times.

Treatments during 1973 were: benomyl, 0, 250, or 750 as a 100 ml drench biweekly, thiophanate ethyl, 0, 250, or 750 ppm as a 100 ml

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[2] Research conducted in partial fulfillment for the degree of Doctor of Philosophy at the University of Maryland. Present address, Department of Horticulture, University of Arkansas, Fayetteville.

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drench biweekly, triarimol as a 0.30, or 90 ppm drench biweekly, and ancymidol as 0, 4, or 12 ppm 100 ml drench on the first date. The 24 treatments were arranged as a randomized complete block with 8 replications and analyzed as a 2 x 3 x 4 factorial design.

Results

Cultivars classified as "Very sensitive" (Table 1) were damaged by ambient pollution levels while those classified as "Tolerant" were not observed to be injured by ambient pollution levels.

In 1972 'Yellow Jess Williams' was not damaged by the concentration of ambient oxidants in the greenhouse, while 'King's Ransom' exhibited extensive damage (Table 2). Ancymidol, as a 4-ppm drench, and benomyl, as a 250-ppm spray, reduced foliar damage when compared to the control. Biweekly applications of Folicote caused yellowing and senescence of the older leaves of both cultivars. SADH, though providing no apparent foliar protection, resulted in plants with the highest flower count, high fresh wt, and best overall appearance. Ancymidol, though providing good foliar protection, resulted in reduced fresh wt and flower count on 'King's Ransom'. Benomyl provided good foliar protection to 'King's Ransom' with little effect on flower number or fresh wt.

In 1973 benomyl, thiophanate ethyl, and ancymidol (Table 3) reduced the oxidant damage on 'King's Ransom'. At the highest rates ancymidol, thiophanate ethyl, and benomyl reduced damage on 'King's Ransom' to equal that of undamaged 'Yellow Jess Williams'. Triarimol was ineffective in reducing oxidant damage and produced root damage at the highest rate. Protectant application to plants in 1973 had little effect on growth and flowering of either cultivar, except that ancymidol reduced fresh wt of 'King's Ransom' and flower count of 'Yellow Jess Williams'. Anthesis in plants treated with ancymidol was delayed 10 days when compared to control.

Table 1. Chrysanthemum cultivar sensitivity to ozone fumigation[z]

Tolerant (0–1.5)[y]		
Ann Ladygo	Spinwheel[x]	Golden Yellow Princess Ann[x]
Bright Yellow Tuneful	Yellow Moon	Jessamine Williams
Dark Yellow Tokyo[x]	Larry	Yellow Jess Williams
Dolli-ette	Mermaid[x]	Red Dessert
Golden Cushion	Queens Lace	Rosey Nook
Fuji Jess Williams	Redskin	
Slightly Sensitive (1.6–3.0)		
Bonnie Jean	Golden Peking	White Grandchild
Distinctive	Lipstick	Wildfire[x]
Flair	Mandalay[x]	
Fuji-Mefo	Ruby Mound	
Sensitive (3.1–4.5)		
Baby Tears	Gay Blade	Sleighride
Chris Columbus	Pancho	Tinkerbell[x]
Corsage Cushion	Penguin	Touchdown
Crystal Pat	Pink Chief	Yellow Supreme
Very Sensitive (4.6–7.0)		
King's Ransom	Minn White	Red Mischief
Mango	Mt. Snow	Tranquility

[z] Classification based on the mean of all experimental exposures. A minimum of 6 plants per cultivar was used in sensitivity evaluation. Plants were fumigated with 0.6 ppm ozone for 3 hours in standard chambers.
[y] Average leaf injury index (scale 0–10) observed on the upper leaf surface of the oldest leaves.
[x] Denotes greenhouse cultivars.

Discussion

Chrysanthemums have been considered insensitive to moderate concentrations of oxidant pollution; however, few of the tremendous number of cultivars have been evaluated for pollution sensitivity. Our data indicates that there is much variation in chrysanthemum cultivar sensitivity to ambient pollution levels.

'Jessamine Williams', 'Yellow Jess Williams', and 'Fuji Jess Williams' were very insensitive to the extreme experimental exposures used. This indicates considerable potential for the development of other pollution tolerant chrysanthemum cultivars.

If breeding programs were conducted in greenhouses cooled with pad and fan cooling systems in areas of high ambient pollution levels, a practical level of pollution tolerance could be determined during the selection process. Those plants showing serious pollution injury could be identified and eliminated from the breeding program. This technique would appear to be more desirable than controlled fumigation in chambers as the plants are under ambient conditions and are exposed to normal environmental stresses with varying concentrations and combinations of pollutants. Next to pollution abatement, cultivar tolerance is probably the most practical long term solution to the problem of air pollution damage to plants.

Sensitive chrysanthemum cultivars can be protected from ambient pollution levels by application of chemical protectants such as benomyl, thiophanate ethyl, or ancymidol. Several workers have reported that higher than recommended concentrations of protectant chemicals are required for pollution protection (2, 9, 12). We also found that a higher than recommended rate was required for complete suppression of symptoms; however, reduction in damage was achieved at recommended rates with benomyl and ancymidol.

Research on chemical protection under controlled conditions with a single exposure of the plant to the pollutant can not demonstrate that full season protection is possible. Kender et al. (6), under field conditions, reported full season protection of grape plants treated with repeat applications of benomyl. We demonstrated that protection of chrysanthemums is possible throughout the growing season with repeated applications of benomyl or thiophanate ethyl or with a single application of ancymidol.

Table 2. The influence of chemical application and 1972 ambient oxidant levels on leaf injury, flower number, and plant fresh wt of 2 chrysanthemum cultivars in the greenhouse.

Treatment	Leaf injury index[z]		Flower number[y]		Fresh wt[x]	
	King's Ranson	Yl. Jess Williams	King's Ransom	Yl. Jess Williams	King's Ransom	Yl. Jess Williams
Control	2.7ab[w]	0.0a	23.2b	43.7b	172.3b	371.8a
Ancymidol (4 ppm)	1.1c	0.0a	5.4d	28.5cd	142.4c	280.2b
Benomyl (250 ppm)	1.0c	0.0a	24.4b	25.2d	202.9a	244.4bc
Folicote (5%)	3.4a	0.0a	17.6c	34.4c	150.2c	237.4c
SADH (1500 ppm)	2.1b	0.0a	32.2a	51.7a	217.5a	362.8a

[z] Values are the mean leaf injury index of 20 replications. Zero indicate no visible injury on the upper surface of the oldest leaves while 10 indicates injury on 100% of these leaves.
[y] Number of flowers showing color on October 13, 1972. Values are the means of 10 replications.
[x] Mean fresh weight (gm) of 10 plants harvested on October 13, 1972.
[w] Mean separation, in columns by Duncan's multiple range test at the 5% level.

Table 3. The influence of chemical application and 1973 ambient oxidant levels on leaf injury, flower number, and plant fresh wt of 2 chrysanthemum cultivars in the greenhouse.

Treatment (ppm)	Leaf injury index[z]		Flower number[y]		Fresh wt[x]	
	King's Ransom	Yl. Jess Williams	King's Ransom	Yl. Jess Williams	King's Ransom	Yl. Jess Williams
Benomyl						
0	5.8bc[w]	0.0g	26.3d	68.5ab	287.1ab	259.1bcd
250	1.3f	0.0g	26.1d	69.6ab	247.9d	279.1abc
750	0.5g	0.0g	26.9d	69.4ab	282.3abc	275.7abc
Thiophanate ethyl						
0	5.1cd	0.0g	26.5d	70.0ab	228.7d	262.3bcd
250	2.7e	0.0g	25.9d	67.5b	247.4d	258.2bcd
750	0.9fg	0.0g	27.4d	70.1ab	251.3cd	270.9bcd
Triarimol						
0	5.8bc	0.0g	27.3d	72.3a	247.9d	260.4bcd
30	6.0b	0.0g	26.6d	67.5b	240.4d	260.8bcd
90	7.0a	0.0g	24.1de	73.4a	256.4bcd	309.3a
Ancymidol						
0	4.8d	0.0g	23.8de	68.1ab	254.6bcd	255.3bcd
4	1.3f	0.0g	27.1d	64.3bc	186.3e	246.2d
12	0.4g	0.0g	19.9e	60.1c	148.2e	252.8d

[z] Values are the mean leaf injury index of 8 replications. Zero indicates no visible injury on the upper surface of the oldest leaves while 10 indicates injury on 100% of these leaves.
[y] Number of flowers showing color on October 10, 1973. Values are the means of 8 replications.
[x] Mean fresh weight (gm) of plants harvested on October 10, 1973.
[w] Means separation in columns by Duncan's multiple range test at the 5% level.

Frequently mentioned disadvantages of chemical protectants are the need for thorough coverage and frequent application, or application just prior to an air pollution episode (2, 4). Benomyl and thiophanate ethyl give at least 2 weeks protection and, when applied as a soil drench, insure complete distribution of the chemical throughout the plant. The use of these fungicides in a disease control program could reduce pollution damage as an added benefit to fungus control.

The use of chemical growth retardants has become firmly established in the production of pot grown chrysanthemums and, if a known pollution susceptible cultivar were to be grown, some protection could be afforded by the use of ancymidol. Cultivar variation in response to growth regulators is frequently reported, indicating the need to determine if a possible delay in anthesis would be offset by the advantages of ancymidol application.

At this time, pollution damage to most greenhouse-, field-, or garden-grown chrysanthemums is not of sufficient magnitude to warrant direct chemical control. The use of chemical controls described here might be applicable for suppression of pollution damage on more sensitive plants being grown in urban areas.

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