

Rapid Determination of Chloride Content of Vegetation for Assessment
of Air Pollution Injury from Hydrogen Chloride

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ABSTRACT

Twenty-eight-day-old tomato plants (*Lycopersicon esculentum* 'Bonny Best') and rooted cuttings of chrysanthemums (*Chrysanthemum morifolium* 'Neptune') were exposed to hydrogen chloride (HCl) gas at concentrations ranging from 2 to 18 ppm for time periods ranging from 1 to 3 hr. Relative humidity of the exposure environment was maintained between 65 and 75%, and a light irradiance of 3.9×10^4 ergs/cm² per sec was provided. Water extracts of macerated plant tissues were titrated with a chloridometer. Large increases in chloride content were recorded for all aboveground parts of

fumigated plants as compared to control plants and plant parts. Greatest increases in tomato occurred in those leaves which were not yet fully expanded. Greatest increases in chrysanthemum occurred in immature upper leaves. The pattern of the uptake of chlorides in tomato and chrysanthemum is similar to that reported for fluorides. The procedure has potential usefulness as a diagnostic tool in assessment of air pollution injury from HCl gas.

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Additional key word: diagnosis.

Diagnosis of injury from certain air pollutants may require chemical examinations of affected tissues to verify the presence of the suspected causal agent. Such determinations assume particular importance when injury to vegetation occurs in areas where the atmosphere is contaminated by a number of pollutants. Therefore, knowledge of the behavior of pollutants within plant tissues is important in establishing proper sampling procedures, as there is considerable variation in the mode of transport of various pollutants (7, 9, 10).

Previous workers (3, 4) showed that tissue analysis for chlorides of plants injured by chlorine gas was inconclusive in determining the cause of injury. Under the conditions of those experiments, the chloride content of affected tissues was related neither to the level of exposure nor to the amount of injury produced by the gas under short-term fumigations. Recently, Hindawi (6) reported injury

to vegetation from hydrochloric acid mist and chlorine gas. A limited number of chemical analyses of affected and nonaffected tissues revealed the presence of high concentrations of chlorides in both types of tissue. More recently, Wood (11) reported injury to northern hardwood species by smoke from the combustion of polyvinyl chloride (PVC) insulation, which contained hydrochloric acid. A positive correlation between foliar chloride levels and degree of defoliation was noted in black cherry (*Prunus serotina*).

Recent studies at the National Bureau of Standards, Washington, D.C. (8), indicate that in the combustion of PVC, hydrogen chloride (HCl) gas is released at temperatures as low as 230 C, and that dark, carbonaceous smoke is not formed unless temperatures exceed 340 C. Boettner & Weiss (2) also reported that HCl gas accounts for 58% of the weight loss in the low-temperature fraction of PVC

combustion. A series of experiments was performed to establish the pattern of uptake of chlorides within plants following fumigation with HCl gas.

MATERIALS AND METHODS.—Tomato plants (*Lycopersicon esculentum* Mill. 'Bonny Best') and rooted cuttings of chrysanthemum (*Chrysanthemum morifolium* [Remat] Hemsl. 'Neptune') were maintained to 4 weeks of age with Hoagland's solution (1) and deionized water in a vermiculite potting base. Both species were fumigated in mylar chambers with HCl gas at concentrations ranging from 2 to 18 ppm for time periods ranging from 1 to 3 hr at relative humidities between 65 and 75% and an irradiance of 3.9×10^4 ergs/cm² per sec. Immediately after exposure, whole plants or individual plant parts were macerated with distilled water in a top-drive macerator. The macerate was centrifuged at 3,500 rpm for 15 min and the supernatant filtered to yield a cell-free extract. The extract was then buffered with 0.1 N nitric acid and 10% acetic acid, titrated with a Buchler-Cotlove (Buchler Instruments, Inc., Fort Lee, N.J.) automatic chloride titrator (Model No. 4-2000). Titration of repeated extracts of the pellet showed that the initial extraction contained $95\% \pm 2$ of the titratable chloride in the cell sap of the test plant tissues. The standard error due to sampling represents ca. 3.8% of the average increase in % Cl⁻ measured, or a real value of 0.0028% Cl⁻.

RESULTS.—Increases in chloride content were recorded in all above- and belowground parts of fumigated plants as compared to control plants. In tomato, immature, not fully expanded leaves showed the greatest increase in chloride levels over similar control leaves, on a fresh weight basis. The per cent chloride in these leaves was 10 times greater than in the control leaves (Table 1).

In chrysanthemum, greatest increases in chloride levels also occurred in immature leaves. Least increases occurred in roots (Table 1).

In all cases, aboveground plant parts accumulated more chloride than did roots. Increases in per cent Cl⁻ were greater in immature leaves, and these leaves also demonstrated higher total per cent Cl⁻ levels. The

distal portion of the leaves also accumulated more than did the proximal portion.

Visible injury was not necessarily coincident with increased chloride levels. Visible symptoms were observed in 62% of the trials in which symptom severity was correlated with chloride content. However, all plants involved in these trials, both with and without visible injury, showed statistically significant increases in chloride at the 5% level of probability.

DISCUSSION AND CONCLUSION.—Our evidence suggests that the pattern of chloride uptake in plants exposed to HCl gas is similar to uptake of fluoride as reported by Treshow (10). Using controlled cultural and fumigation procedures, we have shown increased levels of chloride in the foliar portions of fumigated plants. The small increases in chloride content of roots may have been due to uptake from residual chloride in the potting medium, as no attempt was made to isolate the potting medium from the fumigant. Fluorides in plants are not known to be translocated downward to the roots. Our observations suggest that a similar situation may exist with chlorides, as the increases observed in roots, although statistically significant, were only 10-15% of foliar values in chrysanthemum, and 1-3% of foliar values in tomato. Eaton (5) has reported that a number of plant species accumulate chlorides in equal or nearly equal concentrations in roots and leaves when the source of chlorides is from the soil. Such evidence suggests to us that the roots have no preferential mechanism for excluding chlorides. This information and our own observations suggest that translocation of chlorides in plants differs when the source of chlorides is from the air rather than from the soil.

Further investigations are needed to evaluate the significance of chloride determinations under field conditions where HCl gas injury is involved. The analytical procedures used in the present investigations, however, have proven to be useful and suitable for diagnostic work involving large numbers of specimens. The reproducibility and rapidity of the analytical procedures were satisfactory.

TABLE 1. Chloride concentration in cell sap extracts of tomato and chrysanthemum plants following exposure to hydrogen chloride gas

Plant part	Exposure		% Chloride ^a	
	Concn (mg/m ³)	Time (hr)	Test	Control ^b
Tomato				
Immature leaves	4.19	2	0.1504	0.0152
Mature leaves	4.19	2	0.1151	0.0092
Roots	4.19	2	0.0110	0.0090
Chrysanthemum				
Immature leaves	21.56	2	0.4700	0.0566
Mature leaves	21.56	2	0.4300	0.0400
Roots	21.56	2	0.0503	0.0012

^a Based on fresh weight.

^b For each tissue, the difference between treated and control means was significant at the 5% level of probability.

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