Relationship of Atmospheric Fluoride Levels and Injury Indexes on Gladiolus and Ponderosa Pine

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Gladiolus has been recommended as an indicator plant in the delineation of areas of atmospheric fluoride pollution. Investigations in the Spokane, Wash., area have shown that Ponderosa pine exhibits nearly equivalent foliar response to fluoride contamination. This paper reports the relationships found between the calculated injury indexes for gladiolus and Ponderosa pine exposed in the field to variable effluent fluoride pollution and the average atmospheric fluoride levels existing throughout the period of exposure. A linear correlation exists between the extent of foliar injury produced under field conditions and the average atmospheric exposure concentrations.

An intensive field investigation of the cause or causes of the "Ponderosa pine blight" in the Spokane, Wash., area was conducted during 1949 and 1950 by a team of chemists, plant pathologists, entomologists, and foresters from the State College of Washington and the U. S. Department of Agriculture. Four major factors were investigated: atmospheric pollution, including air and vegetation analysis; fungus and bacterial diseases; insect pests; and soils and climate. The joint findings of this investigative group have been reported in part at the Ponderosa Pine Blight Symposium (*7*) and elsewhere (*2, 5, 6, 8*).

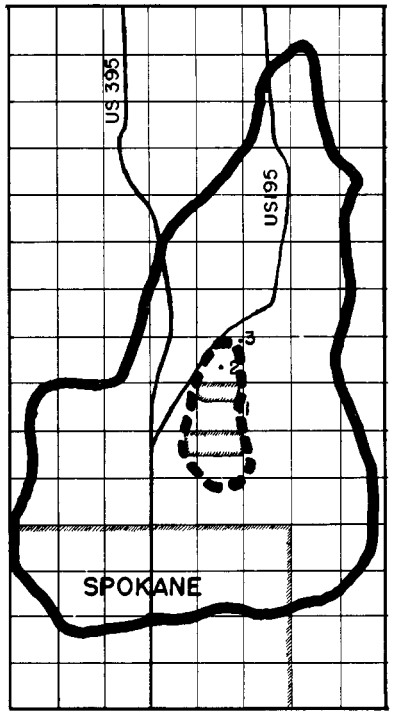
A survey of the "blighted" area in 1950 revealed that many of the Ponderosa pines within a 50-square-mile area showed the chracteristic browning and banding attributed to fluoride. Shaw reported that a large percentage of these trees within a 3-square-mile area had been killed (Figure 1) (*7*). Adams and Shaw found that damaged pine needles contained considerably higher fluoride content than those collected 10 or more miles from the center of damage (*7, 8*).

Based on the work of Allmendinger, Miller, and Johnson (*3*), Shaw, in 1950, once each week sprayed half of replicated exposures of pine and gladiolus at each of 27 exposure locations with a lime suspension which absorbed the airborne fluorides before they could enter the leaf tissue (*7*). The results obtained through this experimental technique prompted a limited 2-week experiment in 1951. It involved the simultaneous exposure of two species of vegetation in this air pollution area at three locations and collection of air samples.

The purpose of this experiment was to compare the gaseous fluoride levels obtained under the meteorological conditions which existed during the experimental period with the extent of foliar damage developed at the three test sites.

Figure 1. Location of exposure sites, Ponderosa pine blight area, Spokane County, Wash.

Area within heavy black line shows approximate maximal limit of visible pine damage, 1951. Area within broken black line, high percentage of kill



Experimental

Three exposure locations were selected to coincide with experimental sites used during the 1950 season. Location 1 was approximately 0.2 mile south of the center of pine damage. Location 2 was approximately 0.5 mile north of the damage center, and location 3 was approximately 0.8 mile north northeast of the center. The locations of these three sites are shown on Figure 1.

The air sampling equipment was of the type used during the 1950 field investigation in the Spokane area. This equipment and the methods used have been described in detail (*2*). Air was passed through alkaline scrubbing medium for 4-hour periods, collected, and subsequently analyzed for fluorine content. The individual atmospheric fluoride levels reported in Figure 2 represent the average fluoride concentrations of consecutive 4-hour periods. A continuous record of the wind direction and speed was obtained at location 1.

Picardy, Snow Princess, and E. C. Cole gladiolus were planted in 1-gallon cans in local soil. Three to five corms were grown in each can. The gladioli were at the 4- to 5-leaf stage when exposed. Two pots of each variety were placed at each of three exposure sites.

Approximately 5-year-old *Pinus ponderosa* seedlings, from the M. F. Gannon Nursery at the State College of Washington, were planted in 5-gallon cans in local soil. Four seedlings were grown in each container. One container was placed at each exposure site.

All specimens were grown in the Pullman atmosphere throughout the 1951 growing season until they were trans-

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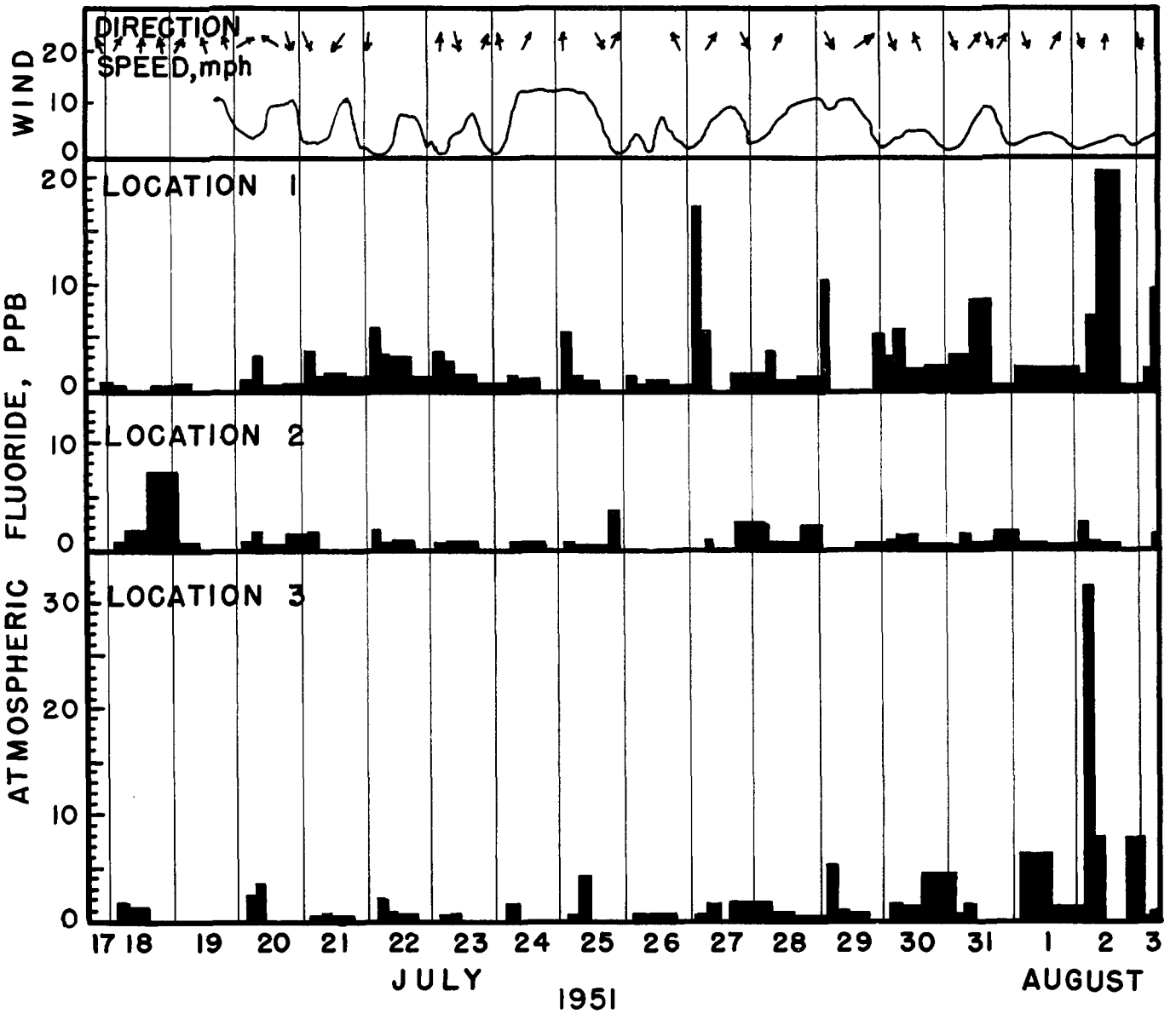


Figure 2. Concentrations of gaseous fluorine compounds at exposure sites with accompanying meteorological conditions

ported to the exposure sites on July 17, 1951. All pots were watered daily by hand throughout the progress of the experiment. The exposure specimens were removed from the Spokane area on August 2, 1951.

The degree of injury to gladiolus attributable to atmospheric fluoride was determined by measuring the length of injured and healthy area on all leaves from each plant. Johnson, Allmendinger, Miller, and Gould (*4*) define the gladiolus injury index as the total length, in inches, of injured area, multiplied by 100, divided by the total length of the leaf. Typical foliar fluoride injury to gladiolus has also been described by these investigators (*4*).

Injury indexes for Ponderosa pine seedlings were determined in a similar manner by Shaw (*7*). However, since other experiments had indicated that needles produced in previous years were resistant to fluoride, only needles produced during the current season—i.e., 1951—were considered in computing the indexes. The total number of injured needles was divided by the total number of needles and multiplied by 100 to determine the percentage of needles burned. Since even the current season's leaves on 5-year-old Ponderosa pine seedling may number above 100, rather than less than a dozen, as is the case in gladiolus, the total length of the injury and the total needle length were measured on 10% of the burned needles. However, these measurements were obtained on at least 10 needles whenever possible, even though 10% of the burned needles might be a lesser number. The needle burn index was then determined by dividing the average needle length by the average length of the injured tissue and multiplying by 100. The pine injury index for each individual seedling was calculated by multiplying the needle burn index by the percentage of the needles burned and dividing by 100. Thus the pine injury index indicates the percentage of the current season's foliage which is injured.

The Ponderosa pine injury indexes for all individual seedlings exposed at one location were then averaged to obtain the injury index for that location. Location injury indexes for gladiolus were obtained in a similar fashion.

Results

The atmospheric fluoride levels determined from the consecutive 4-hour air samples obtained at each of the three test sites have been plotted in Figure 2. Table I represents the average fluoride content of the atmosphere for the period July 17 to August 2, 1951, at each of the experimental locations.

The location injury indexes obtained for the three varieties of gladiolus exposed are indicated in Table II. Location injury indexes for the Ponderosa pine are tabulated in Table III.

The data in Tables II and III have been graphically arranged in Figure 3 to show the linear relationship between the observed degree of foliar injury and the average atmospheric fluoride level for each of the three exposure locations.

Table I. Average Atmospheric Fluoride Concentrations July 17 to August 2, 1951

Location No.	HF, P.P.B.
1	2.36
2	0.49
3	0.77

The correlation coefficients showing the relationship between injury indexes and average atmospheric fluoride levels for the three varieties of gladiolus and Ponderosa pine are given in Table IV. These values show an excellent degree of association between the two variables measured.

Table II. Gladiolus Foliar Location Injury Indexes

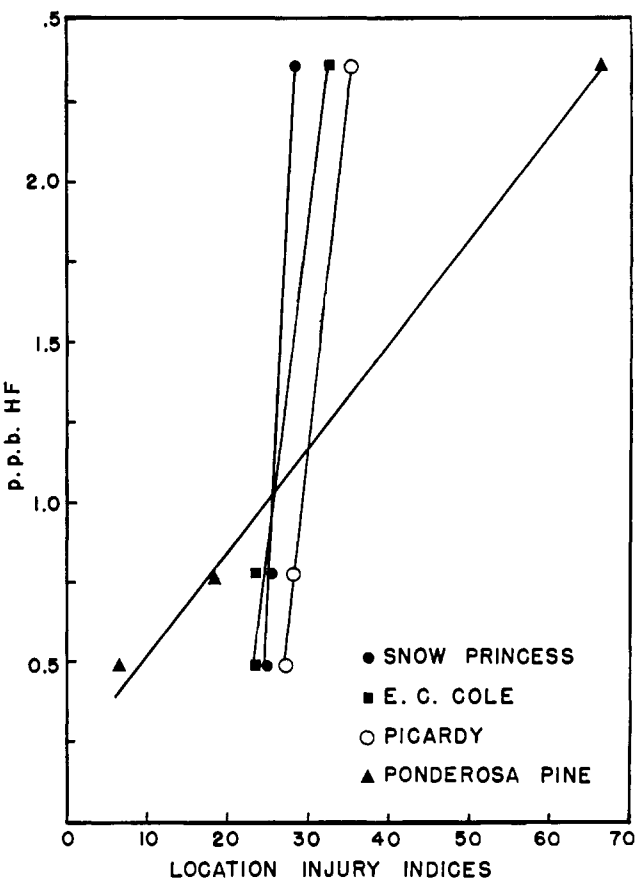
Location No.	Injury Index			
	Snow Princess	E. C. Cole	Picardy	Average
1	28.9	32.6	35.6	32.7
2	24.8	23.9	27.4	25.4
3	25.1	23.7	28.2	25.7

Table III. Ponderosa Pine Location Injury Indexes

Location No.	Injury Index
1	66.7
2	6.3
3	18.2

The gladiolus showed a greater foliar response to atmospheric fluorides at the lower exposure levels than did the Ponderosa pine. This is in agreement with the scale of relative susceptibility to hydrogen fluoride developed for 37 different species (*1*). The rate at which these two species respond to higher fluoride exposure levels is not the same, however. It was observed that Ponderosa pine exhibited a greater degree of foliar burn, as expressed by the injury indexes, at the higher exposure levels than did the gladiolus.

Figure 3. Correlation of location injury indexes with average atmospheric fluoride levels at exposure sites



Summary

Injury indexes for two species, Ponderosa pine and gladiolus, exposed to the atmosphere at three locations within an area of fluoride pollution have been related to the average atmospheric fluoride levels for the period July 17 to August 2, 1951. The relationship between the atmospheric fluoride levels and the observed injury is shown to be approximately linear in nature at the atmospheric fluoride levels existing at the test sites. The correlation of foliar injury, as expressed by the injury indexes, with the average atmospheric fluoride is excellent. Gladioli are more sensitive to low concentrations of atmospheric fluoride, whereas the Ponderosa pine show greater foliar response at the higher atmospheric fluoride levels.

Table IV. Correlation Coefficient Location Injury Indexes and Average Atmospheric Fluoride Levels

Species	Variety	N	r
Ponderosa pine		12	0.99
Gladiolus	E. C. Cole	54	0.98
Gladiolus	Snow Princess	51	1.00
Gladiolus	Picardy	72	1.00

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