There are available data upon which the trend in turbidity during this century can be estimated. Angstrom (*7*) gave 0.098 as the value of the mean annual turbidity β at Washington, D.C. (1903–1907), and 0.024 as the value at the Davos Observatory, Switzerland (1914–1926). The values for Washington were determined from data on solar transmission (by wavelength) published by the Smithsonian Institution; those for Davos were from data attributed to Lindholm on dust absorption. In 1962, determinations of the atmospheric turbidity were begun at the Continuous Air Monitoring Program station (*12*) of the Public Health Service, just a few blocks away from the Smithsonian Institution; the mean annual turbidity for 1962–1966 was 0.154. From 1957 to 1959, determinations of atmospheric turbidity were again made for Davos by Valko (*13*) and were given as 0.043. The $\Delta\beta$ was 0.056 for Washington and 0.021 for Davos; the percentage of increase was 57 for Washington and 88 for Davos. The later Washington and Davos data are published in terms of the "Schüepp coefficient" B, but were transformed into β by the relation

$$B = 1.07\beta \qquad (2)$$

for average conditions (*8*).

When the scattering theory with a Junge distribution of particle size (*14*) is used, the values of $\Delta\beta$ imply an increase in the average annual number of aerosol particles, in the range of 0.1 to 1.0 μ radius, of 2.8×10^7 cm^{-2} and 1.05×10^7 cm^{-2} over Washington and Davos, respectively, during the periods shown. As Davos is at an elevation of somewhat over 1600 m, nearly two-thirds of the Washington increase might be attributed to the increased population and urbanization of the district since the turn of the century. A significant remainder, however, as judged by the Davos increase, may be indicative of a worldwide buildup of atmospheric aerosol.

The increase in atmospheric turbidity due to volcanic eruptions may have temporary effects on atmospheric temperatures. Mitchell (*4*) concluded that temperatures may be depressed ". . . as much as 0.5°F or more in the first or second year following an unusually violent eruption. . . ." However, we suggest that the effects of man's pollution of his environment are monotonically increasing along with the world population. The emission of long-lived aerosol, keeping pace with the accelerated worldwide production of CO_2 (*3*) may well be leading to the decrease in worldwide air temperature in spite of the apparent buildup of CO_2 In any case, it is clear that in this "large-scale geophysical experiment" in which human beings are engaged (*1*), the course of atmospheric turbidity must be documented with concern.

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Atmospheric Ions and Germination of Uredospores of Puccinia striiformis

Abstract. *Atmospheric ions, identified by mobility characteristics, were associated with germination of lyophilized uredospores of* Puccinia striiformis *West. at Bozeman, Montana. Ions of intermediate size were highest in concentration, and percentage germination of spores was lowest during periods conducive to air pollution. In duplicate experiments at an isolated site near Barrow, Alaska, essentially all atmospheric ions were small ions and the fungus spores were consistently germinated near maximum.*

Uredospores of *Puccinia striiformis*, causal agent of stripe rust of wheat, are extremely sensitive to environment (*1*). They often germinate poorly in a so-called controlled environment during about a 4-month period centered on winter solstice, with wide fluctuations in day-to-day values (*2*). Furthermore, the daily germination values are related to external meteorologic conditions (*2*), and certain meteorologic factors can influence natural levels of ions (*3*). There is considerable information on the effects of generated ions on biologic systems (*4*), but there are few quantitative data on the biologic effects of naturally occurring air ions. In earlier studies, exposure of the spores to generated small ions of either charge did increase percentage germination (*2*). My study indicates that the germination process of uredospores of *P. striiformis* is influenced by naturally occurring atmospheric ions.

Techniques for measuring atmospheric ions have been described (*5*). In my study, Royco-412 ion collectors and accessories were used to allow monitoring within a range of mobilities from 0.0064 to more than 0.274 cm^2 volt^{-1} sec^{-1}. This range includes the intermediate and small ions of both polarity groups. Most comparisons were made between negative ions having a mobility of 0.03 to 0.274 cm^2 volt^{-1} sec^{-1} and negative ions having a mobility exceeding 0.274 cm^2 volt^{-1} sec^{-1}.

Spores from two collections of the fungus were dusted onto polyethylene membranes at the same time each day and were exposed to simulated dew at 5°C over a 30-day period from 5 January to 3 February 1967. Concentrations were adjusted to give 20 to 40 spores per microscope field at $\times$ 100. After 6 or 24 hours, percentage germination was determined by microscope examination of a total of more than 800 spores contained on two membranes per treatment. Any spore having a germ tube longer than the spore diameter of about 20 μ was considered germinated. All spores within a collection were harvested at the same time, were lyophilized shortly thereafter, and had the same germination potential throughout the assay period. Spores contained within separate hermetically sealed lyophil tubes were used for each day's assay. External air introduced to the germination chambers and to the ion collectors was not filtered. Duplicate trials were conducted on the university campus at Bozeman, Montana, and in a wanigan located on the tundra about 1.6 km from the Arctic Research Laboratory, Barrow, Alaska.

In the Bozeman trials, the ratio of small to intermediate ions varied greatly

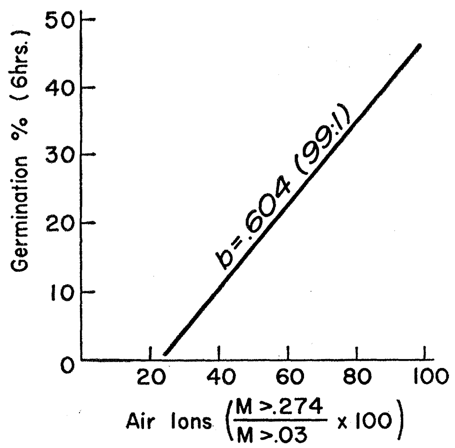

Fig. 1. Relation of germination of *P. striiformis* to air-ion ratios. *M*, Mobility (cm^2 $volt^{-1}$ sec^{-1}); *b*, linear-regression coefficient; *99:1*, significantly different from $b = 0$ at 1-percent level.

throughout the assay period. As the concentration of intermediate ions (mobility exceeding 0.03 cm^2 $volt^{-1}$ sec^{-1}) increased, the percentage germination decreased and the linear-regression coefficient was significant at the 1-percent level (Fig. 1). The data were calculated on the basis of concentrations of negative ions. Positive-ion concentrations were proportional to negative-ion concentrations but were usually slightly higher. Germination was essentially nil on the days when the small ions (mobility exceeding 0.274 cm^2 $volt^{-1}$ sec^{-1}) constituted less than 25 percent of the ions monitored.

Meteorological factors, temperature and wind, also were associated with the germination values at Bozeman but not at Barrow (Table 1). During days of low temperature and low wind velocity at Bozeman the small ions decreased concomitantly with lower germination values; it is believed that this decrease was due to accumulation of air pollutants, enhanced by conditions of temperature inversion (*6*). Relatively high concentrations of small ions were always associated with low concentrations of intermediate ions, and vice versa. Larger air ions (mobility exceeding 0.0064 cm^2 $volt^{-1}$ sec^{-1}) may be the most important in inhibiting germination, but during this study high concentrations of this group were always associated with high levels of ions of mobility greater than 0.03 cm^2 $volt^{-1}$ sec^{-1}.

At the Barrow site essentially all air ions detected were small ions, and percentage germination was near maximum with daily assay (Table 1). Even during favorable days at Bozeman, percentage germination was often significantly lower than at Barrow; such lower percentages may be due to other air ions of lower mobility than those monitored.

It appears obvious that external temperature and wind are not associated with germination at Barrow. There were relatively calm days, with temperatures as low as −33°C, but the location of the site precluded air pollution with associated effects on the mobility spectrum of air ions. The concentration of negative small ions in air varied from 119 to 255 per cubic centimeter; concentrations of positive small ions were proportional but usually slightly higher. Generated positive and negative small ions have been equally effective in stimulating growth of higher plants, but have generally had a moderately lethal effect on microorganisms (*4*).

In this investigation low ratios of small:intermediate air ions were highly correlated with a reduced rate of germination (as shown by the daily 6-hour germination assays) and with reduced total germination (as shown by daily 24-hour germination assays). Although the 24-hour germination values were usually somewhat higher than the 6-hour values, they showed the same correlation with air-ion ratios.

The greatest day-to-day fluctuations in spore germination occur during the relatively short days of fall and winter, when inversions are most likely to enhance air pollution. During longer days, greater solar radiation probably destroys surface inversion layers, and spores of *P. striiformis* more frequently germinate near maximum potential.

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Table 1. Association of weather factors and atmospheric ions with germination of fungus spores. The meteorological and atmospheric ion data are averages of determinations made hourly during the 6-hour germination periods. Intermediate-ion mobility, 0.03 to 0.274 cm^2 $volt^{-1}$ sec^{-1}; small-ion mobility, more than 0.274 cm^2 $volt^{-1}$ sec^{-1}. Periods for the five highest and five lowest germination values between 5 January and 3 February 1967 at Bozeman are compared with the same days at Barrow. Germination percentages analyzed as angles; means with a letter in common do not differ at the 1-percent level according to Duncan's new multiple-angle test (*7*).

Germination (%)	Wind (knots)	Temp. (°C)	Negative ions in air (No./cm^3)	
			Intermediate	Small
		Bozeman		
tr. g	0.7	−12	357	119
tr. g	1.7	−10	714	204
tr. g	0.6	− 8	459	272
2 g	.7	−11	323	102
4 g	2.0	5	289	170
39 f	9.2	6	102	374
39 f	9.1	3	136	442
42 ef	5.0	− 1	34	391
47 def	7.5	6	68	374
48 cdef	3.5	4	17	493
		Barrow		
57 bcde	3.0	−32	0	238
59 abcd	4.0	−21	0	153
60 abcd	4.3	−27	0	187
60 abcd	13.8	−19	34	119
63 abc	4.7	−33	17	136
68 ab	6.0	−13	0	187
68 ab	10.0	−28	0	255
69 ab	10.3	−10	0	238
70 ab	9.3	−19	0	119
72 a	9.0	−23	0	187

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