Effect of Low-Level Ozone Fumigations on Crown Rust of Oats

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ABSTRACT

Exposure of crown rust differential varieties of *Avena* spp. to 10 pphm ozone for 6 hr in the light for 10 days after infection with *Puccinia coronata* significantly reduced the growth of uredia. Urediospores produced on the plants exposed to ozone germinated as well, produced as many appressoria, and resulted in as much infection as spores produced on unexposed leaves. Exposure on dry leaves to 20 pphm ozone for 3 hr for 1-5 days did not affect urediospore germination, appressoria formation, or penetration. Phytopathology 60:252-254.

Few reports of air pollution effects on rust fungi appear in the literature. Field observations indicate that smelter fumes containing sulfur dioxide (SO_2) reduce the incidence of various pathogenic leaf and needle fungi (2, 4). Species of *Melampsora, Pucciniastrum, Coleosporium,* and *Cronartium* were among those most severely affected.

Sharp (5) showed that germination of *Puccinia striiformis* urediospores was reduced when they were exposed to high ion concentrations in the atmosphere during incubation. Ozonated olefin injury was reduced in beans infected with *Puccinia helianthi* (9), but no effects on rust development were noted.

This report describes some effects of low-level ozone exposures on crown rust uredium development, urediospore germination, appressorium formation, and penetration.

MATERIALS AND METHODS.—Oats, *Avena* spp., were grown in a greenhouse in a peat-perlite mix and watered daily with half-strength Hoagland's solution. The first foliage leaves of the 10 oat crown rust differential varieties (8) were inoculated with urediospores of race 264 of crown rust, *Puccinia coronata* var. *avenae* Fraser & Led., when the plants were 10 days old. Infection occurred during a 16-hr period in a mist chamber at 23°C. Infected plants were then placed in separate but identical chambers (1) at 25°C, 80 RH, and a 16-hr photoperiod of 3,000 ft-c. Approximately 10 infected plants of each differential variety, in each of four pots in one chamber, were exposed to 10 pphm ozone (KI corrected Mast value). Exposures were for 6 hr daily at 27°C during the light period on the 12 days following inoculation. The same number of plants in the other fumigation chamber were not exposed.

Infection types, as described by Murphy (3), of individual uredial sori were recorded for each variety 11 days after infection occurred.

Urediospores were collected from plants in each treatment after the 12th exposure, placed on the upper surface of first foliar leaves of 15-day-old Clintland 64 oats, and incubated as described above. Immediately following incubation, leaves were removed from plants

TABLE 1. Effects of ozone on the infection index, infection type, and reaction of *Puccinia coronata avenae* race 264 on the differential varieties[a]

Differential var.		Infection index[b]		Infection type[c]		Reaction[d]	
		10 pphm Ozone	Carbon-filtered air	10 pphm Ozone	Carbon-filtered air	10 pphm Ozone	Carbon-filtered air
Anthony	1	5.1	8.6	2	3+	R	S
Victoria	2	4.3	8.2	2−	3	R	S
Appler	3	4.8	8.3	2	3	R	S
Bond	4	4.9	8.8	2	3+	R	S
Landhafer	5	6.1	9.0	2+	3+	R	S
Santa Fe	6	4.7	8.1	2	3	R	S
Ukraine	7	3.6	6.7	2−	3−	R	S
Trispernia	8	2.7	5.5	1+	2+	R	R
Bondvic	9	3.3	5.8	1+	2+	R	R
Saia	10	0.6	0.8	1−	1−	R	R

[a] Infected plants were exposed to 10 pphm for 6 hr daily for 10 days.

[b] The avg of over 200 pustules/treatment in two experiments when infection types O; 1−, 1, 1+, 2−, 2, 2+, 3−, 3, 3+, 4−, 4, and 4+ were assigned values of 0-12, respectively. According to the Chi Square test, pustules were significantly smaller (1% level) on fumigated plants than on nonfumigated plants of each variety.

[c] The avg infection type calculated from the infection index[b].

[d] As described by Murphy (3). R = resistant; S = susceptible.

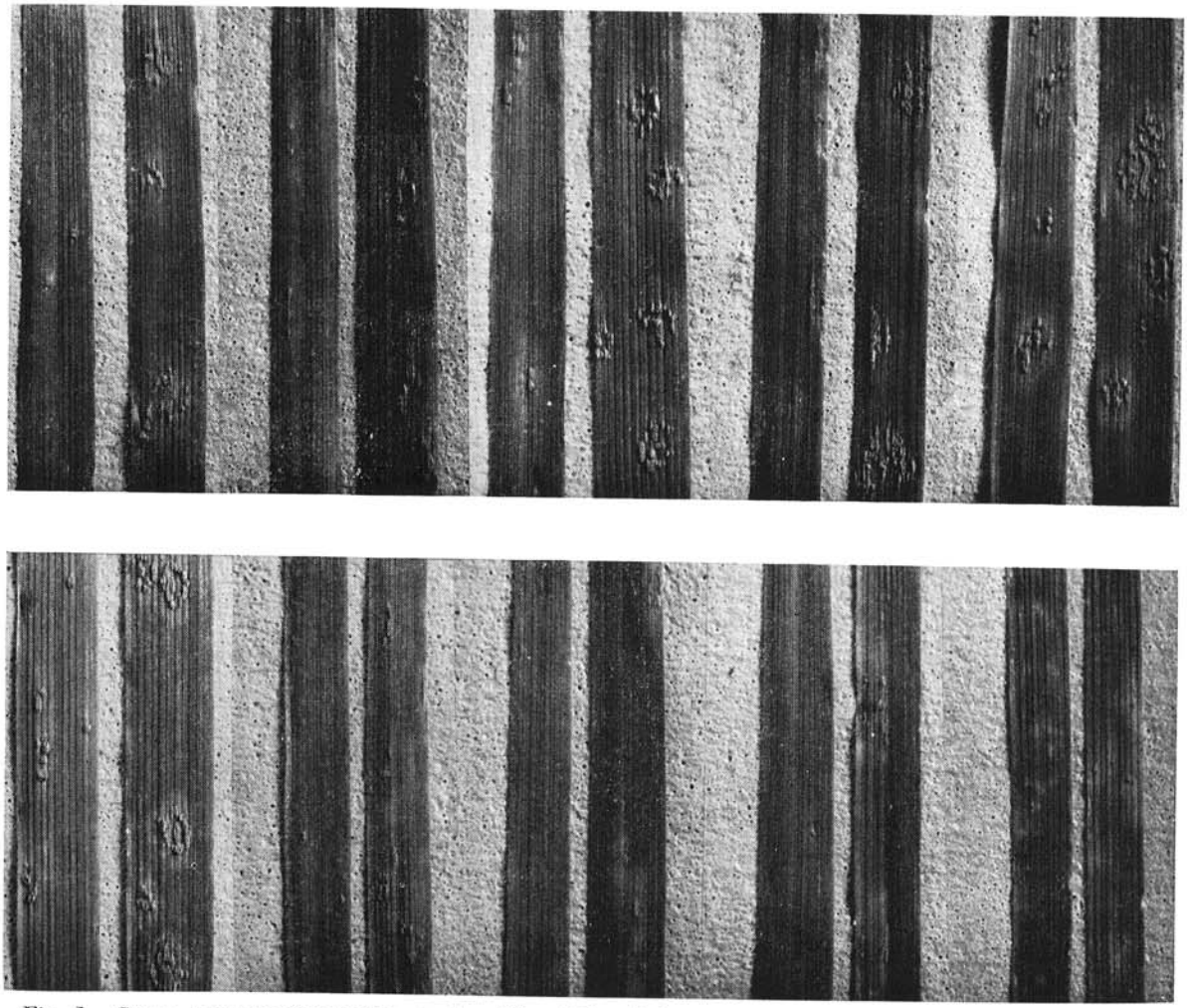

Fig. 1. Crown rust race 264 pustules on the differential varieties 11 days after inoculation. Top row, differentials 1-5; bottom row, differentials 6-10. The left leaf in each pair was exposed to 10 pphm ozone (KI corrected Mast value) for 6 hr on 10 consecutive days following inoculation. The right leaf in each pair was grown in carbon-filtered air.

and processed according to the whole-leaf clearing and staining technique described by Shipton & Brown (6). The percentage of spores that germinated, the percentage that germinated and produced appressoria, and the percentage of appressoria that developed penetration pegs and substomatal vesicles was determined for each treatment.

First foliage leaves of 15-day-old Clintland 64 oats were inoculated with freshly collected urediospores produced in a carbon-filtered greenhouse, and placed in the exposure chambers as described above. Prior to incubation, plants and spores in one chamber were exposed to 20 pphm ozone (KI corrected Mast value) for 3 hr for 1-5 days in the light. Following each exposure, approximately 10 plants were removed from each chamber and incubated, stained, and examined as outlined above.

Each experiment was repeated once. A statistical analysis according to the Chi Square test was performed on the results.

RESULTS.—Pustules in both treatments were first visible at about the same time on all differentials. After 10 days of fumigation, pustules were significantly smaller on leaves exposed to ozone than on nonexposed leaves of all varieties (Fig. 1). In most varieties, the reaction was changed from susceptible to resistant

TABLE 2. Effect of ozone on percentage of spores of *Puccinia coronata avenae* that germinated or germinated and produced appressoria, and percentage of appressoria that resulted in infection[a]

Treatment	% Germination	% Appressoria	% Penetration
10 pphm Ozone	85[b]	22	65
Carbon-filtered air	89	27	58

[a] Urediospores were produced on plants exposed to 10 pphm ozone or carbon-filtered air for 6 hr daily in the light for 12 days after infection.

[b] Each figure is the avg of over 1,000 spores or appressoria on 10 leaves in two experiments.

TABLE 3. Effect of ozone on percentage of spores of *Puccinia coronata avenae* that germinated or germinated and produced appressoria, and percentage of appressoria that resulted in infection[a]

Days exposure	% Germination		% Appressoria		% Penetration	
	20 pphm Ozone	Carbon-filtered air	20 pphm Ozone	Carbon-filtered air	20 pphm Ozone	Carbon-filtered air
1	87[b]	90	34	37	79	78
2	83	85	30	32	69	74
3	88	80	31	28	65	71
4	73[c]	81	22[c]	32	67[c]	70
5	71	64	18	19	57	57

[a] Spores were exposed on dry leaves to 20 pphm ozone or carbon-filtered air for 3 hr daily for 1-5 days in the light.
[b] Each figure is the avg of 700-1,000 spores or appressoria on 7-10 leaves in two experiments.
[c] Data in one experiment were missing.

(Table 1). The average reaction of race 264 on the varieties Trispernia and Bondvic is given by Simons & Michel (7) as susceptible. In this experiment, the reaction on these varieties was resistant. It is possible that environmental conditions or incubation time caused a resistant reaction on Trispernia and Bondvic.

Visible ozone injury was limited to a slight flecking over less than 1% of the leaf surface of all fumigated plants. Near the end of the experiment, the fumigated differentials Victoria, Bond, Trispernia, Bondvic, and Saia showed a slight bronzing on the inoculated leaves.

Urediospores that were produced on plants exposed to ozone germinated as well, produced as many appressoria, and resulted in as much infection as spores produced on leaves grown in an ozone-free atmosphere (Table 2).

Germination, appressorium formation, and penetrations from spores exposed on dry leaves to 20 pphm ozone for 3 hr on 1-5 days was comparable to that on spores on dry leaves in the ozone-free chamber (Table 3).

DISCUSSION.—Urediospore production in the two environments was not measured, but it appeared that about half as many spores were produced in the ozone chamber as in the clean-air chamber. The suppression of crown rust uredium development in this experiment was caused by ozone levels that are commonly surpassed in many areas. This strongly suggests that the development of crown rust, and possibly of other parasites, is affected by photochemical air pollution. Consideration should be given to the possible effects of air pollution in retarding uredia growth where rust race identifications are made. If air pollution alters the development of fungi in the field, the results may or may not be economically important; however, any effect of air pollution on the development of microorganisms is of itself important.

The mechanism of ozone action in retarding uredia development was not determined. This effect may have resulted from direct ozone action on the fungus or ozone action on the host, thereby indirectly retarding uredia development.

LITERATURE CITED

1. HECK, W. W., J. A. DUNNING, & H. JOHNSON. 1968. Design of a simple plant exposure chamber. Nat. Center for Air Pollution Control Pub. APTD-68-6.
2. LINZON, S. N. 1958. The influence of smelter fumes on growth of white pine in the Sudbury region of Canada. Can. Dep. Agr. Pub., Ontario Dep. Lands. 45 p.
3. MURPHY, H. C. 1935. Physiologic specialization in *Puccinia coronata avenae*. USDA Tech. Bull. 433:1-48.
4. SCHEFFER, T. C., & G. G. HEDGCOCK. 1955. Injury to Northeastern forest trees by sulfur dioxide from smelters. USDA Tech. Bull. 1117. 49 p.
5. SHARP, E. L. 1967. Atmospheric ions and germination of uredospores of *Puccinia striiformis*. Science 156: 1359-1360.
6. SHIPTON, W. A., & J. F. BROWN. 1962. A whole-leaf clearing and staining technique to demonstrate host-pathogen relationships of wheat stem rust. Phytopathology 52:1313.
7. SIMONS, M. D., & L. J. MICHEL. 1964. International register of pathogenic races of *Puccinia coronata* var. *avenae*. Plant Dis. Reptr. 48:763-766.
8. SIMONS, M. D., & H. C. MURPHY. 1955. A comparison of certain combinations of oat varieties as crown rust differentials, USDA Tech. Bull. 1112. 22 p.
9. YARWOOD, C. E., & J. T. MIDDLETON. 1954. Smog injury and rust infection. Plant Physiol. 29:393-395.