Presence, Viability, and Movement of *Puccinia recondita* and *P. graminis* Inoculum in the Great Plains

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ABSTRACT

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Kramer-Collins 7-day spore samplers were used to study availability, viability, and movement of *Puccinia recondita* and *P. graminis* urediniospores throughout the year in the Great Plains. From October 1974 to August 1977, the longest period of consecutive days that no spores were trapped at any of the Great Plains locations (Renner, TX; Altus, Goodwell, and Stillwater, OK; and Parsons, St. John, Garden City, Hays, and Manhattan, KS) was 19 for *P. recondita* and 18 for *P. graminis*. Estimated viability of urediniospores trapped was 61% for *P. recondita* and 58% for *P. graminis*. Viable inoculum was present in the central Great Plains wheat-growing areas most of the time samples were taken; therefore, epidemic development was largely dependent on favorable weather and host-parasite combinations. Forecasted wind trajectories were used to indicate spore movement patterns; however, we were unable to develop significant statistical models of urediniospore movement.

The seasonal occurrence of *Puccinia recondita* Rob. ex Desm. f. sp. *tritici* and *P. graminis* Pers. f. sp. *tritici* urediniospores and their relationship to cereal rust epidemics in the Great Plains region of the United States is well documented (2,4,9,10). Infection of large acreages of wheat from a remote inoculum source has been established (1,5,7,8). Movement of urediniospores from Mexico to Canada via the upper Mississippi River Valley was investigated by Asai (1). Infection of wheat on the British Isles by inoculum carried across the English Channel from the European continent has been documented by Hirst and Hurst (5). McEwan (7) concluded that New Zealand cultivars were infected by urediniospores transported from Australia by wind. Mehta (8) reported the spread of *P. graminis* from mountain regions of India to the plains area by airborne inoculum.

Viability of inoculum in air masses over the Great Plains region has not been considered in previous studies. To obtain a better insight into the effectiveness of urediniospores of *P. recondita* and *P. graminis* that move across the central Great Plains in the epidemic development of the wheat rusts, a 4-yr study involving 10 sampling stations in Kansas, Oklahoma, Texas, and Kentucky was undertaken. Using data from nine of these stations, we attempted to trace the movement of urediniospore clouds across the central Great Plains, including Nebraska, Kansas, Oklahoma, and northern Texas, where about one-half of the total wheat acreage of the United States is planted. A second objective was to determine the availability of viable airborne inoculum throughout the year in the Great Plains.

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MATERIALS AND METHODS

Air samples to measure urediniospore concentrations of *P. recondita* and *P. graminis* were taken with Kramer-Collins 7-day spore samplers (6) situated on towers at 10 m above ground level. Previous studies have indicated that at 6 m above ground level or higher, most of the spores trapped are likely to be from a source removed from the sampler location (3,4). The sampler and vacuum pump were fixed to a metal rack that could be raised and lowered by a rope and pulley system. Guide wires attached to the rack prevented the sampler from swinging freely in the wind but an airtight bearing allowed the sampler to rotate, thereby keeping the intake orifice facing into the wind at all times. A vacuum pump was situated on the rack just below the sampler.

The exposed drum of each sampler was removed, the mechanical clock motor used to rotate the drum was wound, and an unexposed drum was inserted in the samplers each week. Unexposed drums were prepared by placing double-coated adhesive cellophane tape around the drum and applying a light coat of silicone on the tape (6) in the laboratory, after which they were mailed to the sampling stations. After servicing a sampler, the exposed drum was returned to our laboratory for processing.

The collecting tapes from exposed drums were removed and transferred to lengths (4 × 45 cm) of 1-mm-thick Plexiglas. The spore depositions were examined directly from the exposed tapes by using a microscope with a stage specially designed to hold the 45-cm strips. These stages were constructed of 6-mm Plexiglas and attached to the existing mechanical microscope stage. Twenty-four-hour segments could be read using the mechanical stage adjustment without repositioning the tape strip.

Urediniospore counts were made by examining portions of the deposits through each 24-hr period and converting those counts to average numbers per cubic meter of air for the 24-hr period for each location.

Urediniospore viability was measured on collections that arrived in the laboratory within 24 hr of removal from the sampler. Germination was measured only on the last 24-hr portion of the weekly deposit. At least three urediniospores had to be deposited in the 24-hr sample for a germination test to be completed. Exposed tapes were incubated for 6 hr in a moist chamber at 21.1 C to ascertain spore viability. A spore was considered viable if the germ tube length was equal to the spore diameter.

Estimates of leaf and stem rust

severities on commercial wheat fields were obtained irregularly throughout the sampling period. Estimates of leaf and stem rust severity on trap plots in the sampling area were obtained one to three times in the fall after planting and four to six times in the spring growing season.

Meteorological data including wind trajectory forecast maps were obtained from National Weather Service Office, Topeka, KS 66601. Wind trajectory forecast maps for the 850-mb level were used to show probable movement of an air particle over a 24-hr period.

The nine sampling stations used in this study were located at agricultural experiment stations or experiment fields in or near the following cities: Renner, TX; Altus, Stillwater, and Goodwell, OK; and Parsons, St. John, Garden City, Hays, and Manhattan, KS. A member of the staff at each location assumed the responsibility for servicing the sampler each week.

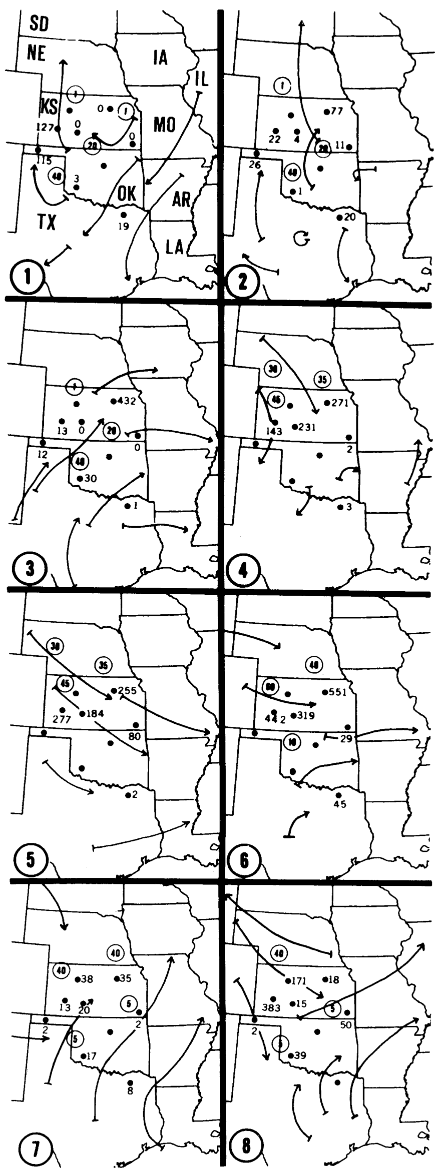
RESULTS

Spore numbers at each location were compared with wind trajectories and rust severities obtained from ground observations (Figs. 1–8). The base of each arrow denotes the area from which the air particle originated. The arrow shaft indicates the direction and distance the air particle was forecast to travel during the 24 hr. The average number of *P. recondita* urediniospores per cubic meter of air sampled at each location is indicated at the locations on Figures 1–8; estimates of leaf rust severities for areas near a sampling location are also included.

Wind direction at Manhattan, KS, on 17 May 1975 (Fig. 1) was from the north, traversing areas where no rust was found on the flag leaves and very little rust had developed on leaves lower in the canopy. Urediniospores were not trapped at the Manhattan site on either 16 or 17 May (Fig. 1). The winds shifted to the south on 18 and 19 May (Figs. 2 and 3), blowing across large wheat acreages in central Oklahoma and south central Kansas, which had moderate severities (20–40%) of leaf rust. Urediniospore numbers began to increase at the Manhattan site and the number of urediniospores trapped remained higher than 100/m^3 as the winds continued from the south for several days. By 1 June, leaf rust severities on the flag leaf began to increase in northern Kansas and southern Nebraska and the number of urediniospores trapped remained higher than 200/m^3 (11–12 June), regardless of the direction of wind movement (Figs. 4 and 5).

The wheat crop was in the soft dough growth stage in northern Kansas by 14 June. Wheat leaf rust severities ranged from 30 to 60% in northern Kansas and into southern Nebraska. Relatively high numbers (>550/m^3) of urediniospores were trapped at Manhattan (Fig. 6) on 14 June, correlating with northwesterly winds. As the wheat crop was harvested to the south and west of Manhattan and southerly winds became predominant again, the number of urediniospores decreased, ranging from 0 to 26/m^3 (19–21 June).

Similar patterns were observed in 1976 and 1977. In northern Texas and southern Oklahoma, southerly winds passed over wheat that was in the soft dough growth stage, and leaf rust severities of 20–40% were observed. As expected, exceptionally high numbers of urediniospores (360–450/m^3) were trapped at Altus, OK, on 20–21 May 1976. Harvest was in progress in the Chillicothe, TX, area and to the south when northerly winds on 25 May 1976, passing over areas with lower leaf rust severities, resulted in a 95% reduction in the number of urediniospores trapped at all sites except Renner, TX, and Altus, OK. Locally released spores were probably being trapped at those two sites. By 3 and 4 June, urediniospore numbers at the Kansas sites began to increase while those in Texas and southern Oklahoma began to decrease. As the crop season progressed, the difference in number of spores trapped at the sites became more pronounced. Data from 15 June (Fig. 7) and 16 June (Fig. 8) serve as excellent examples of the effect of wind direction on the transport of spores. With wheat harvest essentially completed on 15 June (Fig. 7) in Texas and Oklahoma, southerly winds on that date correlated with very low numbers of urediniospores trapped in Kansas. As winds changed to a



Figs. 1–8. Number of *Puccinia recondita* urediniospores collected by volumetric sampling at 10 m above ground level at nine Great Plains locations. State abbreviations: AR = Arkansas, IA = Iowa, IL = Illinois, KS = Kansas, LA = Louisiana, MO = Missouri, NE = Nebraska, OK = Oklahoma, SD = South Dakota, and TX = Texas. Forecasted wind trajectories for the 24-hr period are shown as arrows. Wheat leaf rust severities are shown as circled numbers. Dates by figure: **(1)** 17 May 1975, **(2)** 18 May 1975, **(3)** 19 May 1975, **(4)** 11 June 1975, **(5)** 12 June 1975, **(6)** 14 June 1975, **(7)** 15 June 1976, and **(8)** 16 June 1976.

Table 1. Number of consecutive days that no urediniospores were trapped by volumetric samplers on 10-m towers at any of the Great Plains locations (Renner, Altus, Goodwell, Stillwater, Parsons, St. John, Garden City, Hays, Manhattan)

		Puccinia	
Year	**Month**	***recondita***	***graminis***
1974	October	2	3
	November	1	3
	December	0	10
1975	January	3	13
	February	4*[a]	10*
	March	10*	3*
	April	0	1
	May	1	4
	June	0	0
	July	7*	9*
	August	2*	14*
	September	2*	6*
	October	3	5
	November	4	14
	December	8*	12*
1976	January	7*	14*
	February	6*	17*
	March	5	10
	April	2	7
	May	0	0
	June	0	0
	July	2	1
	August	5	3
	September	12	6
	October	6*	9*
	November	14*	17*
	December	16*	19*
1977	January	18*	14*
	February	16*	12*
	March	11*	18*
	April	3*	11*
	May	4	3
	June	0	0
	July	4	2
	August	3	4

[a] Asterisk after a number means that at least one sampling station was not operating during this period.

Table 2. Percentage germination of *Puccinia recondita* and *P. graminis* urediniospores trapped at 10 m above ground level in the Great Plains

Location	Date	Percent urediniospores germinated	
		P. recondita	*P. graminis*
Manhattan, KS	24 Nov. 1974	44	25
	15 Dec. 1974	14	...
	22 Jan. 1975	14	...
	16 Mar. 1975	80	...
	10 May 1975	58	...
	10 Jun. 1975	82	58
	21 Jul. 1975	33	...
	10 Oct. 1975	50	67
	14 Feb. 1976	0	...
	30 Apr. 1976	66	...
	21 May 1976	69	...
	12 Jun. 1976	82	84
	10 Aug. 1976	81	100[a]
Avg.		73	75
Renner, TX	18 Nov. 1974	60	33
	16 Jun. 1975	61	40
	11 Jun. 1976	43	0[a]
	20 Jun. 1977	47	50
Avg.		48	33
Altus, OK	25 Nov. 1974	37	22
	24 May 1975	60	0[a]
	25 Oct. 1975	0	0[a]
	13 Jun. 1976	73	70
	10 Jun. 1977	54	56
Avg.		50	53
Goodwell, OK	12 Nov. 1974	18	20
	18 May 1975	58	50
	11 Oct. 1975	33	0[a]
	9 Jun. 1976	66	50
	15 Jun. 1977	63	43
Avg.		53	38
Garden City, KS	13 Jun. 1976	79	64
St. John, KS	13 Jun. 1975	63	62
	11 Oct. 1976	55	71
	15 Jan. 1976	55	71
	14 Jun. 1977	57	14
Avg.		61	63
Parsons, KS	10 Jun. 1975	65	44
	12 Jun. 1976	50	25
Avg.		57	41
Stillwater, OK	16 Jun. 1977	56	53
Avg. for all locations		61	58
Avg. for fall season		35	35
Avg. for spring season		64	61

[a] Fewer than three urediniospores were found in the 24-hr period indicated.

northerly direction on 16 June (Fig. 8), however, spore numbers showed a marked increase at Hays and Garden City, KS.

Table 1 lists the number of consecutive days during each month from October 1974 to August 1977 during which no urediniospores of *P. graminis* and *P. recondita* were trapped at the sampling stations in northern Texas, Oklahoma, and Kansas. The longest single period was 19 days during December 1976. Generally, extended periods occurred during the winter months, whereas spores were often trapped each day at each collection site during late spring and early summer, corresponding with the growing and harvest seasons of wheat.

The percentages of viable *P. recondita* and *P. graminis* urediniospores (Table 2) trapped at 10 m above ground level at the sampling locations in the Great Plains were twice as high (64 vs. 35%) in the spring growing season (March–June) as during the inoculum oversummering (July–September) or overwintering (December–February) seasons. Sampling location had no effect on viability.

DISCUSSION

Maps of spore concentrations overlaid by trajectories of wind movement at various locations indicate that forecasted wind trajectories can be used to indicate spore movement patterns (Figs. 1–8), because spore concentration increased or decreased as the air mass being sampled traversed areas containing differing levels of disease severity. Actual number of urediniospores trapped at a location correlated very well with daily forecasted wind trajectories and disease severity estimates along the trajectory path. Because of sampler malfunction and the small number of sampling stations, however, we were unable to develop a satisfactory model or forecast of the travel distance of airborne urediniospore concentrations (spore clouds).

Knowledge of the increase or decrease in disease severity on the wheat flag leaf along the path of a trajectory enabled us to use wind trajectories to forecast increasing or decreasing spore concentrations at a sampling site where disease severities were very low (Figs. 7 and 8). Viable inoculum in the form of airborne urediniospores was present at one or more sites in the Great Plains region every month sampled of the period October 1974–August 1977 (Table 2). However, sampler malfunction or nonavailability of exposed drums within 24 hr of removal from the sampler limited our analyses at several locations.

Viability (64%) of urediniospores collected from March through July was almost twice as high as viability (35%) of those collected during the overseasoning period (summer or winter). Viability of urediniospores collected from uredinia in commercial fields near the samplers and incubated at 21.1 C on water agar ranged from 91 to 98%. Viability of inoculum trapped by the samplers on the same day ranged from 66 to 82%. Nonsignificant differences in viability of urediniospores were observed between the sampler and water agar techniques when the same spore source was used. The greatest spore concentrations and the highest spore viability were observed during periods of active epidemic development within the region.

During the period covered by this study, however, neither leaf nor stem rust developed into a serious epidemic in the Great Plains region. Results of this study indicate that viable *P. recondita* and *P. graminis* inoculum was present most of the time in the central Great Plains. Epidemic development was dependent on favorable weather and host-parasite combinations.

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