Air-Spora Above a Kansas Wheat Field

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ABSTRACT

Kramer-Collins volumetric spore samplers were operated in the wheat canopy and on towers 1, 3, 6, and/or 14 m above ground level to measure concentrations of *Puccinia graminis, P. recondita, Erysiphe graminis, Cladosporium,* and *Alternaria* spores, and hyphal fragments above a wheat field in 1967-1971. Comparison of hourly meteorological factors and hourly spore concentrations showed that within a 24-hour period concentrations of airborne spores fluctuate as influenced by wind velocity, turbulence, dew, rain, and storm fronts as well as by periodicity in spore production. Location of spore samplers in relation to spore sources and wind direction was shown to be extremely important in determination and analysis of spore concentrations.

We were unable to determine any statistical relationships which could be used to predict hourly spore concentrations using only meteorological variables such as wind velocity, turbulence, rain, dew, or temperature.

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Airborne spores are of utmost importance in the rapid dissemination of many plant pathogens from a source area both in local and long distance dispersal. In a previous paper (1), we reported that urediospores of *Puccinia graminis* Per. f. sp. *tritici* trapped within a wheat canopy were an indication of the number of spores being released from a point source. Urediospore counts from traps placed at canopy height (1 m) were less than 10% of those trapped within the canopy; at 6 m above ground they were less than 2%. Roelfs (5) reported that 13.7% of *P. graminis* urediospores released 1 m above ground would still be at the same height at 100 m downwind; Gregory (2) stated that only 25% of the spores released at 1 m would still be airborne 100 m downwind. These studies (1) indicate a very small percentage of spores produced and available to serve as inoculum, becomes airborne and is effective in either local or long-distance dispersal.

Meteorological factors influence the percentage of spores [such as urediospores of the wheat rust fungi, and conidia of *Erysiphe graminis* (DC.) Mérat, *Cladosporium,* and *Alternaria*] that become airborne from a source area. Generalized statements have been made concerning the effects of temperature, light, wind, relative humidity (RH), dew, rain, raindroplets, and storm fronts on the release of such spores into the atmosphere in a variety of locations. There have been, however, few comparisons of the effects of those factors on the air spora over a wheat crop and few attempts to relate, statistically, airborne spore concentrations to meteorological factors. In this paper we attempt to show how spore deposition of several fungal species may relate to meteorological factors occurring simultaneously with, or several hours preceding, sampling.

MATERIALS AND METHODS.—Kramer-Collins volumetric samplers (3) were used to sample air at various heights above ground level from approximately 15 April to 30 June in 1967 through 1971 and 1 August to 30 October in 1967. One sampler, referred to as the "canopy sampler," was located within the wheat canopy; it was raised periodically to keep the sampling orifice at the same level as the majority of sporulating uredia of *P. recondita* Rob. ex Desm. f. sp. *tritici.* Other samplers were located at various heights on a tower at the same location. One, referred to as the "1-m sampler," was raised as the wheat increased in height to keep the sampling orifice approximately 15 cm above the wheat canopy. Another was located 3 m above ground level. The highest sampler was located 14 m above ground level in 1967-68, and at 6 m in 1969-70. Samplers were operated at both the 6- and the 14-m levels on the tower in 1971. In 1970, two additional samplers were operated at approximately 40 and 65 cm above the ground within the wheat canopy; in 1971, only the one at 65 cm was used. Rotary intake tubes (4) were used to keep sampling orifices pointing into the wind and to keep precipitation out of all samplers.

In 1967-69, the sampling site was the wheat nurseries on the Rocky Ford experimental plots northeast of Manhattan, Kansas. In 1970-71 (1), the sampling site was a 6.07-hectare (15-acre) field of wheat on the Ashland Agronomy Farm south of Manhattan.

Instruments used to obtain meteorological data were located approximately 6 m from the base of the tower. Wind tunnel psychrometers (4) operated continuously by 110 V AC motors were used to obtain wet-bulb/dry-bulb temperature measurements for relative humidity (RH) determinations in the canopy. Occurrence of free moisture was determined by visual observations, dew recorders, and National Weather Service records (6). Periods when free moisture occurred on the plants of the canopy are recorded as periods of rain or dew depending on the source of the moisture. Anemometers were used to measure the along-wind, across-wind, and vertical-wind components. A record of the three wind components was made on separate strip chart recorders every 4 seconds. A turbulence value was calculated by obtaining the absolute value of the difference between the maximum and minimum vertical wind movement during an hour. Observations of disease severity, crop growth stage, and location of diseased tissue on the wheat plants, were made several times a week.

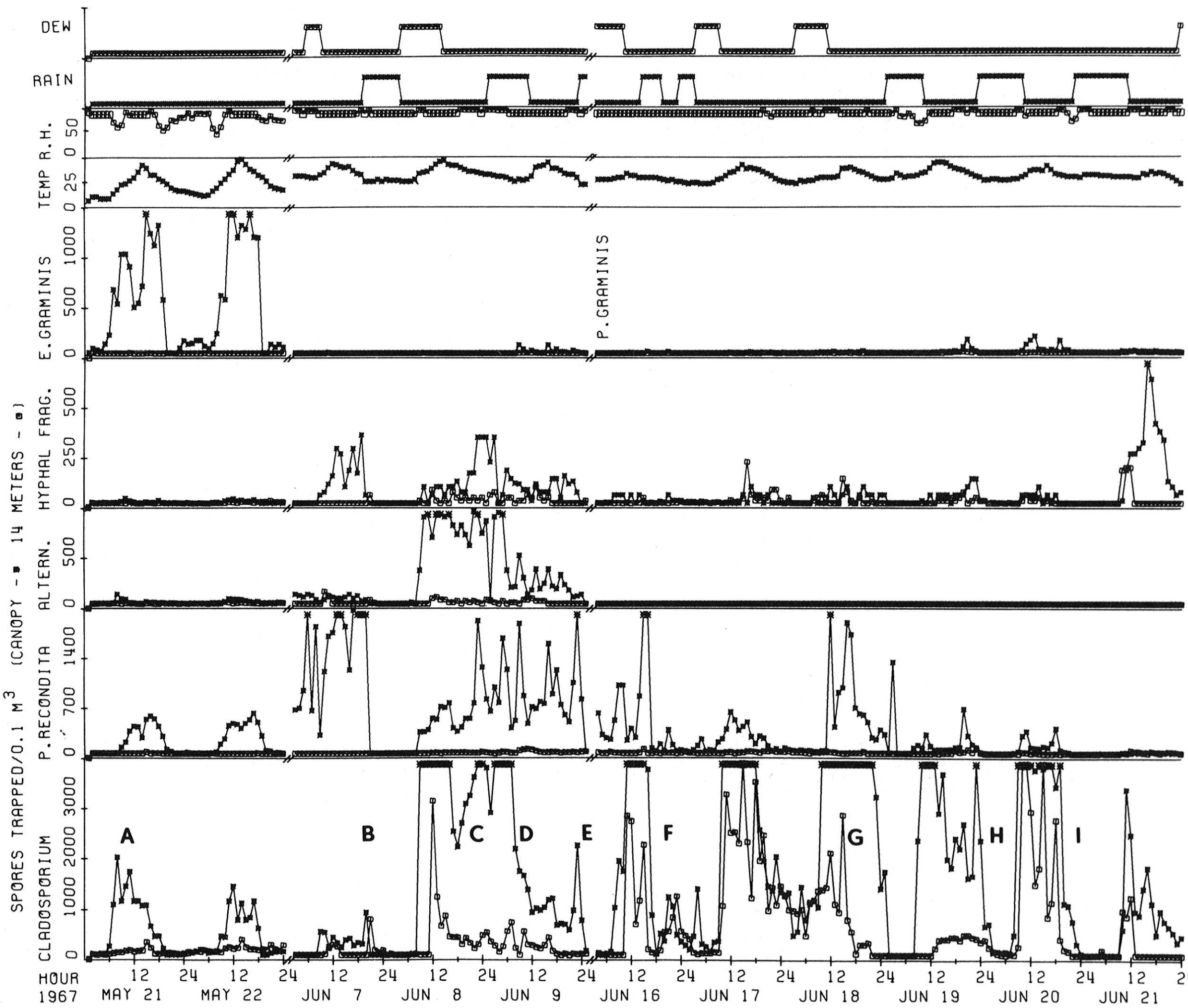

Fig. 1. Comparison of hourly concentrations of spores of *Puccinia graminis, P. recondita, Erysiphe graminis, Cladosporium* spp., *Alternaria* spp., and hyphal fragments trapped using Kramer-Collins volumetric samplers in a wheat canopy (*) and at 14 m (□) above ground level. Meteorological data were obtained 1.0 m above ground level. Data shown are representative of hourly data collected in a wheat field near Manhattan, Kansas, from 15 April to 30 June 1967 through 1971, and 1 August to 30 October 1967.

Exposed slides were examined under a microscope and the number of spores of each species collected per hourly band were counted (3). Hourly spore data were recorded as spores trapped per 0.1 m^3 of air sampled. Multiple regression techniques were used to analyze spore and meteorological data. All tests of significance were calculated at $P = 0.05$.

RESULTS.—Meteorological factors, especially wind velocity, dew, rain, and storm fronts, influenced the variation in concentrations of all species trapped. A graphic comparison of the effects of these meteorological variables on concentrations of spores of *P. graminis, P. recondita, E. graminis, Cladosporium* spp., *Alternaria* spp., and hyphal fragments trapped by the canopy sampler and at 14 m is shown in Fig. 1. As representative of the information obtained during the 5 years of sampling (1967-1971) only data from the canopy sampler and the 14 m sampler for certain periods in 1967 are included. During periods of dry weather (no rain or dew), which included 22 May (Fig. 1), circadian patterns were noted in the spore concentrations of all species trapped. Circadian is used in reference to any cyclic pattern of approximately 24 hours duration. Numbers of all spore forms trapped were reduced by periods of mist or fog as in the 3-hour period at midday on 21 May (Fig. 1-A). Rain (Fig. 1-B, C, E, F, H, I) washed all spore forms from the air usually within an hour after rains started. Spore numbers in the canopy were reduced more rapidly than those at 14 m by occurrence of rain (Fig. 1-H). Spore numbers increased immediately prior to the beginning of a rain due to increased wind velocities or turbulence (Fig. 1-C, F, G, H, I). As mist, fog, heavy dews, or rains ended and plant tissues dried, the spore numbers of all species again increased. Passage of cold fronts with accompanying high wind velocities and rain first caused an increase in spore numbers, then a decrease in spores trapped of all species (Fig. 1-B, E). Shifts in wind direction (Fig. 1-D, E) caused increased concentrations of *Alternaria* and *Cladosporium* to be trapped because the wind was blowing over trees or other plants which were the sources of *Alternaria* and *Cladosporium* spores.

Neither RH nor temperature could be shown as the cause of peaks or rapid fluctuations in spore concentration of any of the species within the canopy or at 14 m (Fig. 1).

Values for coefficients of determination (r^2) between spore concentration in the canopy or at 14 m and individual meteorological variables were obtained in regression analysis of all hourly data in which there were no missing elements. Coefficients of determination for temperature, RH, wind velocity, turbulence, rain, and dew were 0.14, 0.15, 0.17, 0.24, 0.01, and 0.03, respectively. Only the r^2 value for turbulence (0.24) was significant $P = 0.05$.

Analysis of hourly data for 24- to 96-hour periods surrounding the occurrence of peaks or rapid fluctuations in spore concentrations resulted in significant r^2 values being obtained between spore concentration and turbulence (0.74), wind velocity (0.52), RH (0.48), and temperature (0.32).

Analyses indicated that hourly meteorological factors occurring from 1 to 96 hours prior to spore collections had no effect on spore concentration. All correlations and r^2 values calculated for the data obtained from 1 to 96 hours preceding spore deposition were nonsignificant $P=0.05$.

DISCUSSION.—Seasonal occurrence of the various spore forms of the six organisms studied is dependent on temperature and moisture requirements, and the availability of host tissue to support active sporulation. Early in the season, cool, moist conditions favor growth and sporulation of *E. graminis,* but by June high temperatures have effectively reduced conidial production. As nighttime temperatures increase during the growing season, *P. recondita* urediospores become more prevalent until all leaf tissue available to support sporulation has become desiccated. Urediospores of *P. graminis* are not found in the air in significant numbers until daily minimum temperatures of above 10 C are reached: hence, the maxima of spore concentrations occurs near wheat maturity, usually 2 weeks later than for *P. recondita*.

Cladosporium may be collected throughout the growing season, but becomes more abundant as plant tissue decays and moisture and temperatures increase. Hyphal fragments were detected in the atmosphere in small numbers throughout the season with no distinct daily pattern being observed. *Alternaria* was collected early in the season and reached its peak spore concentration near maturity of the wheat crop.

Concentrations of airborne spores fluctuate within a 24-hour period as influenced by wind velocity, turbulence, dew, rain, and storm fronts in addition to periodicity in spore production. Knowledge of circadian rhythms and other fluctuations in the air spora within and above a host crop canopy is essential in the prediction, analysis, and simulation of plant disease epidemics caused by airborne fungi. During periods of dry environmental conditions, daytime maxima of dry spores due to increasing winds and turbulence in the daytime and calm conditions at night may be observed in spore-forms produced and released in the proximity of the trapping surfaces. Reduction in the number of all spore-forms released and subsequently trapped occurs during periods of rain, fog, mist, or dew. However, increasing wind velocities and turbulence associated with storm fronts or prior to rain storms increase spore concentrations within and above the host canopy.

Increases in wind velocities and turbulence increase spore numbers released and trapped within or above the canopy as long as spores are continually being produced and introduced into the system from a source. When wind velocities of greater than 2 m/second occur for several hours the number of spores trapped do not continue to increase, but usually decrease with increasing wind speeds unless additional spores are available for release into the system.

Location of the spore samplers in relation to spore sources and wind direction is extremely important in determination of spore concentrations. When the spore source is windward and on the same level or higher than the spore sampler, the number of spores trapped in the canopy and up to 14 meters above are nearly equal. If the spore source is leeward of the samplers, very few spores are trapped by samplers at any elevation.

We were unable to determine any statistical relationships that could be used to predict the spore concentration at a point in time using only meteorological variables such as wind velocity, turbulence, rain, dew, or temperature.

LITERATURE CITED

1. EVERSMEYER, M. G., C. L. KRAMER, and J. R. BURLEIGH. 1973. Vertical spore concentrations of three wheat pathogens above a wheat field. Phytopathology 63:211-218.
2. GREGORY, P. H. 1951. Deposition of airborne Lycopodium spores on cylinders. Ann. Appl. Biol. 38:357-376.
3. KRAMER, C. L., and S. M. PADY. 1966. A new 24-hour spore sampler. Phytopathology 56:517-520.
4. LONG, D. L., and C. L. KRAMER. 1972. The air spora of two contrasting ecological sites in Kansas. J. Allergy 49:255-266.
5. ROELFS, A. P. 1972. Gradients in horizontal dispersal of cereal rust urediospores. Phytopathology 62:70-76.
6. UNITED STATES DEPARTMENT OF COMMERCE. Climatological data: Kansas. Environmental Science Services Administration. Vol. 81 (5, 6), 1967; Vol. 82 (5, 6), 1968; Vol. 83 (5, 6), 1969; Vol. 84 (5, 6), 1970; and Vol. 85 (5, 6), 1971.