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Air spora of two contrasting ecological sites in Kansas

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Studies of the air spora were made at two sites: one on an exposed prairie hilltop, the other in a woodland ravine at the base of the hill. Collections were made hourly with a Kramer-Collins Spore Sampler at various times of the year during periods of different environmental conditions in the spring, summer and fall of 1968 and 1969. Daily periodicity in the occurrence of the various spore types was most pronounced at the woodland site, indicating that a larger proportion of spores collected there were from local rather than distant sources. Hourly variation was greater and daily periodicities less distinct at the exposed prairie hilltop than at the woodland site, indicating that a greater proportion of the spores collected were being transported in the atmosphere from remote sources.

Surveys of air spora have been made in many different types of habitats throughout the world.¹⁻⁴ However, only a few studies have been made to compare two contrasting ecological sites located near one another. Hamilton⁵ noted that the most abundant spore groups at a country site in England were the same and had similar patterns of occurrence as those in the city, but their concentration was much less in the city than in the country. Adams and associates⁶ collected similar spores (which also had similar occurrence patterns) in broadleaf and coniferous woodlands and in the city of Cardiff, Great Britain; but they found that the average concentrations of fungal spores at the woodland sites were two times that at Cardiff. Lacey,⁷ who compared the summer air spora of a protected woodlot near a stream and an adjacent exposed grassy hilltop (at Silwood Park near Ascot, Berkshire, England), found 2.6 times

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more spores at the stream site (where "damp air spora" such as *Sporobolomyces*, 3 bar ascospores, and basidiospores such as those of *Ganoderma* were common) than at the hill site. Hourly patterns of spore concentrations were similar, however.

Most of the work done on the air spora in Kansas has been from the roof of a building on the Kansas State University campus.⁴⁻⁷ Therefore, we compared the hourly occurrence of air spora at different times of the year and during periods of different environmental conditions at two contrasting ecological sites located near one another in Kansas.

MATERIALS AND METHODS

The two sampling sites are 6.6 miles north of Manhattan, Kansas, on the east side of Tuttle Creek Reservoir. One, at the base of a wooded ravine with a heavy canopy of predominately oak and elm trees, is approximately 1,090 feet above sea level and 2,500 feet east of and downwind of prevailing winds from Tuttle Creek Reservoir. This location will be referred to hereafter as the woodland site. The other, on the crest of a hill approximately 1,240 feet above sea level, is 1,500 feet southeast of the woodland site, which it overlooks. This location, in a typical tall-grass prairie of the Kansas Flint Hills Region, will be referred to hereafter as the prairie site.

The Kramer-Collins (K-C) spore sampler⁸ was used throughout this study. Samplers were positioned with the intake tubes 2 feet above ground. A rotary intake tube designed to turn with the wind and thus keep the orifice facing into the wind was placed on each sampler to obtain maximum sampling efficiency. Flowmeters were used with each vacuum pump in order that the flow rate of air sampled could be adjusted to one cubic foot per minute. Samplers were equipped with 4 point cams that turned the vacuum pump on for an operating time of $2\frac{1}{2}$ minutes for a total sampling time of 10 minutes each hour. Thus, the total volume of air sampled each hour was 10 cubic feet (0.28 M³). The samplers are constructed to move an adhesive-coated glass microscope slide a distance of 2 mm. past the intake orifice each hour automatically. In this way, 4 samples taken at 15 minute intervals are superimposed on a single hourly band with 24 such bands being collected daily on a slide. The spores are counted using the high-dry objective of a microscope. Counts are converted to numbers per cubic foot of air.

Temperature and relative humidity readings were obtained using a 2 channel Rustrack model 135 B temperature recorder and a wind tunnel psychrometer. Two thermistors positioned in the airstream of the wind tunnel, one with a wet soc, were used as sensors. The psychrometers were positioned 2 feet above ground on wooden boxes that housed and protected the Rustrack recorders. A detailed account of the techniques used in this study may be found elsewhere.¹⁰

Collection periods were: July 31 to August 20, September 11 to 24, and October 21 to November 7, 1968; and May 14 to June 25, September 23 to October 5, and October 28 to November 2, 1969. However, only 5 series (of 4 or 5 days) at each site, selected as representative of the air spora during periods of different environmental conditions and at different times of the year, are discussed here.

RESULTS

Series I, August 11 to 16, 1968 (Fig. 1)

The preceding month had been wetter than normal, and it rained the day before sampling was started. Hence, conditions were excellent for growth and sporulation of fungi in the surrounding areas.

In this series, spore numbers were consistently greater at the woodland site, primarily because of ascospores and of basidiospores (counts of which often exceeded those of the prairie site by 4 or 5 times). At both sites, daytime maxima were evident in *Cladosporium* and *Alternaria*, and ascospores and basidiospores were more abundant during the night than during the day. However, the periodic pattern in ascospores and basidiospores was not so distinct at the prairie as at the woodland site.

Series II, October 28 to November 2, 1969 (Fig. 2)

Although moisture was plentiful, temperatures were too low to offer the most favorable conditions for growth and sporulation of fungi. Rain occurred almost continuously for the 24 hour period of October 29; 0.5 inch fell on October 31.

Although spore numbers did not reach the concentrations of Series I, they were again higher at the woodland site, primarily because of more ascospores and basidiospores at that site. There were no consistent periodicities in the occurrence of any spore type.

Series III, May 27 to 30, 1969 (Fig. 3)

During this series, moderate temperatures, high humidities, and 4.16 inches of rain during May made conditions favorable for fungal growth and sporulation at both sites. For 24 hours after a rain of 1.12 inches on May 29, spore numbers of most types increased decidedly. At the prairie site, spore numbers were approximately double those at the woodland site both before and after the rain. Distinct periodicities were evident in the occurrence of all major spore groups at the woodland site. At the prairie site, however, there was considerable hour-to-hour variation, which obscured any periodic pattern.

Series IV, September 12 to 16, 1968 (Fig. 4)

The weather was clear with moderate temperatures; no rain fell during or for 2 weeks preceding this series. As a result, conditions generally were unfavorable for growth and sporulation of fungi. At the woodland site, spore numbers gradually decreased as environmental conditions became less favorable. There was considerable variation from hour to hour, especially at the prairie site. *Cladosporium*, hyphal fragments, and *Alternaria* counts were highest at the prairie site, with peak numbers generally corresponding to strong daytime winds. Ascospores were low in this series and did not exhibit daily maxima.

Series V, September 17 to 22, 1968 (Fig. 5)

This series followed a 3 week dry period; it was broken only on the day prior to the series by 0.4 inch of rain, which was insufficient to produce a period favorable for growth and sporulation of fungi. As in Series IV,

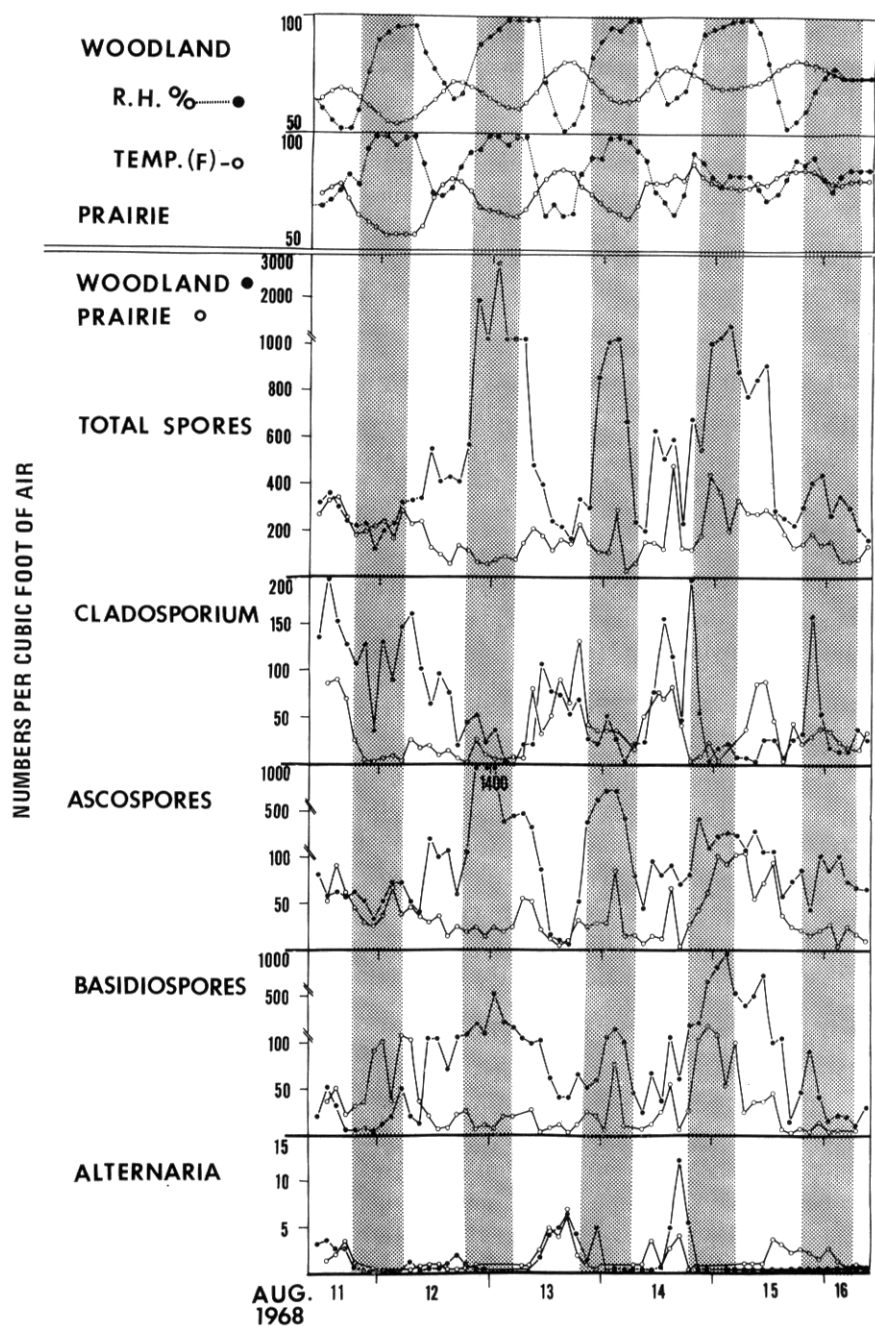


FIG. 1. Series I, August 11 to 16, 1968. Concentrations of total air spora and major components per cubic feet of air plotted at 2 hour intervals for both woodland and prairie sites. Shaded areas are from 1800 to 0600 hours. **R. H.** = relative humidity. This series is included in the summary woodland and prairie wet series of Fig. 6.

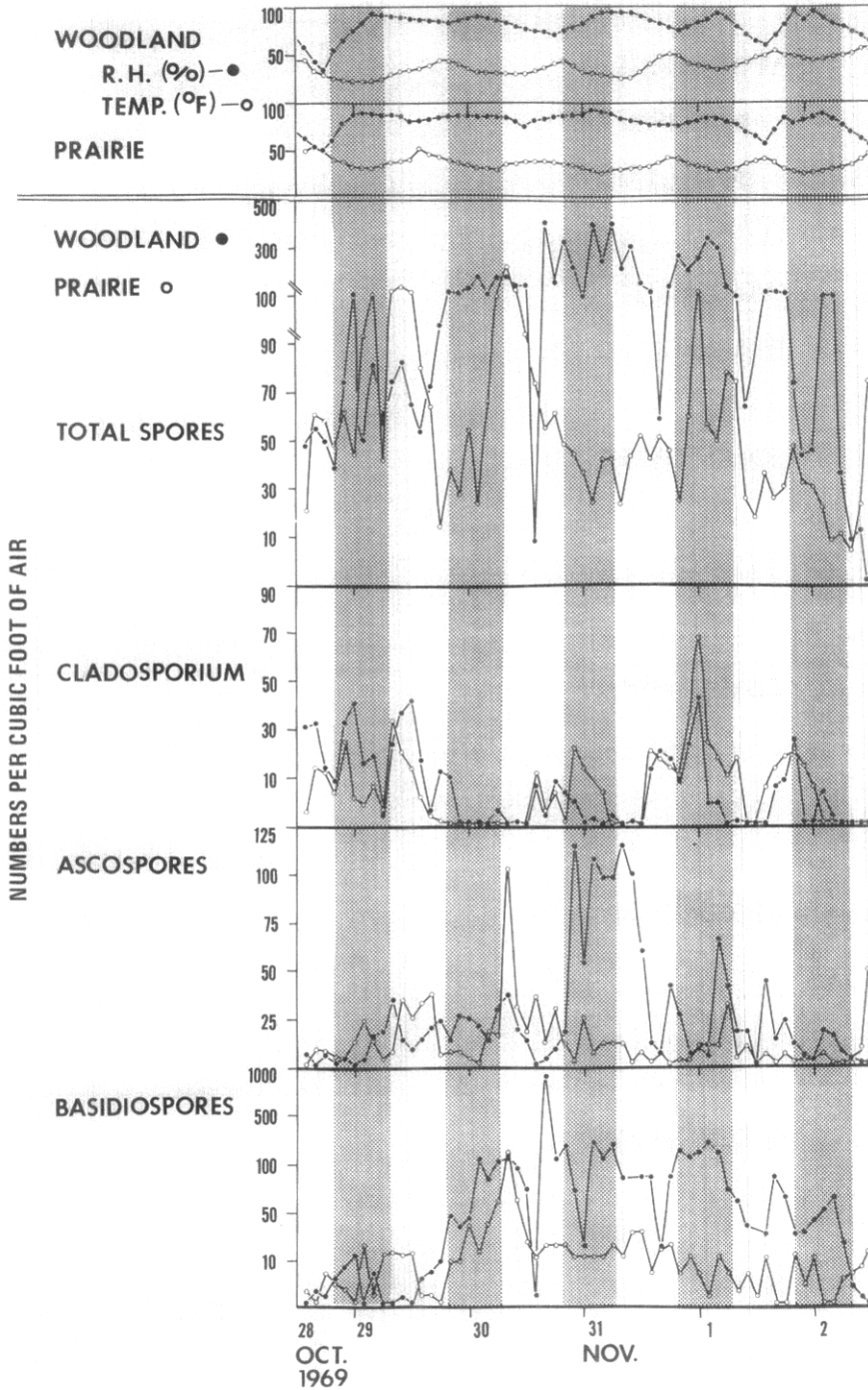


FIG. 2. Series II, October 28 to November 2, 1969. This series is included in the summary woodland and prairie dry series of Fig. 6.

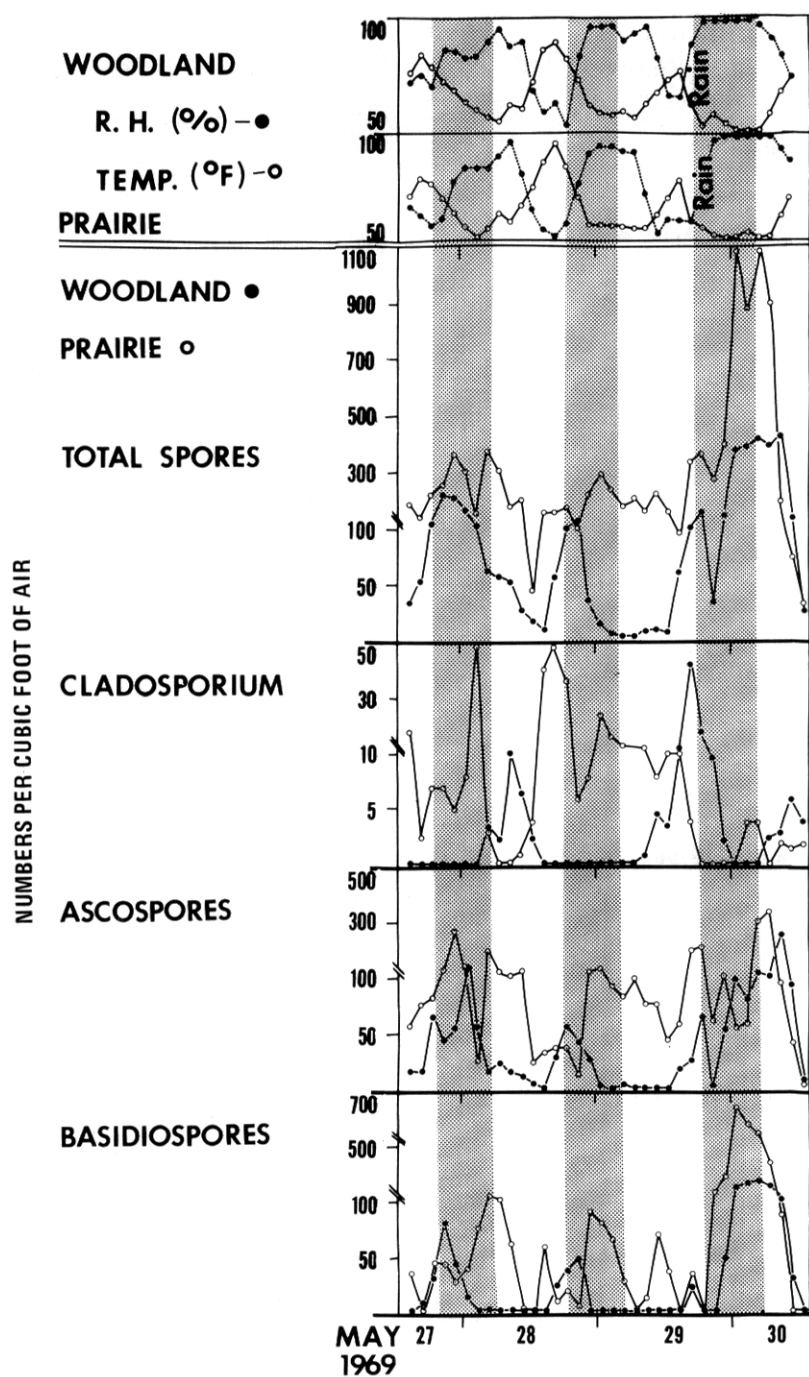


FIG. 3. Series III, May 27 to 30, 1969. This series is included in the summary woodland and prairie wet series of Fig. 6.

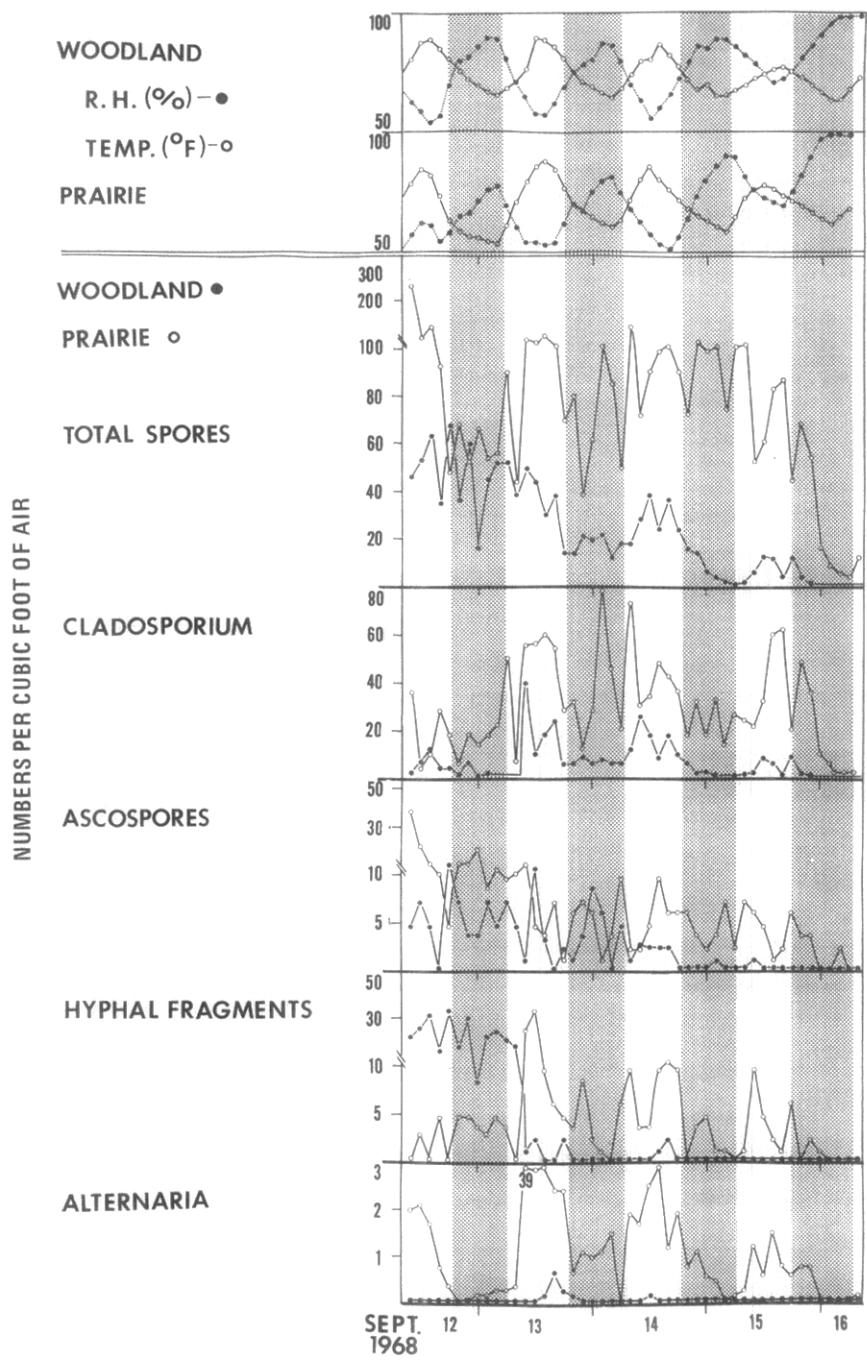


FIG. 4. Series IV, September 12 to 16, 1968. This series is included in the summary woodland and prairie dry series of Fig. 6.

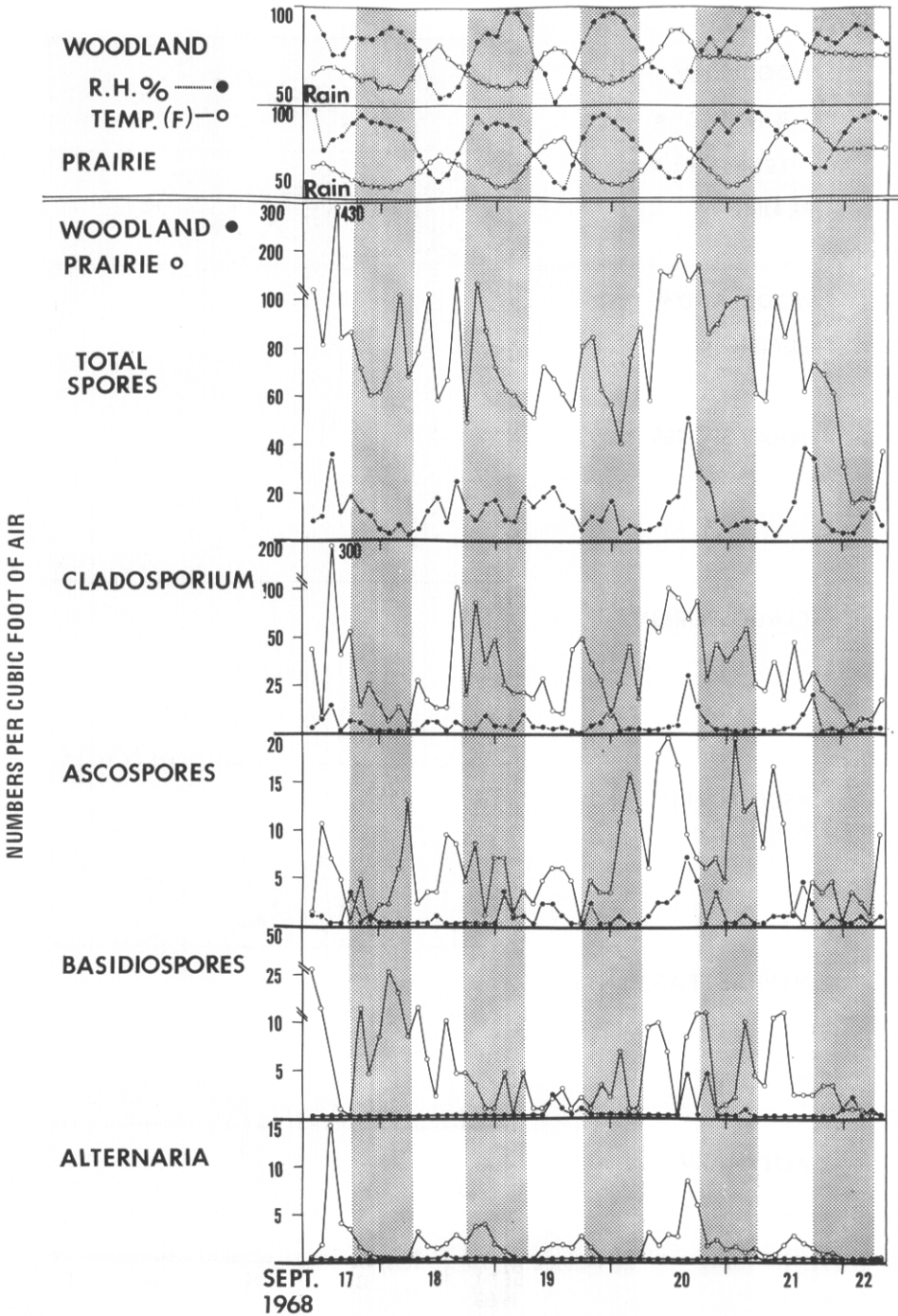


FIG. 5. Series V, September 17 to 22, 1968. This series is included in the summary woodland and prairie wet series of Fig. 6.

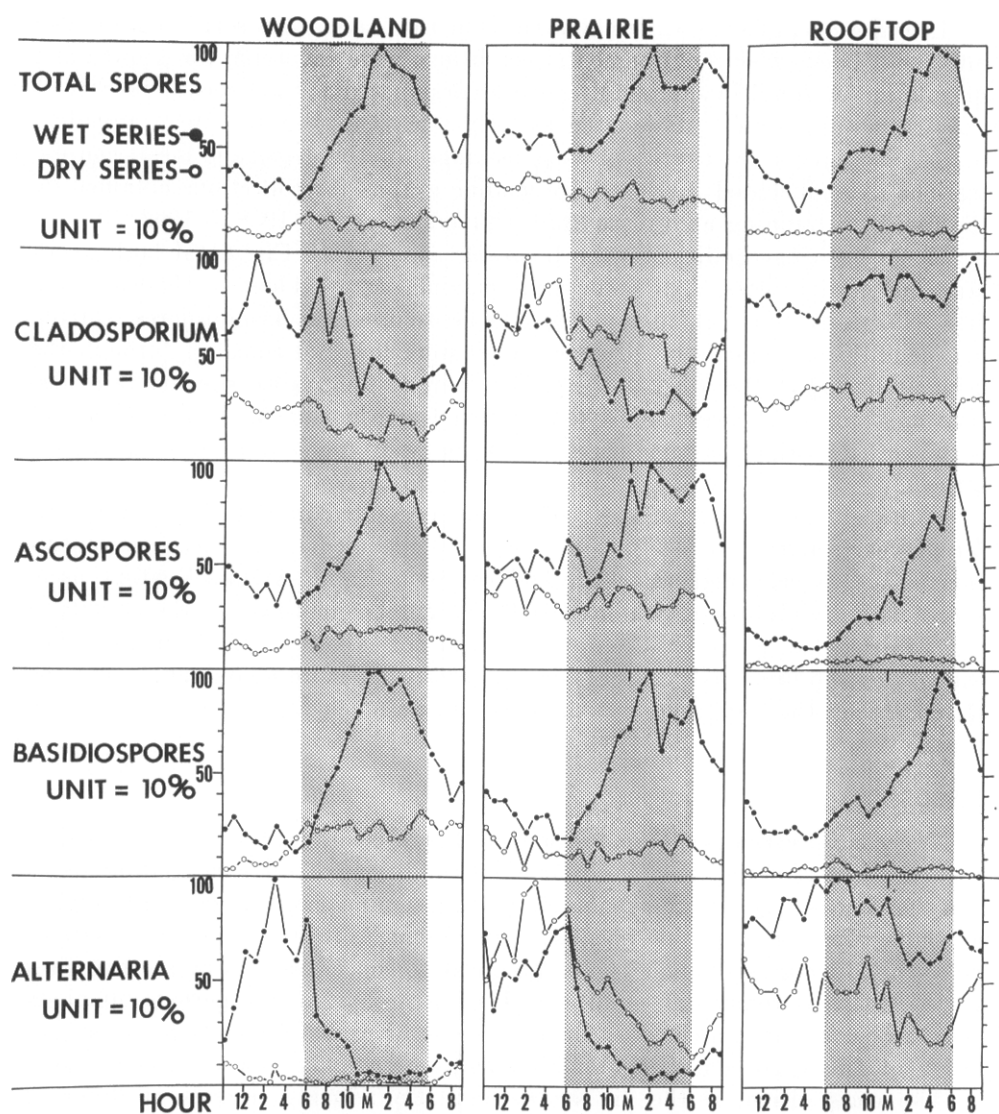


FIG. 6. Mean circadian periodicity curves expressed as percentages of the peak geometric mean concentration from series taken when environmental conditions for growth and sporulation of fungi of surrounding areas were favorable (wet series) and unfavorable (dry series) at the woodland and prairie sites. Similar graphs are presented for comparison from data obtained during 1958 to 1962 on the roof of a building on the Kansas State University campus. The woodland and prairie dry series were compiled from 15 individual 24 hour series; woodland and prairie wet series were compiled from 9, 24 hour series; and the rooftop dry from 13, 24 hour series and wet from 25, 24 hours series.

for all 4 spore forms, numbers were much higher at the prairie than at the woodland site. This included ascospore and basidiospore counts which were low compared with those taken during favorable environmental conditions. Daily periodicities were less evident than they were in Series IV. Only *Alternaria* showed distinct daily maxima.

In order to illustrate differences between the 2 sites, the series are divided into those taken when environmental conditions were favorable for growth and sporulation of fungi in surrounding areas (designated as "wet series" in Fig. 6) and when unfavorable (designated as "dry series" in Fig. 6). Mean circadian periodicity curves are expressed as percentages of the geometric mean concentrations. Also included in Fig. 6 are similar graphs for collections obtained on the roof of a building at Kansas State University during 1958 to 1962.^{7, 11}

When growing conditions were favorable (wet series, Fig. 6) at both woodland and prairie sites, distinct daytime maxima were evident in *Cladosporium* and *Alternaria* and nighttime maxima in ascospores and basidiospores. During dry conditions, numbers of all spore types were low and constant through the 24 hour period at the woodland site. However, at the prairie site that was also true only for ascospores and basidiospores; *Cladosporium* and *Alternaria* not only showed distinct daytime maxima but also were higher than during the wet series.

Although the data from the rooftop site presented in Fig. 6 are from different years, a total of 63, 24 hour series are included in the mean concentrations; thus, direct comparisons are believed to be valid. At this location, ascospores and basidiospores exhibited patterns similar to those at the woodland and prairie sites. However, *Cladosporium* did not exhibit maxima during either the wet or the dry series. *Alternaria* was somewhat more abundant during the daytime than the nighttime, but the pattern was much less distinct than at the prairie site.

DISCUSSION

The concentration and composition of the air spora varied at the two sites with the season of the year, environmental conditions of the surrounding areas, and the time of day. During spring and summer, numbers were generally higher at the prairie than at the woodland site during either wet or dry weather. However, during late summer and fall, relative concentrations at the two sites varied with environmental conditions. During prolonged dry periods, numbers were higher at the prairie site; during periods favorable for growth and sporulation of fungi, concentrations of air spora were higher at the woodland site.

The composition of the air spora population during periods of different environmental conditions may explain some of these variations. At the prairie site, *Cladosporium*, which occurs abundantly on surrounding prairie grasses, was most abundant in dry weather; then, maxima occurred during the daytime, that fungus seemingly reflecting a spore release pattern that correlated with higher daytime winds. At the more protected woodland site which also lacks the prairie grasses on which *Cladosporium* occurs so abundantly, numbers of *Cladosporium* spores were relatively constant at a comparatively low level

through a 24 hour period. These numbers probably largely represent *Cladosporium* in the atmosphere moving over the sites during these periods.

A pattern similar to that of the woodland site was obtained from the rooftop sampling station in the center of the Kansas State University campus, approximately 3 miles upwind from the nearest prairies where large numbers of *Cladosporium* spores could be released.^{3, 11, 12} There, maxima occurred at any time of day or night, depending on the concentration of the spores in the air mass passing over the site.

The pattern with daytime maxima at the prairie site was more distinct during wet than during dry periods, indicating that a larger proportion of *Cladosporium* was from the surrounding grasslands. The somewhat less distinct pattern during dry periods would indicate that a comparatively larger percentage of the spores collected were transported in the atmosphere from remote sources.

Alternaria had daily patterns similar to *Cladosporium* at all 3 collection sites during both dry and wet periods. The daytime maxima at the prairie site, during both dry and wet periods, were in fact more pronounced than in *Cladosporium*, probably because a greater percentage of the *Alternaria* spores were from the surrounding grassland and this more closely reflected the pattern of daytime release. Although some spores of *Alternaria* and *Cladosporium* undoubtedly were released during the nighttime, especially when winds were comparatively high, it is believed that most of the spores collected at night were from remote sources.

Numbers of basidiospores and ascospores in the atmosphere are influenced by moisture conditions of the environment more than conidia of fungi such as *Cladosporium* and *Alternaria*. In dry weather, discharge of basidiospores and ascospores is halted, and spore numbers in the atmosphere decline to a low level. However, conidia of *Cladosporium* and *Alternaria* which are formed during wet periods may become temporarily lodged on leaf surfaces; during later dry periods, they may be released into the air.

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