A COMPARISON OF THE AIR SPORA OF TWO SITES NEAR TUTTLE CREEK RESERVOIR, POTTAWATOMIE COUNTY, KANSAS

by

DAVID LAWRENCE LONG

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Major Professor

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INTRODUCTION

Studies of the air spora date back to the works of Miquel (1883-1889) in Paris. Since then numerous studies have been done in various parts of the world using a variety of sampling techniques. However, most did not use quantitative methods, nor were their methods designed to show hourly variations in the spore population through 24-hr periods. It was not until 1952, when Hirst designed a volumetric suction trap that a means was made commercially available for determining quantitatively the composition of the air spora hourly throughout 24-hr periods. This trap operated continuously, moving an adhesive coated slide at a known constant rate past a slit-like orifice. Data collected with this trap could be correlated with hourly, daily and seasonal changes in the environment.

Hirst (1953), using the Hirst Spore Trap placed 2 meters above ground level near Rothamsted, England, showed that the composition and concentration of the air spora changes from hour to hour through a 24-hr period. Certain spore types such as basidiospores and ascospores were most abundant at night while spores of *Cladosporium*, *Erysiphe*, *Alternaria,* rusts and smuts, were characteristic of the day spora. However, he also showed that abrupt changes in the environment had a pronounced effect on both the concentration and composition of the air spora. Prolonged rain was found to remove the normal daytime components of the air spora and cause an increase in hyaline ascospores and basidiospores that were usually found during the night or in the early mornings when dew was present.

This study provided the stimulus for a number of similar studies done at locations differing ecologically. During the summer of 1954, Gregory and Sreeramulu (1958), using a Hirst Spore Trap, studied the hourly variations in the atmospheric spore content of an estuarine area. This area was selected because the ecological factors were different from areas previously studied in England. They found that spores of crop pathogens including *Ustilago*, *Erysiphe*, and *Alternaria*, were much less abundant than in agricultural areas, but hourly changes in the air spora were in general similar in both areas.

Hamilton (1959) compared the air spora at Rothamsted with that of an urban area near London. She noted that in both the city and country the same twelve spore groups comprised the most abundant fungi and that they followed similar patterns in their occurrence throughout a 24-hr period even though their concentration in the city was much less than that in the country.

Another study designed to compare the air spora of two contrasting ecological sites was done by Adams et al., (1968) who located a Hirst Spore Trap in a woodland of broadleaf trees and another among coniferous trees. These studies were compared with collections made in the city of Cardiff, Great Britain. Similar patterns of hourly variations in the composition of the air spora through a 24-hr period occurred at all 3 locations, however, the average concentrations of fungal spores at the woodland sites were 2 times that at Cardiff.

A comparison of the air spora of two ecologically different habitats situated near one another was done by Lacey (1962). She compared the summer air spora of two contrasting adjacent rural sites at Silwood Park, near Ascot, Berkshire, England; one in a protected woodlot near a stream, the other on an exposed grassy hilltop. She found that overall there were 2.6 times more spores in the air at the stream site than at the hill site. The difference was greatest with components of the 'damp air spora' such as Sporobolomyces, 3-bar ascospores, and basidiospores such as those of Ganoderma. However, as in previous studies done in England, although the magnitude of the spore concentration varied with a given spore type at the two locations, the hourly patterns were similar.

Although climatic conditions in Kansas are quite different from those of England, similar results were often obtained in a study of the air spora during 1959-1964. During this time samples were taken through 24 & 48-hr periods on the roof of a campus building at Kansas State University (Pady et al., 1962 and Kramer et al., 1963). During periods when environmental conditions of surrounding areas were favorable for growth and sporulation of fungi, most ascospores and basidiospores occurred at night. Under the same conditions, conidia of Deuteromycetes such as Cladosporium, Alternaria, etc... were generally more abundant during the daytime. However, this was not always true of Cladosporium; on many days there also would be peaks in spore concentrations of greater or lesser magnitudes occurring at other times of the day (Pady et al., 1962).

The distinct periodic patterns of ascospores and basidiospores and in some cases the conidial forms were interpreted as a direct reflection of circadian[1] patterns of spore release or discharge from fungi growing in close proximity to the sampling station. Field and laboratory studies of numerous Ascomycetes and Basidiomycetes have since shown that in most situations, their spores were discharged primarily at night (Hirst, 1953; Gregory & Hirst, 1957; Gregory, 1958; Sreeramulu, 1959; Hamilton, 1959; Meredith, 1962; Lacey, 1962; Adams, 1964; and Adams et al., 1968). It has also been shown from studies done in the field at locations where fungi such as Cladosporium were growing abundantly, that in most situations,

[1]Cyclic pattern of spore discharge over a period of approximately 24 hr.

their spores were released during the daytime (Pady et al., 1969).

From the studies listed above, it is assumed that when conditions were not favorable for growth and sporulation of fungi in the surrounding areas, the concentration of these spore types was considerably lower and thus distinct daily periodicities were not evident. It was felt that many of the spores collected during such periods were from remote sources and thus due to their apparent longer period of residence and subsequent dispersal in the atmosphere before being collected, their occurrence in the hourly samples did not reflect a periodic pattern of release. Thus, it seemed evident that the population of air spora at a given location was influenced both by spores being released locally and by spores being transported from remote sources and that the relative importance of each of these was in a large part dependent on the environmental conditions and the ecological habitat of the surrounding area. With this in mind it was decided to study the air spora on an hourly basis at various times of the year during periods of varying environmental conditions at two locations near one another. It was hoped that such a study would provide a better understanding of the relative importance that locally released spores and those transported from remote sources have on the composition and concentration of the air spora at a given location.

MATERIALS AND METHODS

The two sampling sites that were selected for this study were 6.6 mi north of Manhattan, Kansas, on the east side of Tuttle Creek Reservoir on the premises of the Elks Club private recreation area. The first site was located at the base of a wooded ravine through which was a creek bed that carried water only after heavy rains. The site was approximately

1090 ft above sea level and 2500 ft east and downwind from the direction of prevailing winds from the main body of the Tuttle Creek Reservoir, which was approximately 1 mi across at that point. This location is referred to hereafter as the woodland site. The second site was located on the crest of a hill approximately 1240 ft above sea level, in a typical tall grass prairie 1500 ft southeast and overlooking the woodland site. This location is referred to hereafter as the prairie site.

Collections were generally taken daily for periods up to 4 weeks at various times of the year. However, data are presented as series of 4-5 consecutive days selected as representative of the air spora at the 2 collecting sites during periods of varying environmental conditions and at different seasons of the year. These collections were made at the following times: July 31-August 20, September 11-24, and October 21-November 7, 1968, and May 14-June 26, September 23-October 5, and October 28-November 2, 1969.

The Kramer-Collins (K-C) Spore Sampler (Kramer & Pady, 1966) was used throughout this study (Fig. 1). A 4-lobed cam was used to activate the vacuum pump for 3 min at 15 min intervals for a total sampling time of 12/min hr. The vacuum pump operated at a flow rate of 0.8 ft^3/min, providing a total volume of 10 ft^3 of air sampled per hour. The 4 samples taken during the hour were superimposed onto one hourly band. A rotary intake tube (Fig. 2), designed to keep the orifice facing into the wind was placed onto the sampler intake tube.[2] The opening of the rotary intake tube was .0928 in^2 which approximates the opening of the Hirst Spore Trap.

[2]Rotary intake tubes are now commercially available from the GR Manufacturing Co., Route 2, Manhattan, Kansas, 66502, manufacturers of the K-C Spore Sampler.

Fig. 1. Kramer-Collins (K-C) Spore Sampler and vacuum pump.

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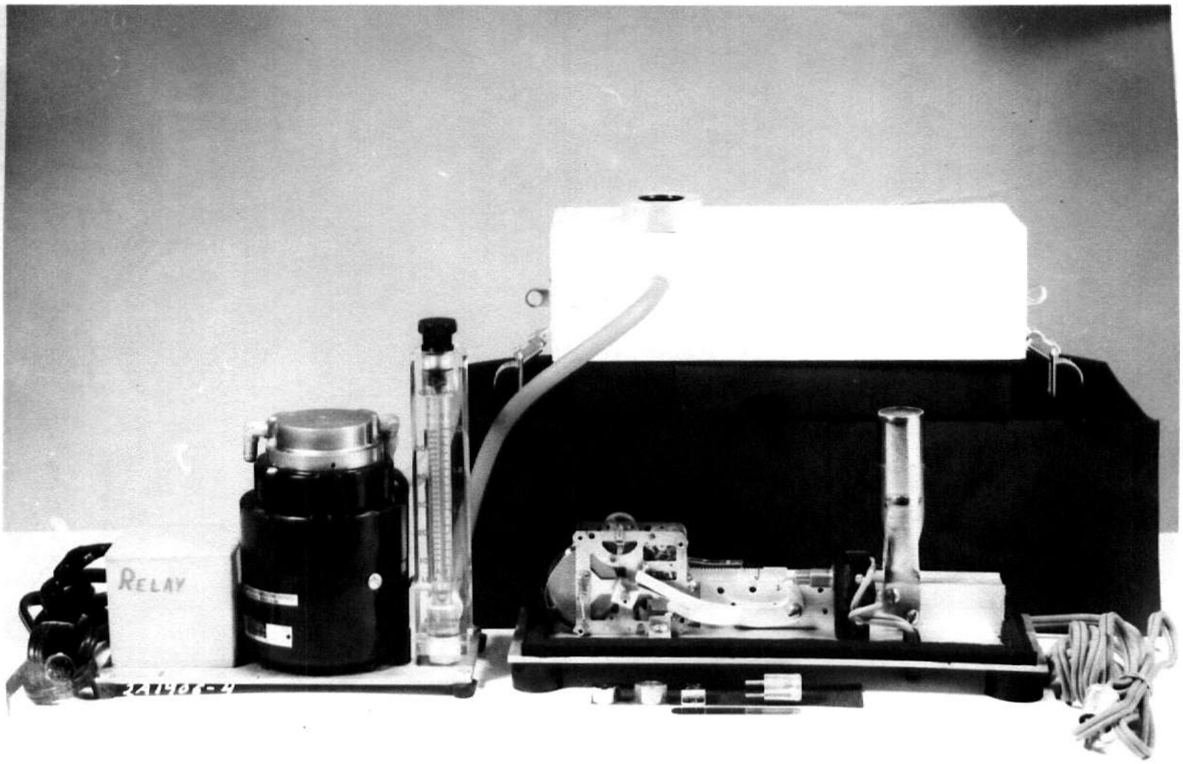

Fig. 1

Fig. 2. Rotary intake tube for use with the K-C Spore Sampler.

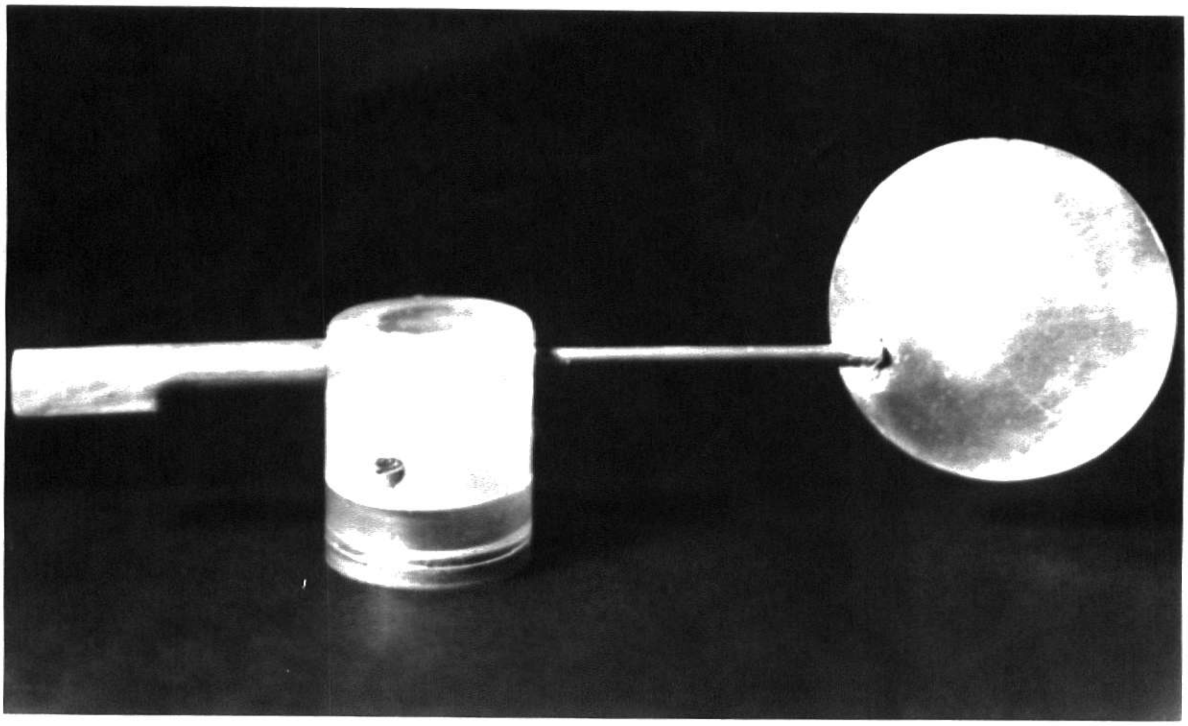

Fig. 2

During operation, air entered the intake tube at a rate of 17.38 ft/sec of 12 mi/hr.

During August 1968, a Serdex Hygrothermograph was used to measure temperature and relative humidity at the woodland site. This instrument was operated by a spring wound clock and required no outside power source. The humidity sensor was an animal membrane and the temperature sensor was a bimetal strip. This recorder was satisfactory for mid-range humidity but the performance at low and high levels was not satisfactory.

In 1968 a 2-channel Rustrak Model 135B Temperature Recorder with a ni-cad rechargeable power pack was obtained. The power pack operated continuously for 8 days before recharging was necessary. This model recorder used thermisters with an accuracy of ±2% over the range of the recorder. The calibration was periodically checked in the field by a mercury thermometer and sling psychrometer. The Rustrak recording system was extremely sensitive with a time lag of only 15 seconds compared to 1 min for a mercury thermometer and 5 min for the Serdex Hygrothermograph.

In order to obtain relative humidity readings, a wind tunnel psychrometer was constructed from a 12 in length of 1 in diameter copper tubing affixed to a small squirrel cage fan (Fig. 3). Two ports were constructed on the upper side of the copper tube to accept the thermisters of the 2-channel recorder. The port downwind had a matching opening on the under side of the copper tubing through which a wet sock, attached to the thermister was suspended into a water reservoir. The thermister cords were taped to the ports so that the thermister probes were suspended in approximately the center of the wind tunnel. Dry bulb readings were taken from the thermister located upwind in the wind tunnel. The recorder operated continuously from the ni-cad battery, however, a spring wound clock timer

Fig. 3. Battery operated, wind tunnel-type psychrometer and a 2-channel Rustrak Model 135B Temperature Recorder with a ni-cad rechargeable power pack.

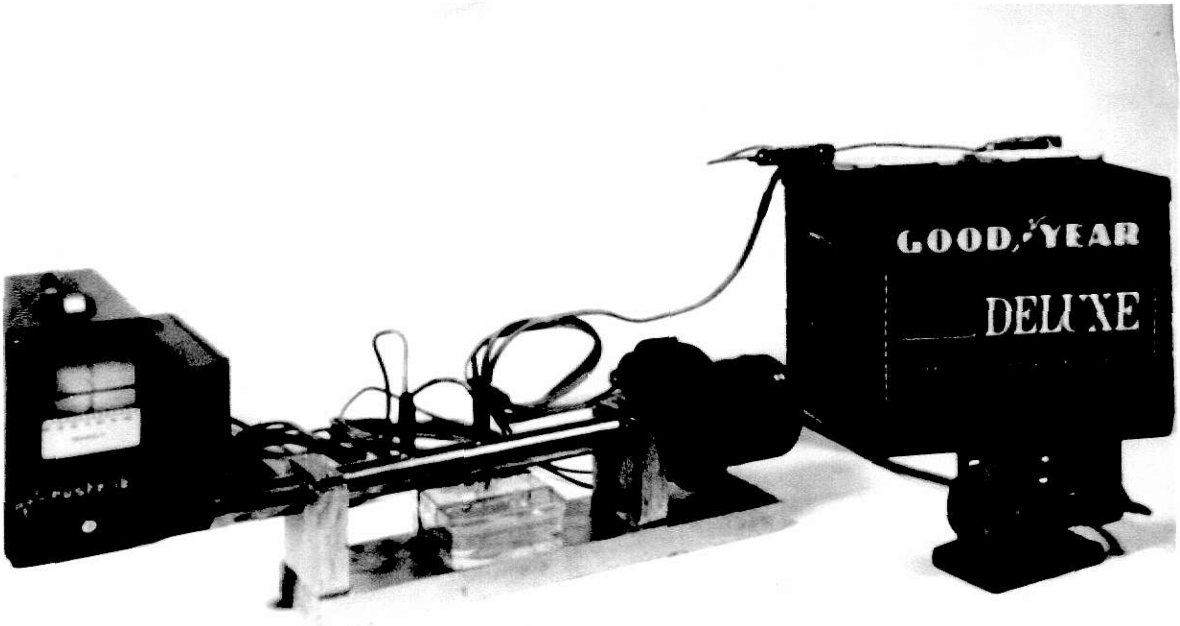

Fig. 3

with a cam-operated microswitch operated the wind tunnel for 5 min periods at 30 min intervals. Readings were taken only from these periods. A 12 v automobile battery served as the power source for the wind tunnel fan.

The woodland sampling site was located near the base of the wooded ravine under a heavy canopy of predominately oak and elm trees (Fig. 4). The K-C sampler was placed on a wooden box with the intake opening approximately 2 ft above ground. Line electricity was avilable through an extension cord from a nearby outlet so that 115 v AC motors could be used at this site. The psychrometer was also positioned approximately 2 ft above ground while the Rustrak recorder and the cam-operated clock were placed in a wooden box to protect them from rain.

The prairie sampling site, was located on the crest of a hill in a typical tall grass prairie (Fig. 5). The K-C sampler was again placed in position with the intake tube approximately 2 ft above ground. The wind tunnel psychrometer was placed in position 2 ft above ground similar to that at the woodland site, however, a wooden shelter was used to protect it from the direct rays of the sun. At this location all motors operated from battery power. In addition to temperature and RH data obtained at the sampling site precipitation records were obtained from the US Corps of Engineers Environmental Recording Station located near the Tuttle Creek Dam, located 1.3 mi from the sampling sites.

Silicone-coated slides were changed once a day at a time that was most convenient to the experiment. In 1968, most slides were changed about 9 AM, and in 1969 at about 1 PM. Sometimes the first deposit of spores was heavier due to the disturbance created in changing slides, thus, the first band was normally not counted.

Exposed slides were stored dry in slide boxes until counts were made.

Fig. 4. Kramer-Collins sampler and psychrometer set-up at the woodland site.

Fig. 4

Fig. 5. Kramer-Collins sampler and psychrometer set-up at the prairie site. (Note: wooden shelter is not in position).

Fig. 5

The microscope used for counting was equipeed with a Howard counting disc and calibrated so that either the entire band or portions of the band could be counted and numbers converted to a per ft^3 basis.

RESULTS

Collections were generally taken daily for periods up to 4 weeks, however, data are presented as series of 4-5 days, selected to represent the air spora at the 2 collecting sites during periods of different environmental conditions and at different seasons of the year.

Series I, August 11-16, 1968 (Figs. 6 & 7). The preceding month had been wetter and warmer than normal with a total of 8.57 in received between July 23 and Aug. 10 with an additional 0.65 in on the day before the start of the series. During the series on Aug. 14, 0.10 in of rain was received. This provided excellent conditions for growth and sporulation of fungi prior to and during the sampling period. Temperatures from Aug. 1-10 were moderate with a maximum of 98 F and a minimum of 62 F. From Aug. 11-16, temperatures were in the high 70's and low 80's during the daytime and in the 60's at night. The relative humidity (RH) was generally 60-70% during the daytime and 90-95% at night. At the prairie site the relative humidity was approximately 3% higher, while at the woodland site the temperature was approximately 4 F lower.

At the woodland site (Fig. 6), total spore counts averaged 4-500/ft^3 compared with nearly 2000/ft^3 at the prairie site. Following the rain prior to the series, Cladosporium spores were somewhat irregular for Aug 11 & 12, but developed distinct daytime maxima on Aug. 13, 14, & 15 at both sites. Alternaria spores also exhibited daytime maxima similar to Cladosporium at

Fig. 6. Series I, August 11-16, 1968. Woodland site. Numbers of spores are per cubic foot per hour. Shaded area represents nighttime.

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Fig. 6

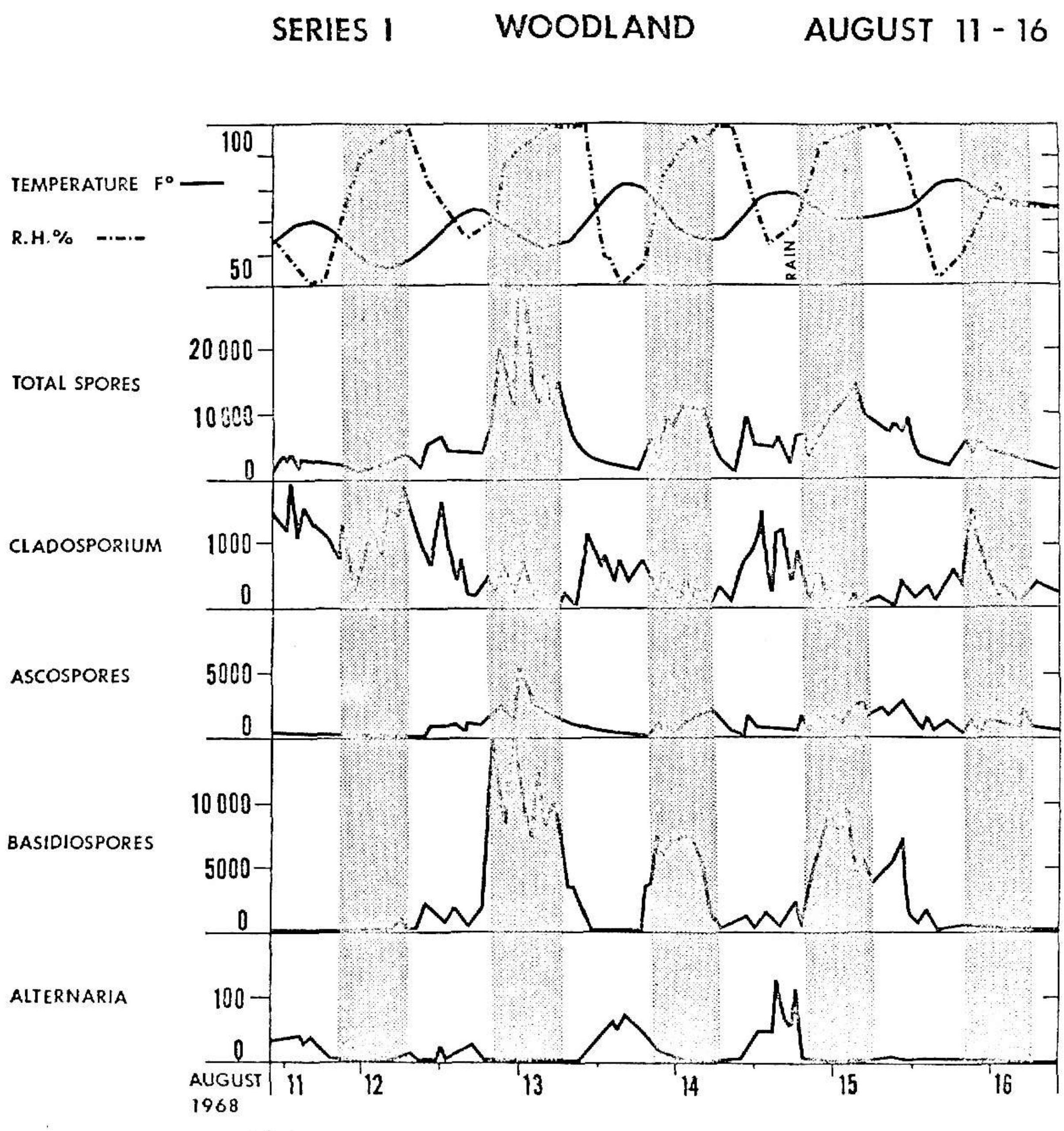
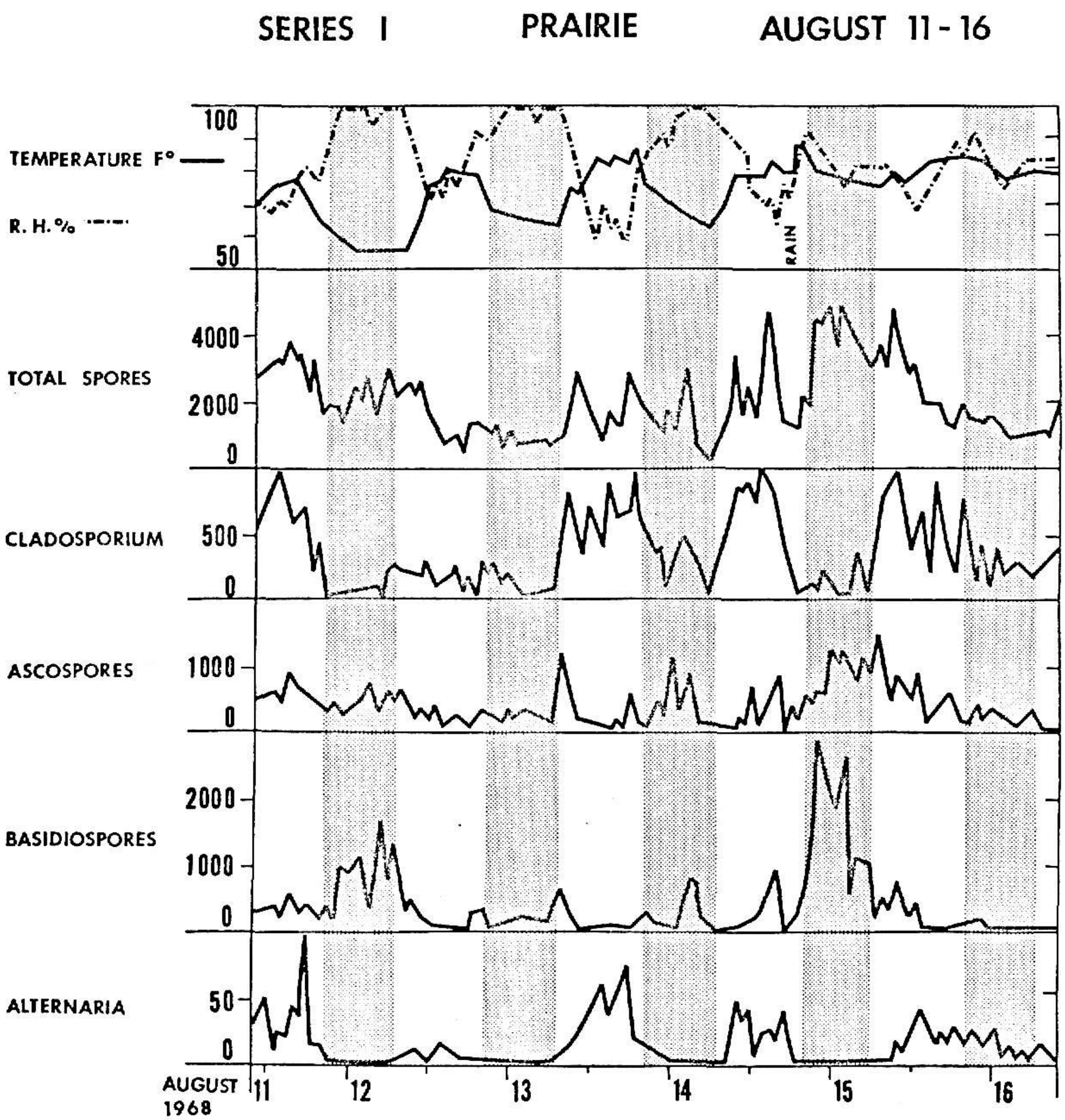

SERIES I
WOODLAND
AUGUST 11 - 16
TEMPERATURE F°
R.H.%
100
50
RAIN
TOTAL SPORES
20 000
10 000
0
CLADOSPORIUM
1000
0
ASCOSPORES
5000
0
BASIDIOSPORES
10 000
5000
0
ALTERNARIA
100
0
AUGUST 1968
11
12
13
14
15
16

Fig. 7. Series I, August 11-16, 1968. Prairie site.

Fig. 7


SERIES I
PRAIRIE
AUGUST 11-16
TEMPERATURE F°
R. H. %
100
50
RAIN
TOTAL SPORES
4000
2000
0
CLADOSPORIUM
500
0
ASCOSPORES
1000
0
BASIDIOSPORES
2000
1000
0
ALTERNARIA
50
0
AUGUST
1968
11
12
13
14
15
16

both sites. Basidiospores and ascospores that usually occur at night, did not exhibit maxima on the night of Aug. 11/12 at the woodland site. However, on the following three nights distinct maxima were evident. Basidiospore counts at the woodland site often exceeded the prairie counts by 4-5 times.

At the prairie site (Fig. 7), the periodic pattern in both the ascospores and basidiospores was not as distinct as at the woodland site where collections apparently reflected the release pattern of spores locally produced.

Series II, September 12-16, 1968 (Figs. 8 & 9). The weather was clear with moderate temperatures and no rain was received during or for 2 weeks preceding this series. Relative humidity was low during the day and reached a maximum of not over 90% in the early morning. As a result, conditions generally were unfavorable for growth and sporulation of fungi throughout the series.

At the woodland site (Fig. 8), as weather conditions became more unfavorable for growth and sporulation of fungi, total spore numbers decreased. At the beginning of the series, spore numbers averaged 60/ft^3 of air while several days later numbers were closer to 3 spores/ft^3. This gradual decrease in spore numbers was particularily evident in ascospores. *Cladosporium* spores although relatively low in number, were generally more abundant during the daytime, indicating that most of these spores were released locally. An unusual feature of this series was the high number of hyphal fragments collected during the first 24 hr of the series. These were probably old conidiophores, no longer sporulating. This high number was attributed to the relatively high winds during this time.

Fig. 8. Series II, September 12-16, 1968. Woodland site.

Fig. 8

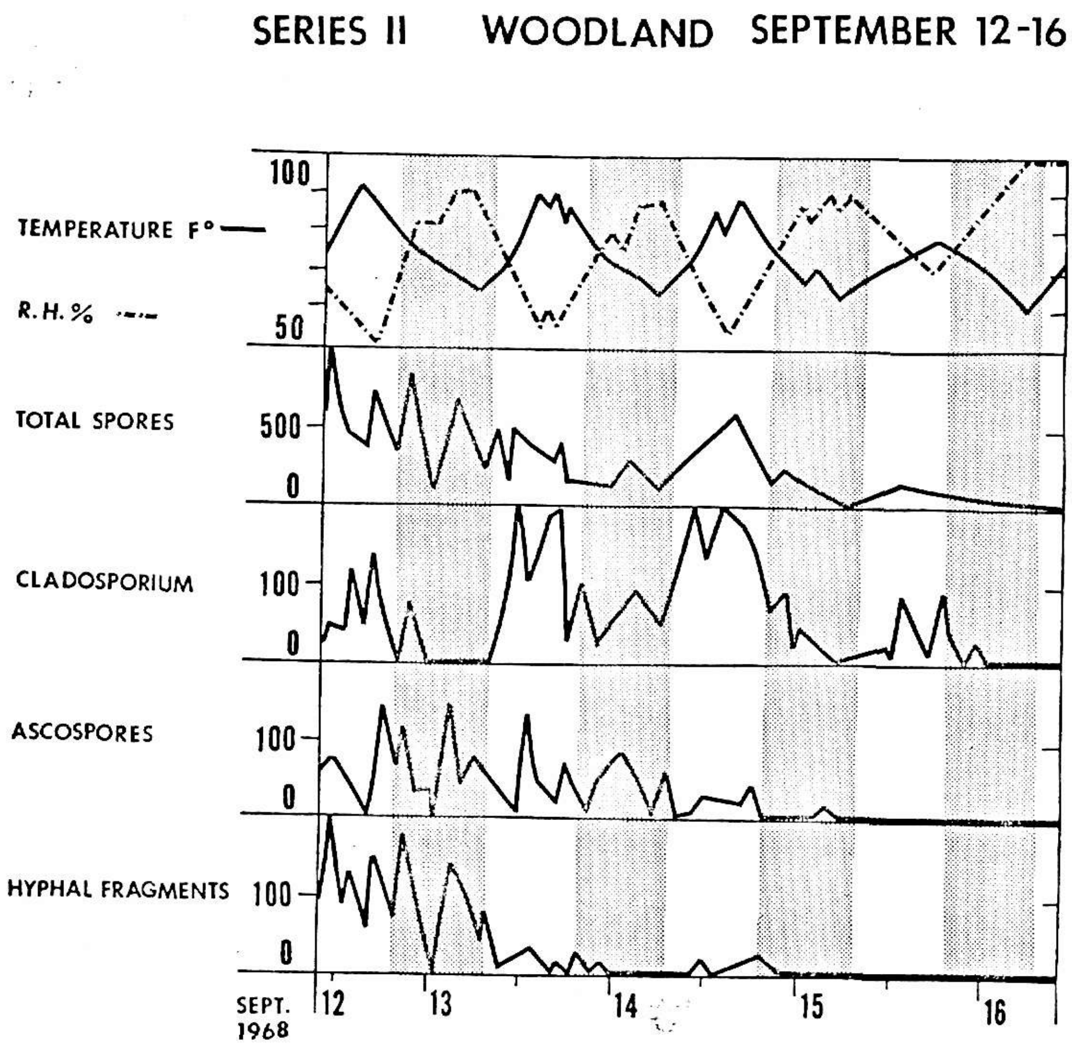
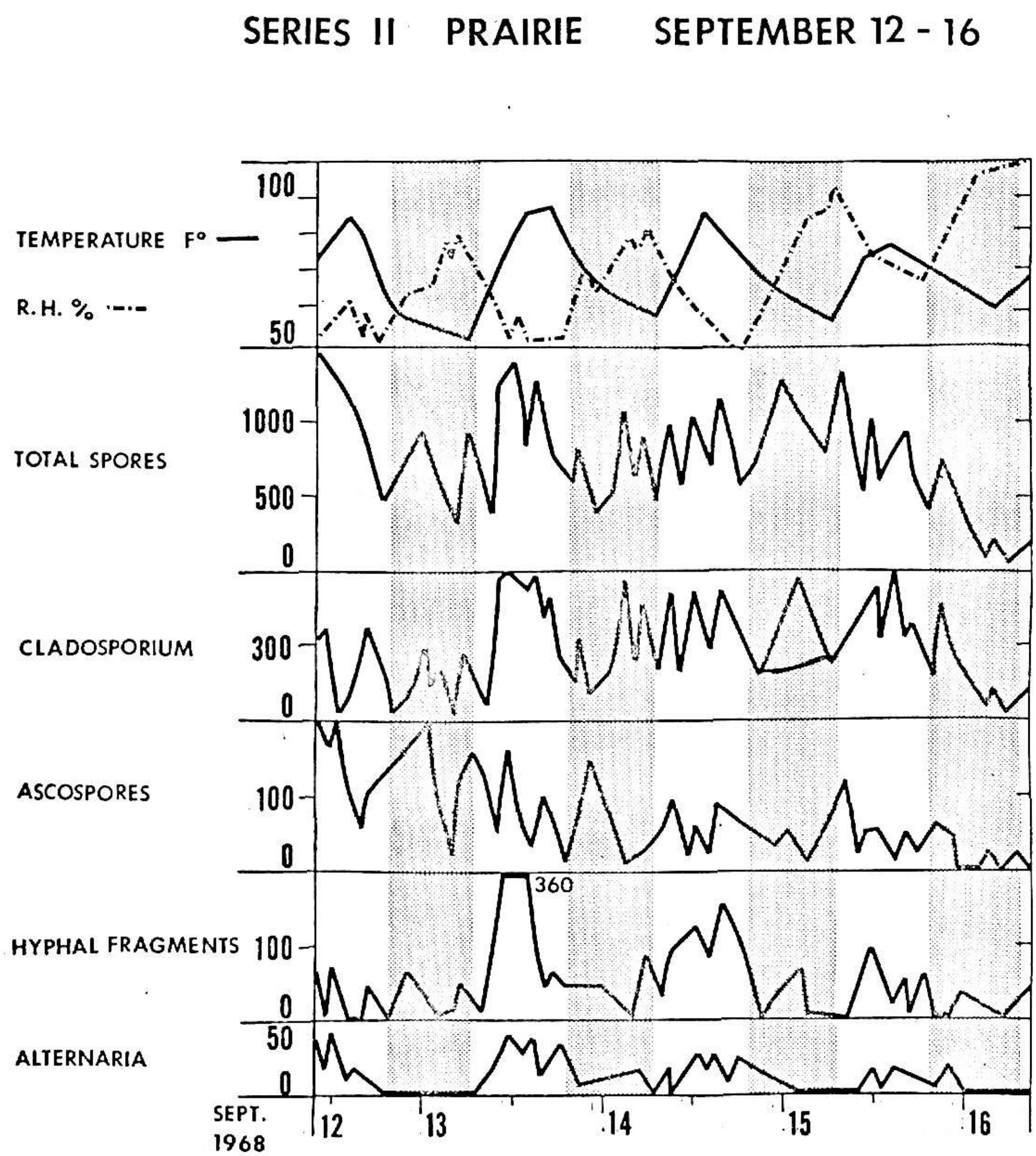

SERIES II WOODLAND SEPTEMBER 12-16
TEMPERATURE F°
R.H.%
100
50
TOTAL SPORES
500
0
CLADOSPORIUM
100
0
ASCOSPORES
100
0
HYPHAL FRAGMENTS
100
0
SEPT.
1968
12
13
14
15
16

Fig. 9. Series II, September 12-16, 1968. Prairie site.

Fig. 9


SERIES II PRAIRIE SEPTEMBER 12 - 16
TEMPERATURE F°
R.H. %
100
50
TOTAL SPORES
1000
500
0
CLADOSPORIUM
300
0
ASCOSPORES
100
0
360
HYPHAL FRAGMENTS
100
0
50
ALTERNARIA
0
SEPT.
1968
12
13
14
15
16

At the prairie site (Fig. 9), total spore and Cladosporium counts were higher than at the woodland site but distinct periodicities were not evident, indicating that most of the collected spores were from the general air mass passing over the sampling site. The gradual decrease in ascospore numbers was similar to that which occurred at the woodland site. The most striking differences between the two sites were the Alternaria and hyphal fragment numbers which were insignificant and exhibited no periodicity at the woodland site, but were in appreciable numbers at the prairie site expressing a daytime periodicity correlated with daytime winds needed for release.

Series III, September 17-22, 1968 (Figs. 10 & 11). On the day prior to the start of the sampling period, 0.40 in of rain was received, breaking a 3-week dry period. During the 5-day series, the weather was overcast with heavy dew in the mornings, while 0.04 in of rain fell at noon on Sept. 17.

At the woodland site (Fig. 10), spore numbers generally were low. There were sharp peaks in Cladosporium and ascospores during and immediately following the rain, however, it was not until the second day following the rain that total spore numbers were expressed in distinct daytime maxima. These were primarily a result of the periodicity in the occurrence of Cladosporium spores which were apparently being produced locally in the vicinity of the sampler.

At the prairie site (Fig. 11), spore numbers were considerably higher with minima generally exceeding the maxima of the woodland site. However, there was little evidence of a periodic pattern in any of the spore types with the exception of Alternaria spores which were more abundant during the daytime. The rain on Sept. 17 resulted in sharp maxima in Cladosporium,

Fig. 10. Series III, September 17-22, 1968. Woodland site.

Fig. 10

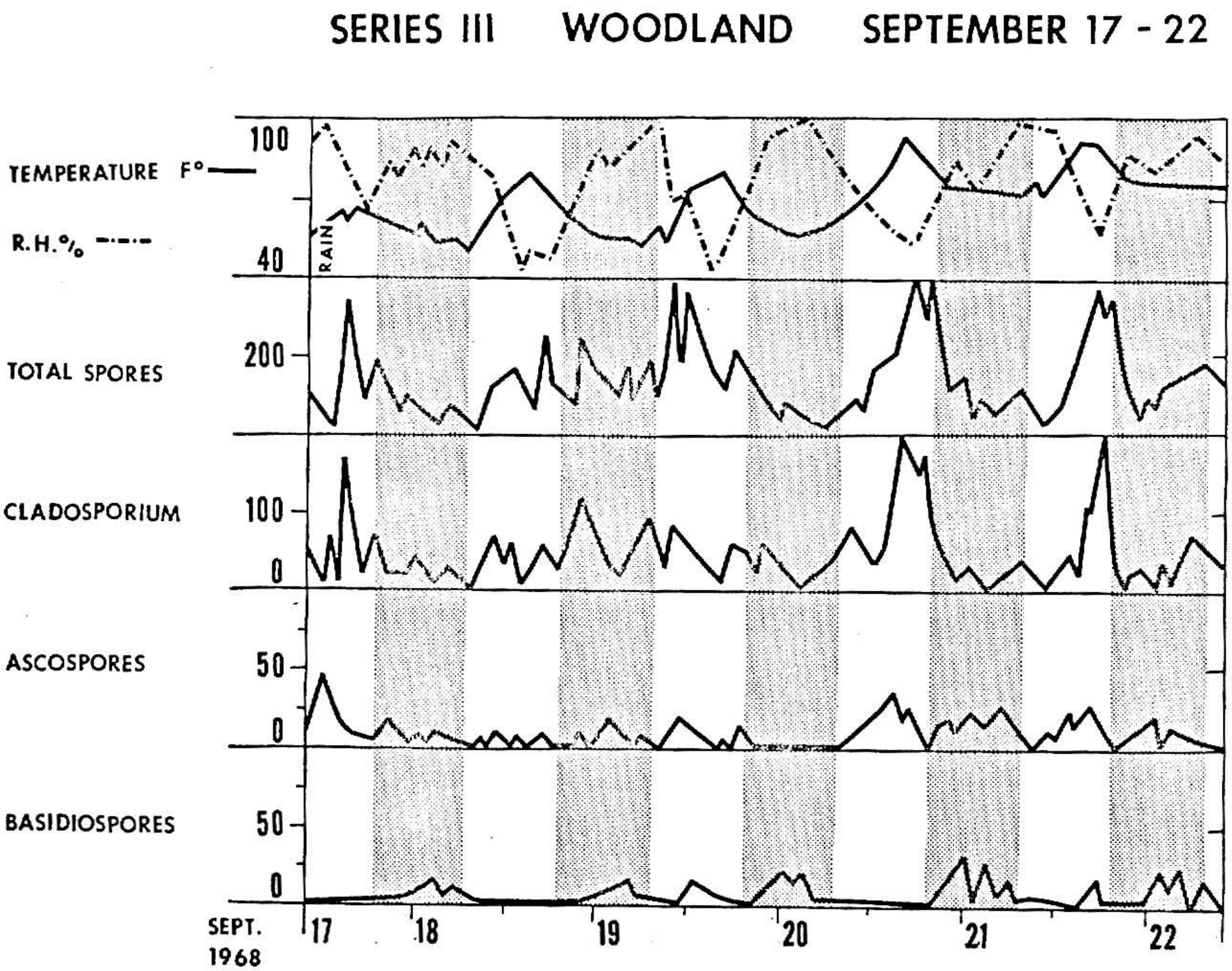
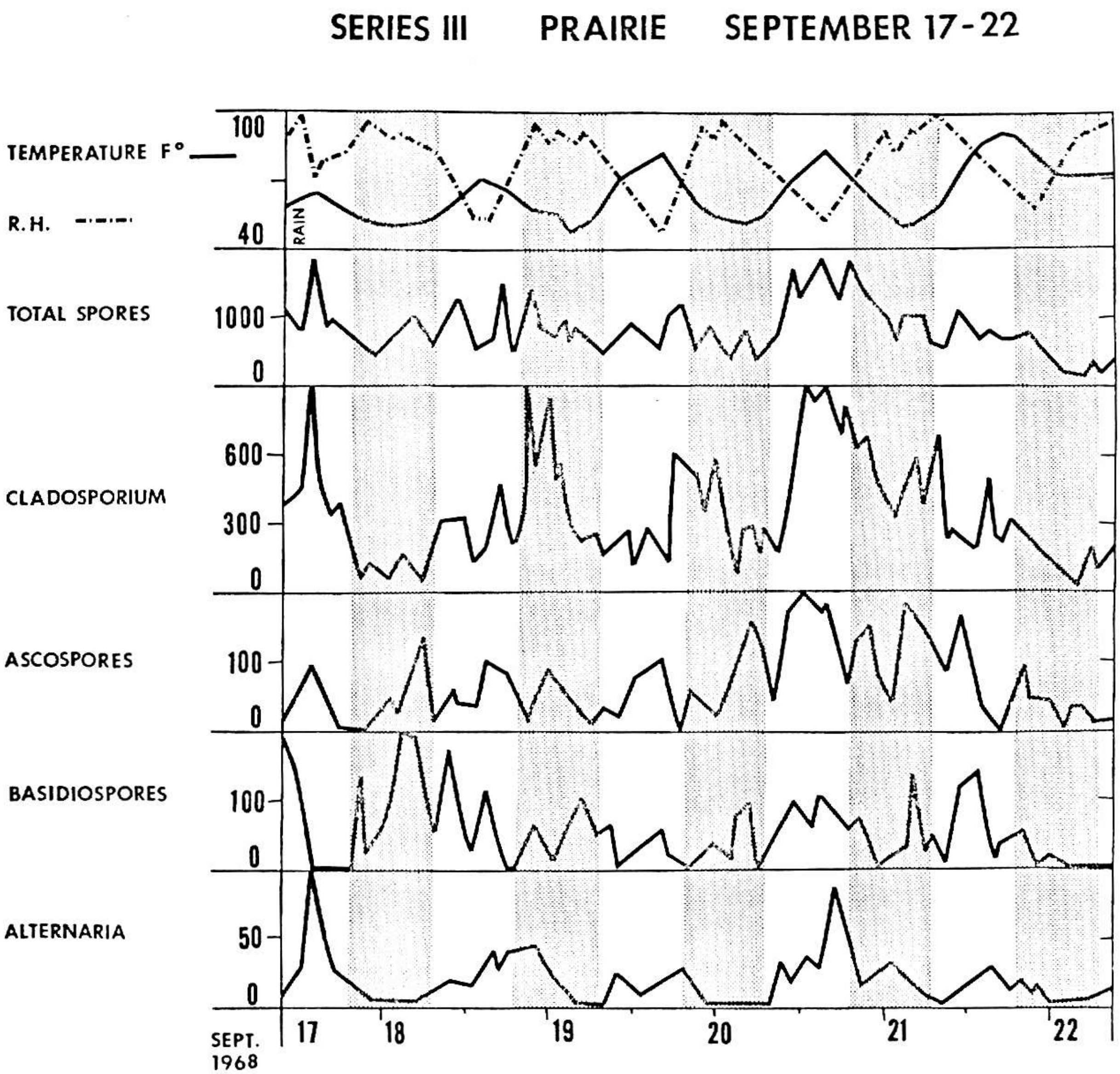

SERIES III WOODLAND SEPTEMBER 17 - 22
TEMPERATURE F°
R.H.%
100
40
RAIN
TOTAL SPORES
200
CLADOSPORIUM
100
0
ASCOSPORES
50
0
BASIDIOSPORES
50
0
SEPT.
1968
17
18
19
20
21
22

Fig. 11. Series III, September 17-22, 1968. Prairie site.

Fig. 11


SERIES III PRAIRIE SEPTEMBER 17-22
TEMPERATURE F°
R.H.
100
40
RAIN
TOTAL SPORES
1000
0
CLADOSPORIUM
600
300
0
ASCOSPORES
100
0
BASIDIOSPORES
100
0
ALTERNARIA
50
0
SEPT. 1968
17
18
19
20
21
22

ascospores and Alternaria as well as conidia of other Deuteromycetes. However, basidiospores did not occur during this time and were not evident until the nighttime. The majority of spores collected at the prairie site were undoubtedly not produced locally but were being transported in the general air mass from remote sources. The periodicity in the spore release pattern was not reflected in their catch.

Series IV, October 30-November 3, 1968 (Figs. 12 & 13). This series is considered representative of the air spora during periods when environmental conditions of the surrounding areas are unfavorable for growth and sporulation of fungi. Although 4.66 in of rain was received during the first part of October, none was received during the 2 weeks prior to the sampling period. At the woodland site (Fig. 12), temperatures were in the 60's and 70's during the day and 40's and 50's at night. During the day the relative humidity was in the 50's and 60's and at night it was in the 70's and 80's. Generally, at the prairie site (Fig. 13), the temperature averaged 4 F lower and the relative humidity readings corresponded with those found at the woodland site.

Spore numbers were low averaging less than $50/ft^3$ for any of the major components of the air spora at either site. Because of the low numbers and absence of any periodic patterns in their occurence, it was believed that a large percentage of the spores collected were from remote areas being carried in the air mass passing over the collecting sites.

Series V, May 27-30, 1969 (Figs. 14 & 15). During this series, moderate temperatures plus high humidites and 4.16 in of rain during the month of May made conditions favorable for fungal growth and sporulation at both sites. A rain of 1.12 in received on May 29, caused a decided increase in

Fig. 12. Series IV, October 30 - November 3, 1968.
Woodland site.

Fig. 12

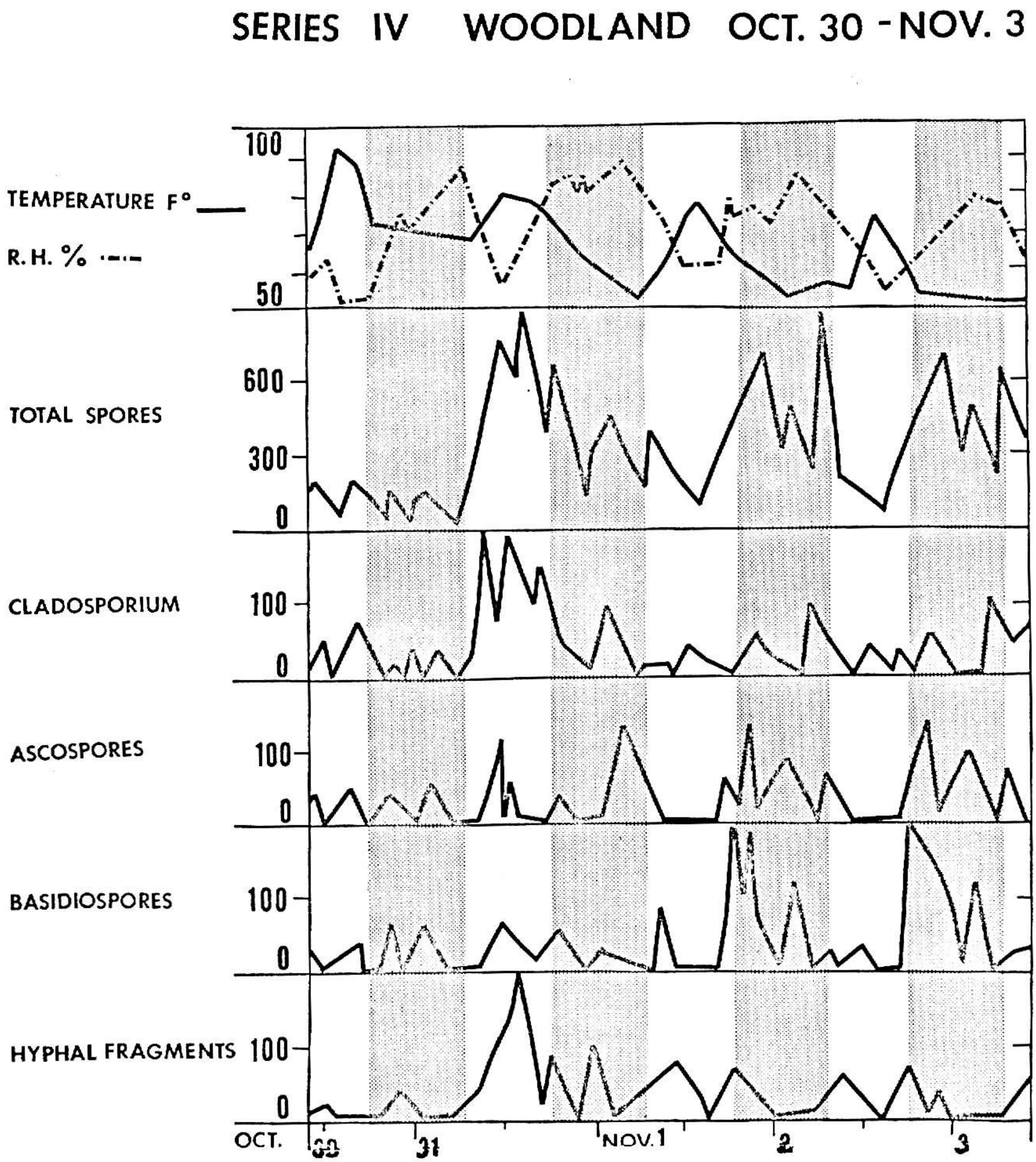

SERIES IV WOODLAND OCT. 30 - NOV. 3
TEMPERATURE F°
R.H. %
100
50
TOTAL SPORES
600
300
0
CLADOSPORIUM
100
0
ASCOSPORES
100
0
BASIDIOSPORES
100
0
HYPHAL FRAGMENTS
100
0
OCT.
30
31
NOV. 1
2
3

Fig. 13. Series IV, October 30 - November 3, 1968.
Prairie site.

Fig. 13

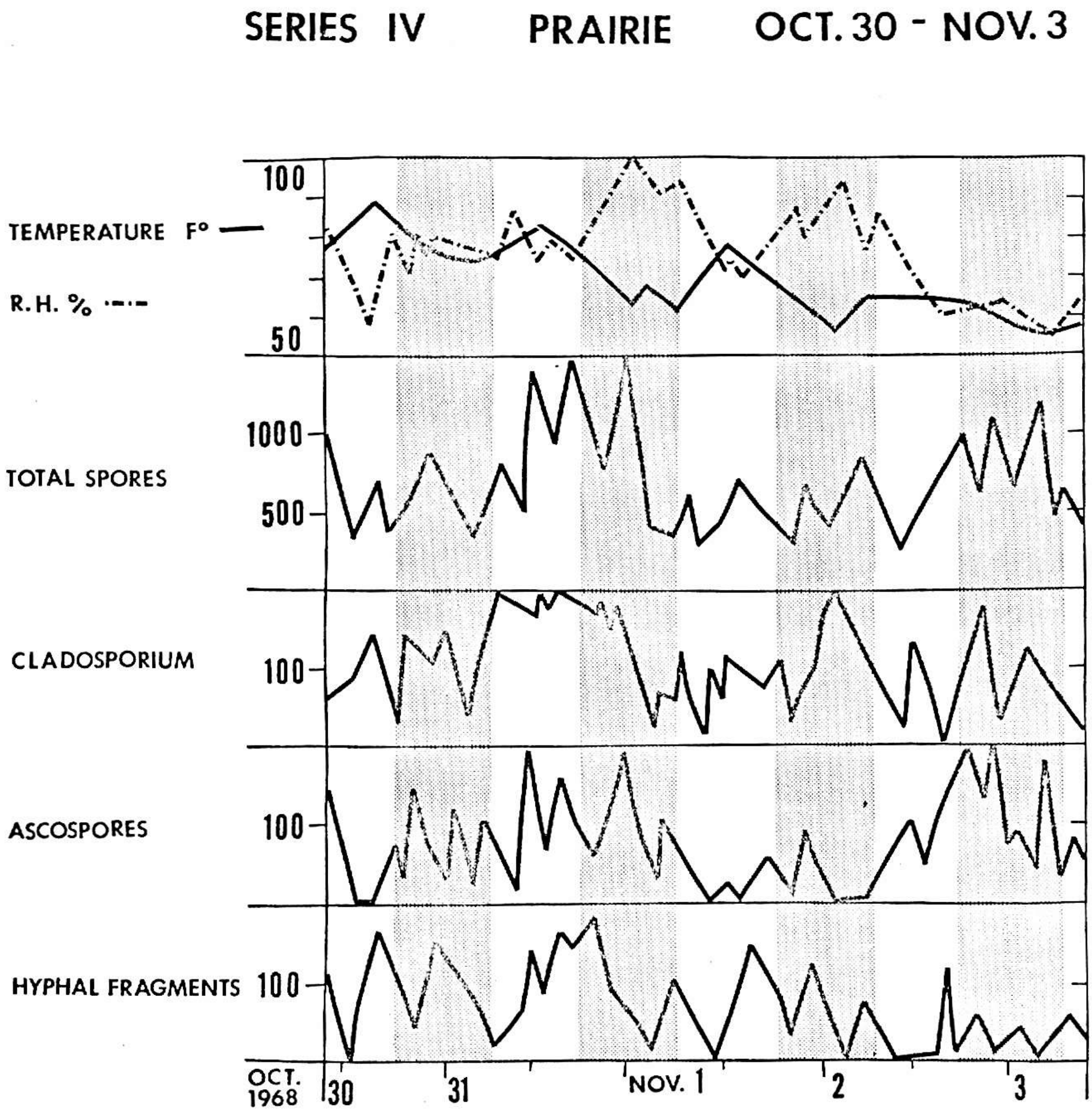

SERIES IV PRAIRIE OCT. 30 - NOV. 3
TEMPERATURE F°
R.H. %
100
50
TOTAL SPORES
1000
500
CLADOSPORIUM
100
ASCOSPORES
100
HYPHAL FRAGMENTS
100
OCT. 1968
30
31
NOV. 1
2
3

Fig. 14. Series V, May 27-30, 1969. Woodland site.

Fig. 14

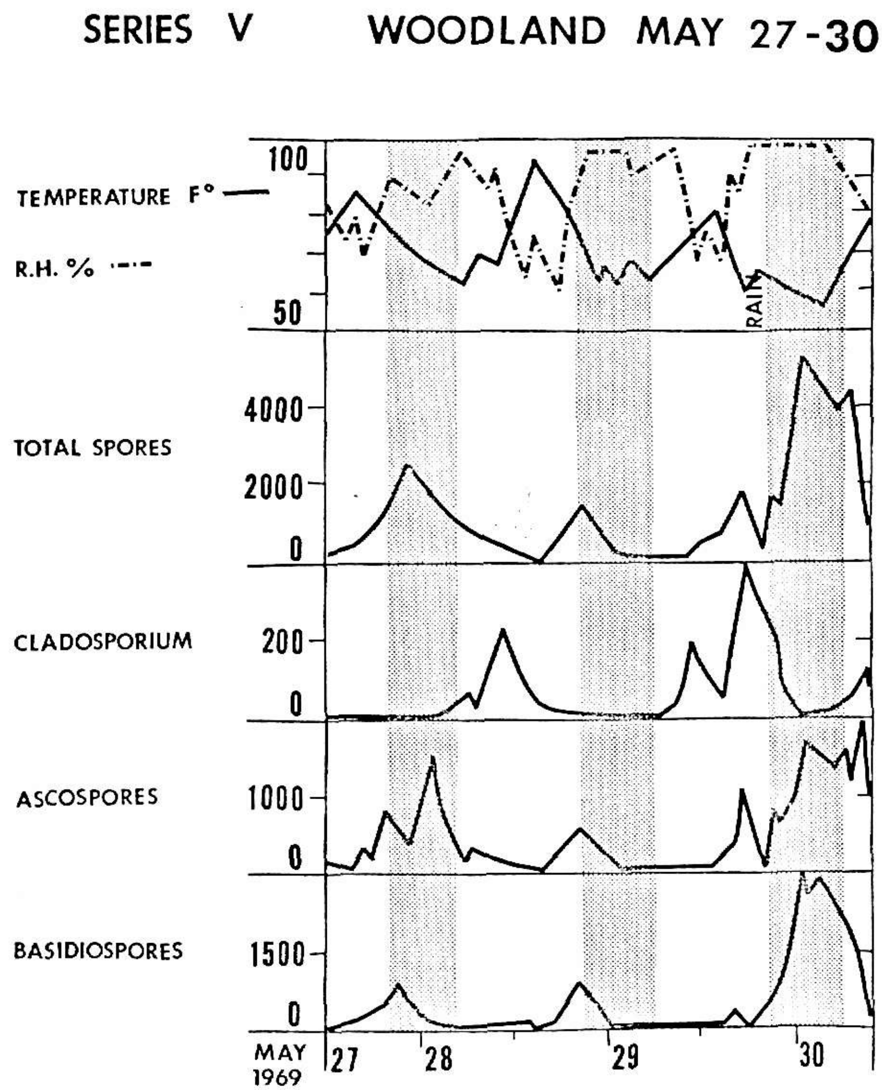
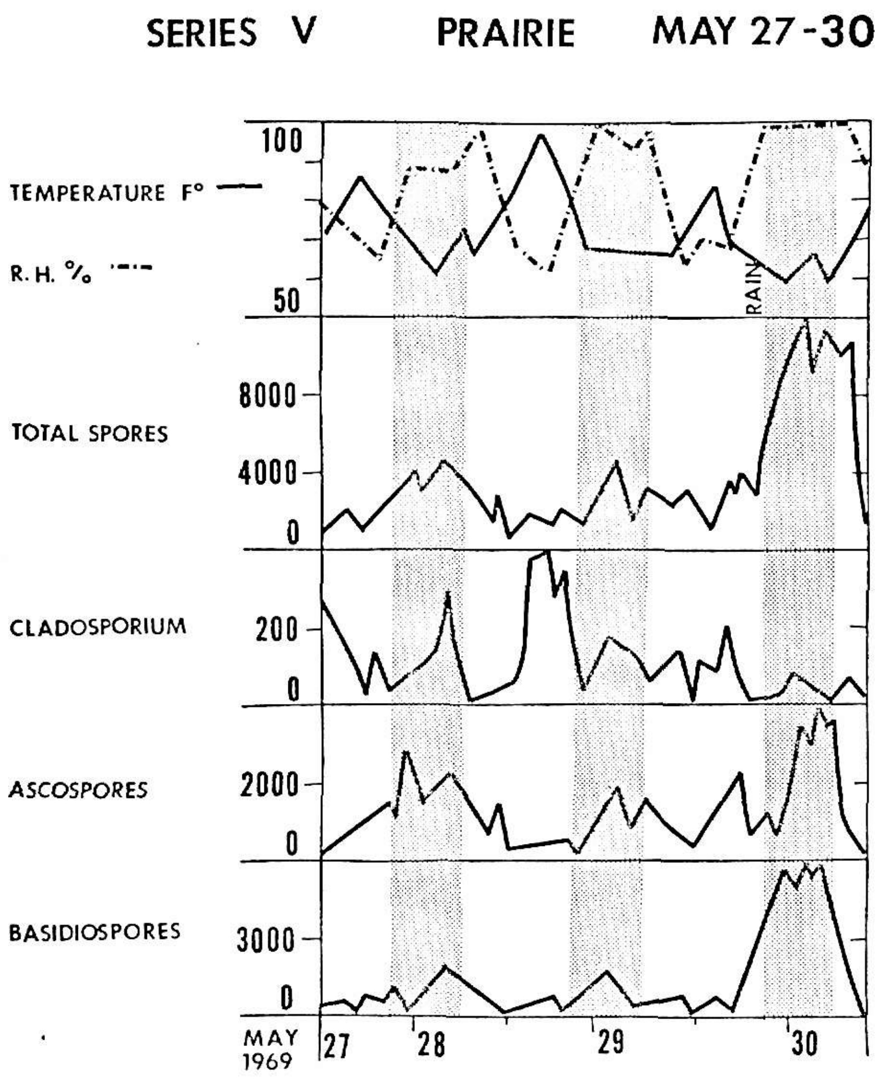

SERIES V WOODLAND MAY 27-30
TEMPERATURE F°
R.H. %
100
50
RAIN
TOTAL SPORES
4000
2000
0
CLADOSPORIUM
200
0
ASCOSPORES
1000
0
BASIDIOSPORES
1500
0
MAY
1969
27
28
29
30

Fig. 15. Series V, May 27-30, 1969. Prairie site.

Fig. 15


SERIES V PRAIRIE MAY 27-30
TEMPERATURE F° ——
R.H. % -·-
100
50
RAIN
TOTAL SPORES
8000
4000
0
CLADOSPORIUM
200
0
ASCOSPORES
2000
0
BASIDIOSPORES
3000
0
MAY
1969
27
28
29
30

spore numbers of most types during the next 24 hrs. At the woodland site (Fig. 14), total spore numbers averaged approximately 300/ft^3 the first 48 hrs of the series and 650/ft^3 the 24 hr period following the rain. At the prairie site (Fig. 15), spore numbers were approximately double those at the woodland site both before and following the rain. At both sites, ascospores and basidiospores accounted for 90% of the total spore numbers. Distinct periodicities were evident in the occurrence of all 3 major spore groups at the woodland site, however, at the prairie site there was considerable hour to hour variation obscuring any periodic pattern.

Series VI, June 2-6, 1969 (Figs. 16 & 17). During the 2 weeks preceding this series, 2.05 in of precipitation fell in a series of scattered rains. Rain occurred the day prior to the sampling period and a trace fell during the afternoon of June 3. During this series at both sites, temperatures were moderate, in the 60's-70's during the day and relative humidity was high in the 90's at night providing favorable conditions for growth and sporulation of fungi.

At the woodland site (Fig. 16), total spore numbers were relatively low averaging 70/ft^3 the first two days of the series and then increased to an average of 440/ft^3 the last two days with nighttime maxima. Ascospores and basidiospores were responsible for the increase. Also at both the sites Alternaria, Cercospora, and wheat rust urediospores were present but were too infrequent to indicate periodicity.

At the prairie site the ascospores and basidiospores again accounted for the total spore nighttime maxima. These numbers compared favorable with the woodland numbers, however, the nighttime periodicity was not as explicit as at the woodland site.

Fig. 16. Series VI, June 2-6, 1969. Woodland site.

Fig. 16

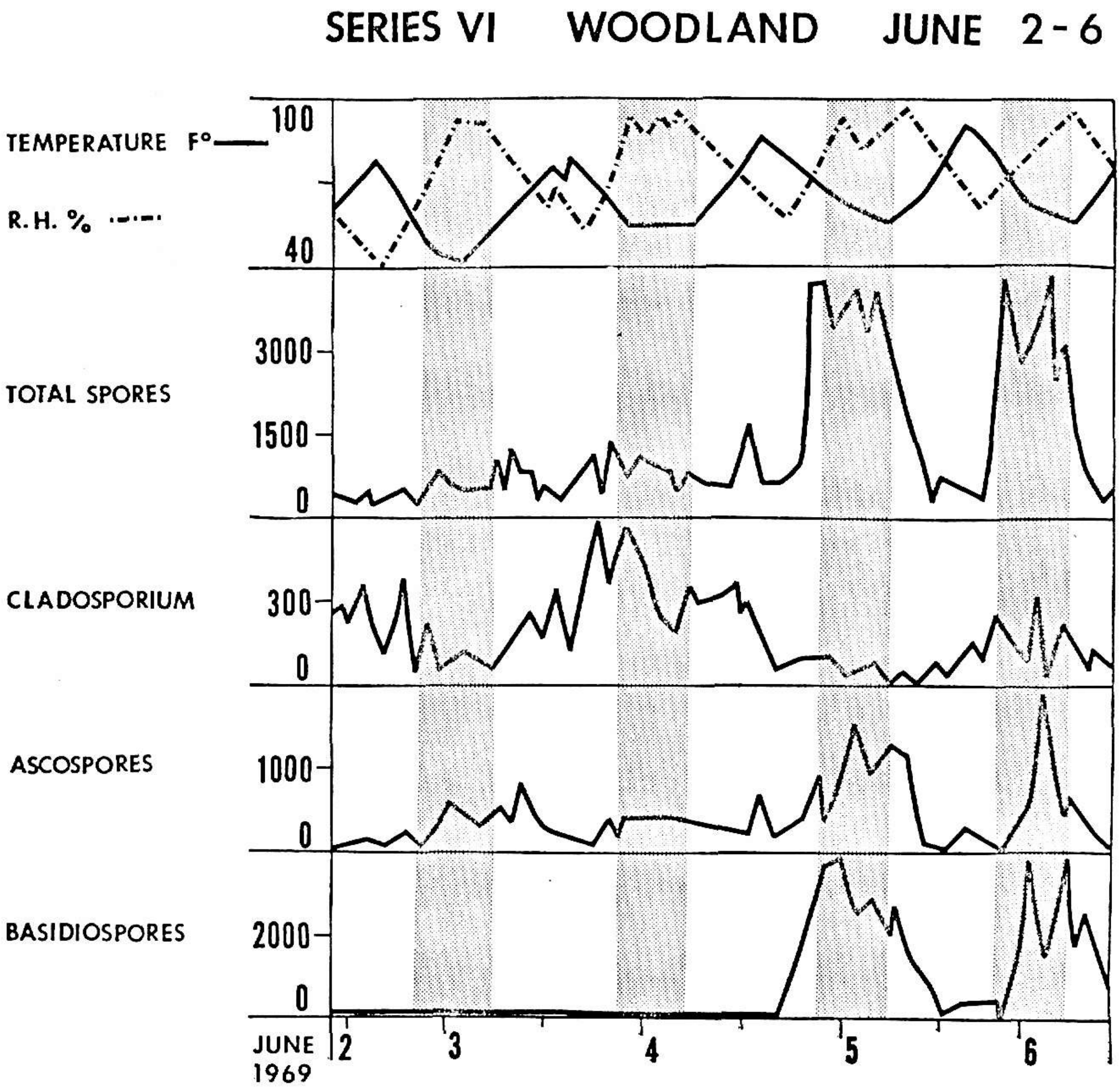
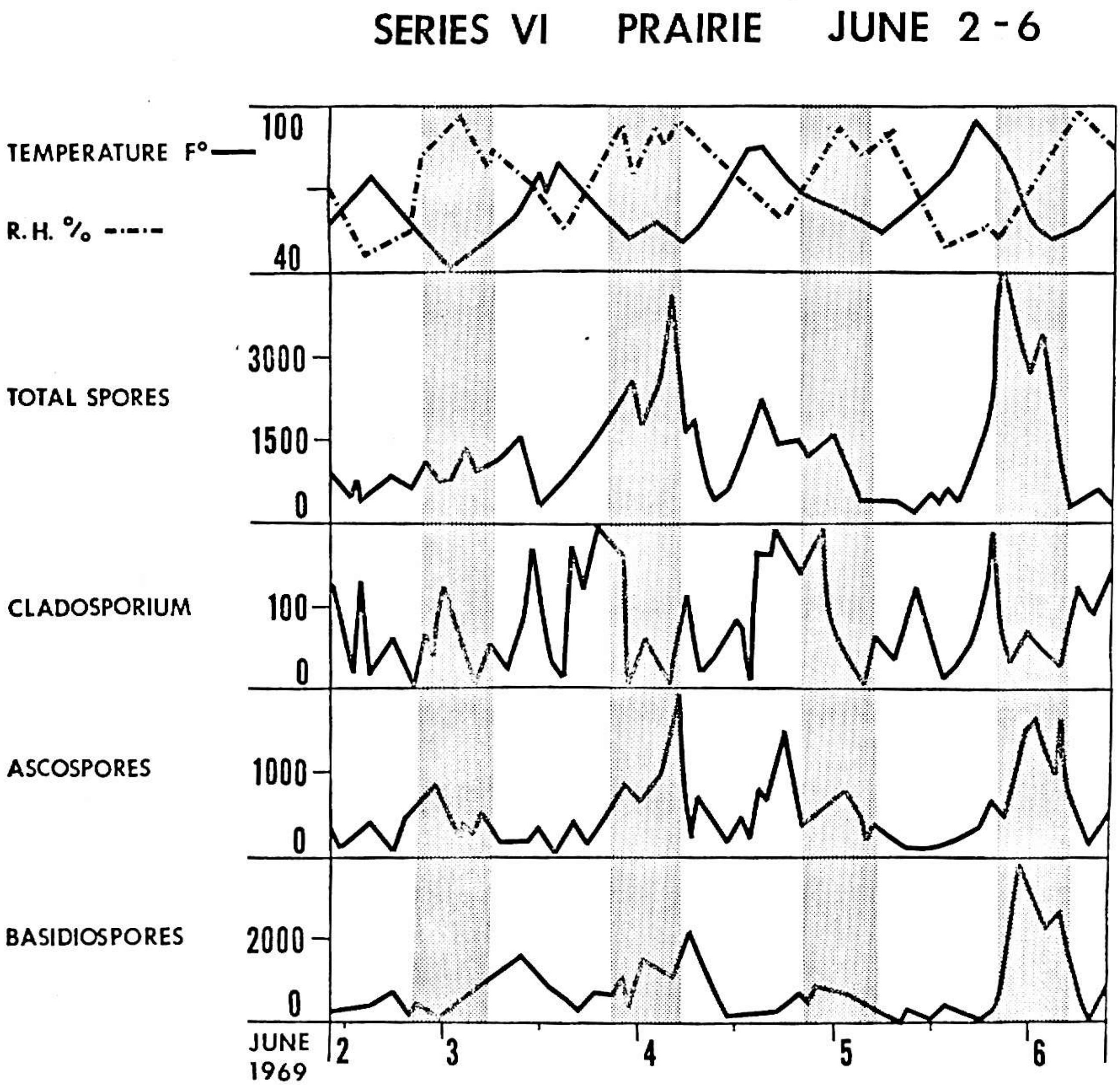

SERIES VI WOODLAND JUNE 2-6
TEMPERATURE F°
R.H. %
100
40
TOTAL SPORES
3000
1500
0
CLADOSPORIUM
300
0
ASCOSPORES
1000
0
BASIDIOSPORES
2000
0
JUNE
1969
2
3
4
5
6

Fig. 17. Series VI, June 2-6, 1969. Prairie site.

Fig. 17


SERIES VI PRAIRIE JUNE 2-6
TEMPERATURE F°
R.H. %
100
40
TOTAL SPORES
3000
1500
0
CLADOSPORIUM
100
0
ASCOSPORES
1000
0
BASIDIOSPORES
2000
0
JUNE 1969
2
3
4
5
6

Series VIII, September 28-October 3, 1969 (Figs. 18 & 19). During this series the weather was clear with moderate temperatures and no rain was received during or the week preceding this series. At both sites the relative humidity was in the 50's during the day and reached a maximum of near 90% in the early morning.

At the woodland site (Fig. 18), spore numbers were high with minima generally exceeding maxima of the prairie site. However, there was no evidence of periodic patterns with the exceptions of Cladosporium and Alternaria which did show minor daytime maxima. Unusual in this series was the high ascospore and basidiospore counts during the night of Sept 30/Oct 1. No explanation could be found for these high numbers which occurred only during this night.

At the prairie site (Fig. 19), spore numbers were generally low with no periodicity observed in any of the spore types. The Sept. 30 slide of this series was slightly smeared and this explained the missing data for that day. It was interesting to note that this was the second time in our studies that the prairie site numbers generally were lower than the woodland numbers.

Series IX, October 28-November 2, 1969 (Figs. 20-21). During this series moisture was plentiful but temperatures were too low to offer favorable conditions for growth and sporulation of fungi. Approximately 1.25 in of rain fell during this series with the greatest amount (0.73 in) falling continuously throughout the 24-hr period of Oct. 29. Throughout the entire series the sky was cloudy with low temperatures and high relative humidities that were approximately the same at the two sites.

There was no consistent daily periodic pattern in the occurrence of

Fig. 18. Series VIII, September 28-October 3, 1969.
Woodland site.

Fig. 18

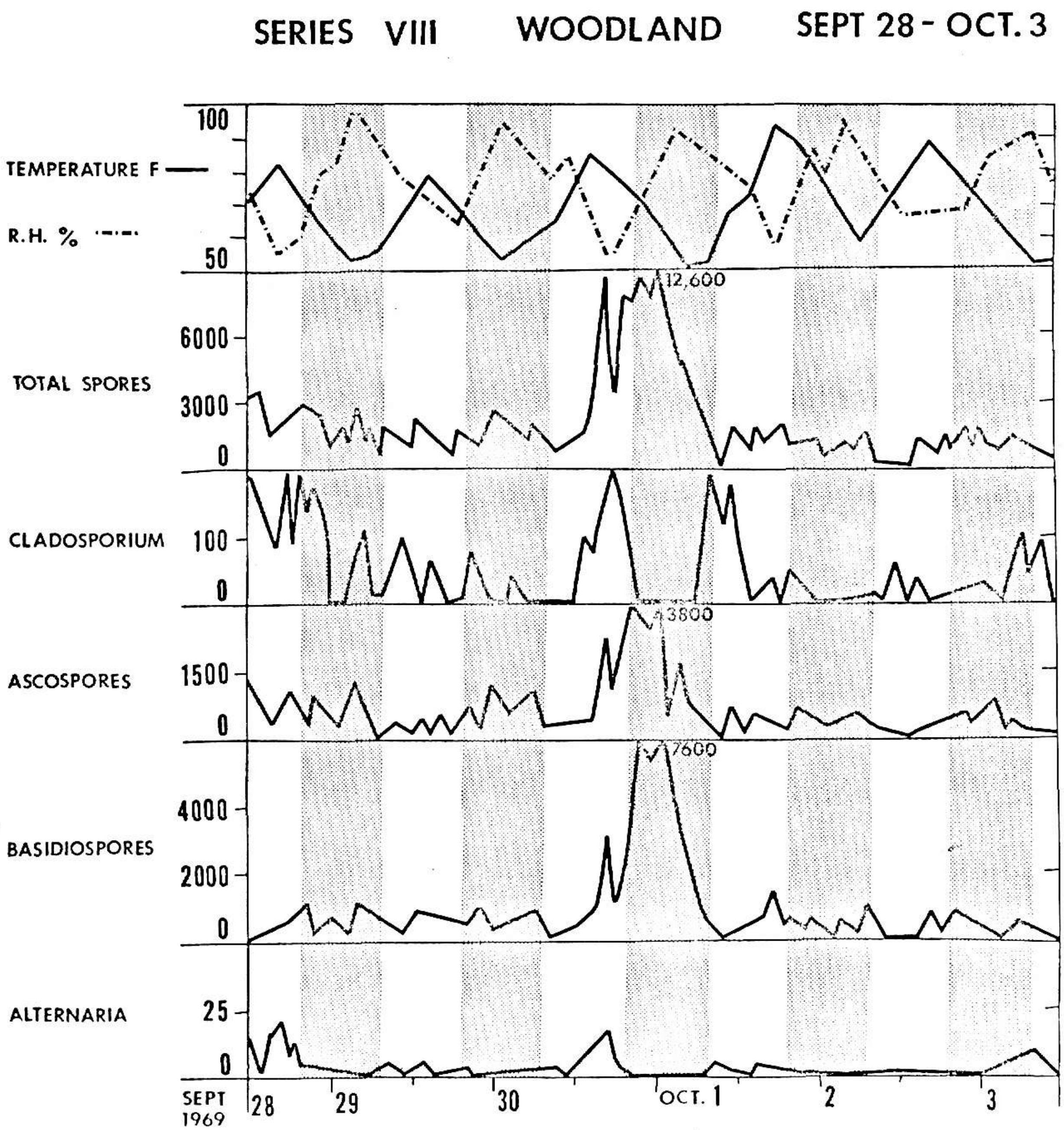

SERIES VIII WOODLAND SEPT 28 - OCT. 3
TEMPERATURE F
R.H. %
100
50
TOTAL SPORES
6000
3000
0
12,600
CLADOSPORIUM
100
0
ASCOSPORES
1500
0
3800
BASIDIOSPORES
4000
2000
0
7600
ALTERNARIA
25
0
SEPT 1969
28
29
30
OCT. 1
2
3

Fig. 19. Series VIII, September 28-October 3, 1969. Prairie site. (Malfunction of the sampler was responsible for the missing data on Sept. 30).

Fig. 19

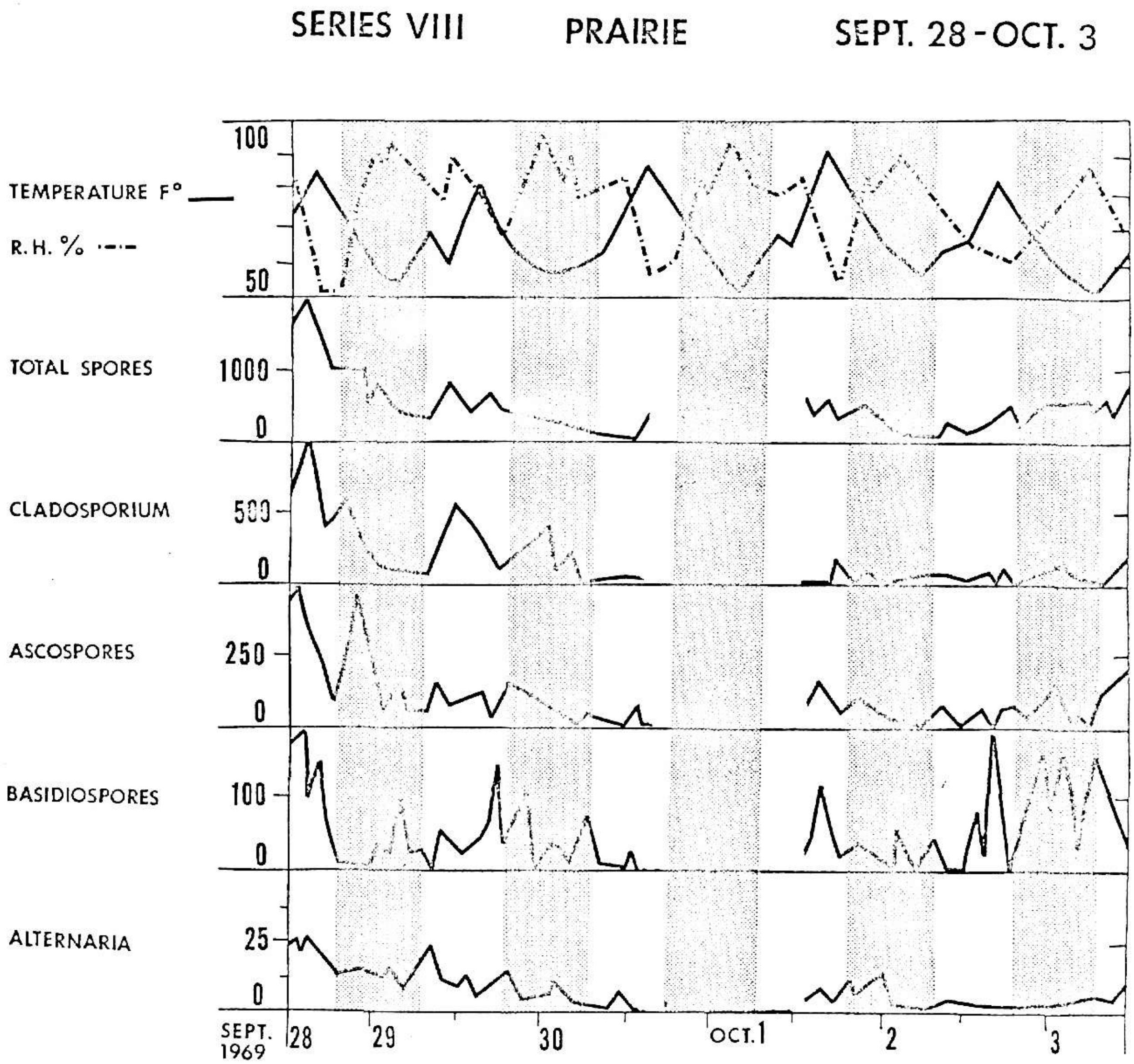

SERIES VIII
PRAIRIE
SEPT. 28 - OCT. 3
TEMPERATURE F°
R.H. %
TOTAL SPORES
CLADOSPORIUM
ASCOSPORES
BASIDIOSPORES
ALTERNARIA
100
50
1000
0
500
0
250
0
100
0
25
0
SEPT. 1969
28
29
30
OCT. 1
2
3

Fig. 20. Series IX, October 28-November 2, 1969.
Woodland site.

Fig. 20

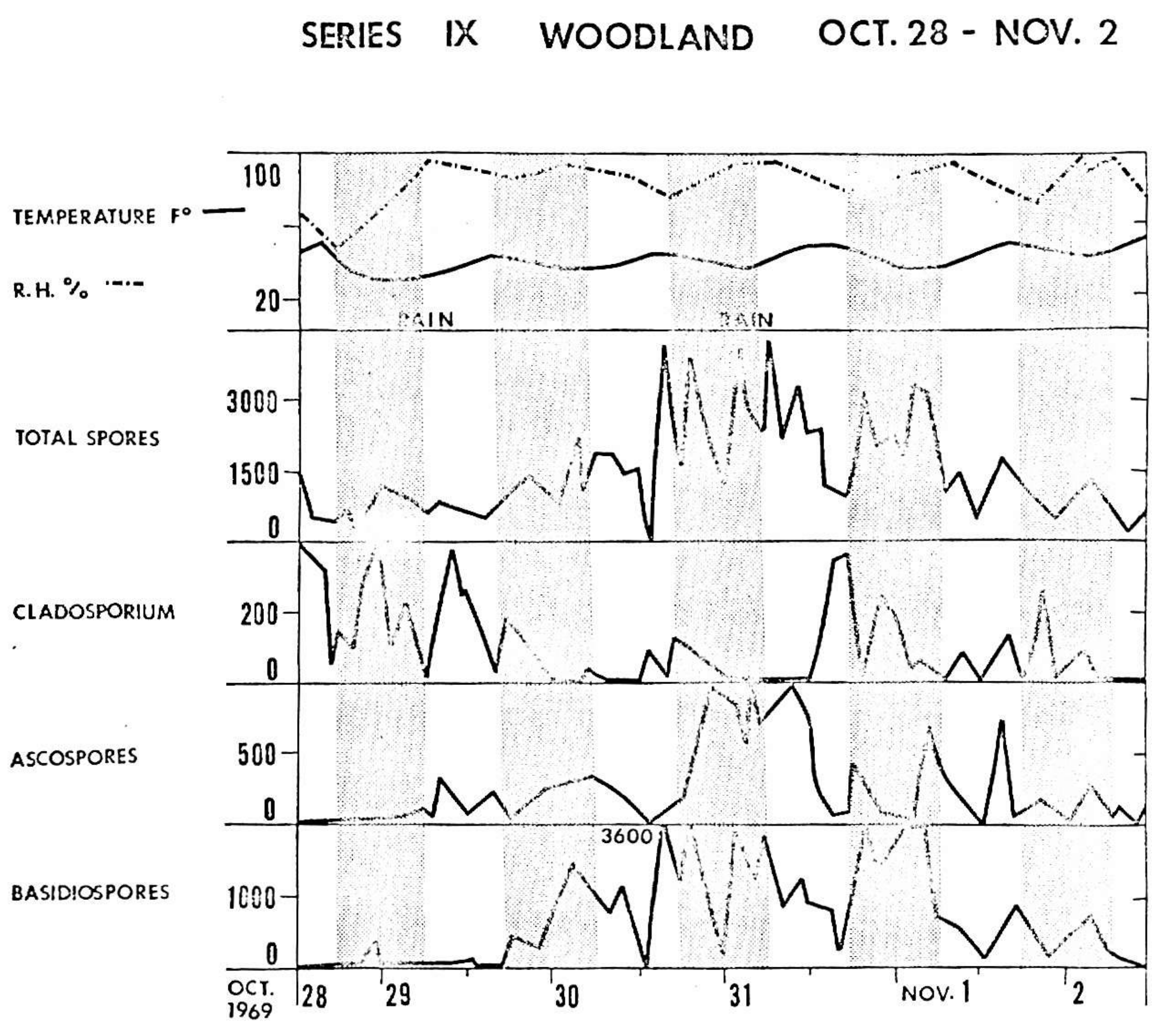

SERIES IX WOODLAND OCT. 28 - NOV. 2
TEMPERATURE F°
R.H. %
100
20
RAIN
RAIN
TOTAL SPORES
3000
1500
0
CLADOSPORIUM
200
0
ASCOSPORES
500
0
BASIDIOSPORES
3600
1000
0
OCT. 1969
28
29
30
31
NOV. 1
2

Fig. 21. Series IX, October 28-November 2, 1969.
Prairie site.

Fig. 21

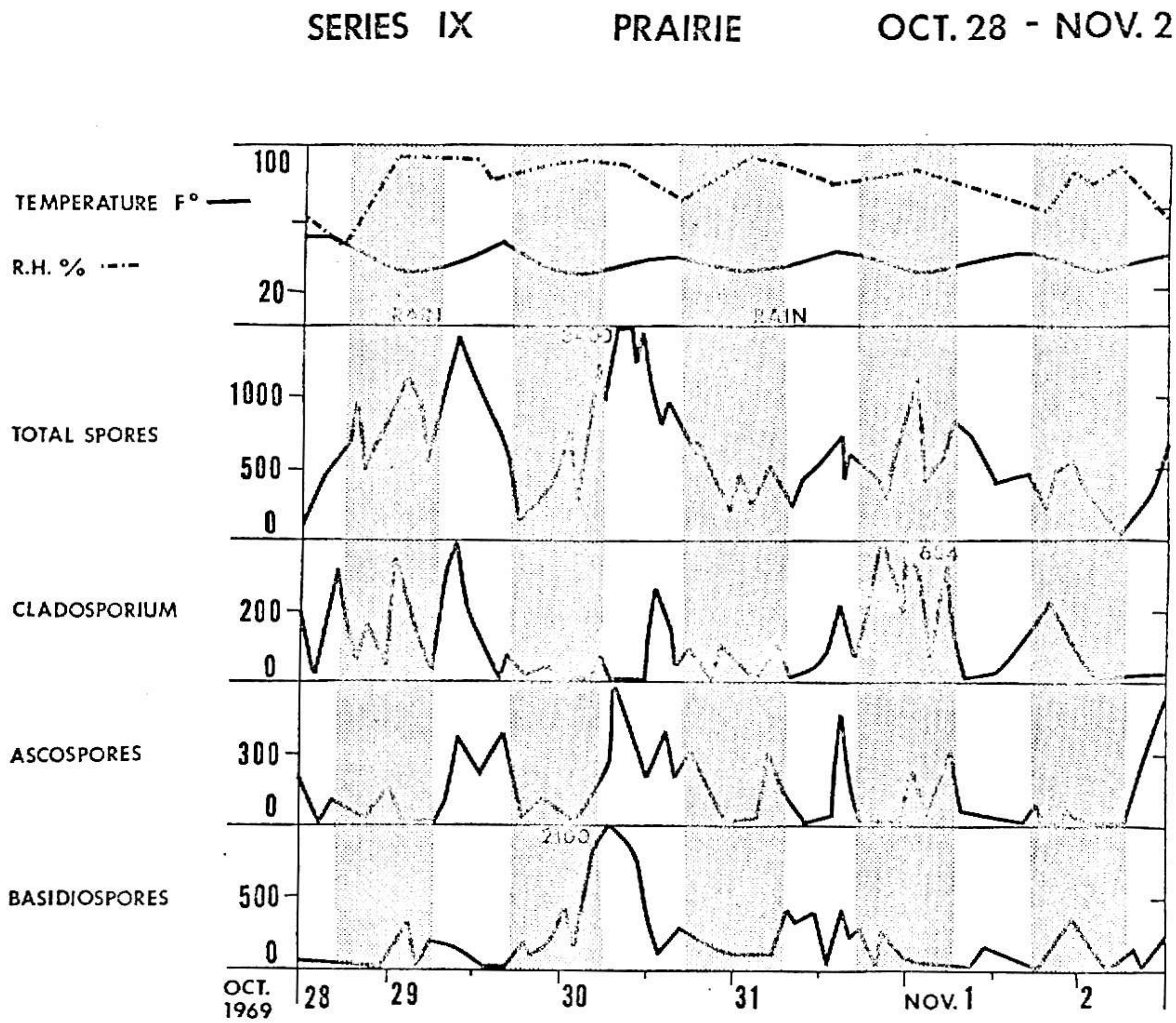
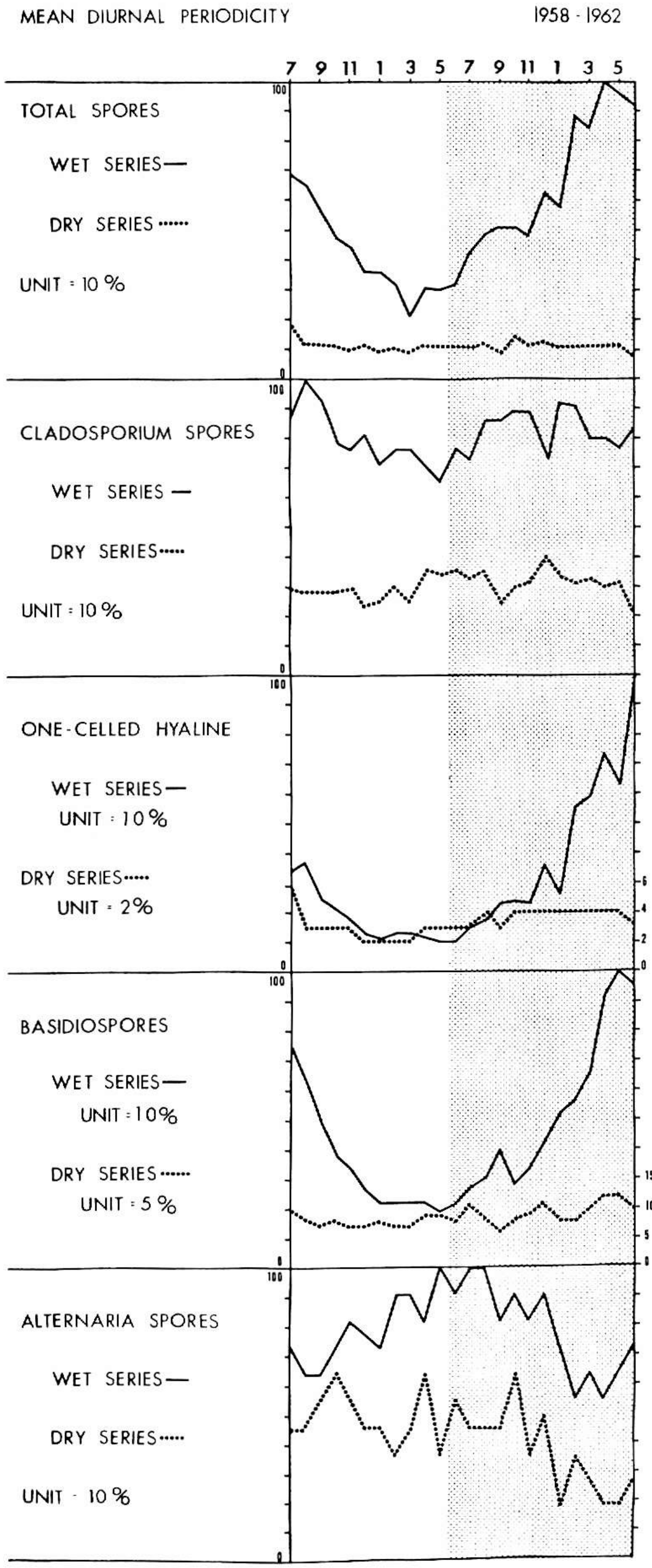

SERIES IX PRAIRIE OCT. 28 - NOV. 2
TEMPERATURE F°
R.H. %
100
20
RAIN
RAIN
TOTAL SPORES
1000
500
0
CLADOSPORIUM
200
0
ASCOSPORES
300
0
BASIDIOSPORES
2100
500
0
OCT. 1969
28
29
30
31
NOV. 1
2

Fig. 22. Numbers of spores per hour in wet and dry series. Wet series were taken when environmental conditions were favorable for the growth of fungi. Dry series were during periods that were unfavorable. Figures are percent of total. Kansas Aeromycology XV: Summer air spora, 1958-1962.

Fig. 22


MEAN DIURNAL PERIODICITY
1958 - 1962
7 9 11 1 3 5 7 9 11 1 3 5
TOTAL SPORES
WET SERIES—
DRY SERIES······
UNIT = 10 %
CLADOSPORIUM SPORES
WET SERIES —
DRY SERIES·····
UNIT = 10 %
ONE-CELLED HYALINE
WET SERIES—
UNIT = 10 %
DRY SERIES·····
UNIT = 2%
BASIDIOSPORES
WET SERIES—
UNIT = 10%
DRY SERIES······
UNIT = 5 %
ALTERNARIA SPORES
WET SERIES—
DRY SERIES·····
UNIT - 10 %

any of the spore types at either location. The rains that occurred on two days of the series had little effect on the concentration or composition of the air spora.

Figure 22 has been compiled from data obtained by Kramer et al. (1963, 1964) and Pady et al. (1962) during their studies of the air spora of Kansas from 1958-1962. In these studies distinct daily periodicities were found in the various spore types which occurred only during periods when moisture was sufficent to support growth of fungi in the vicinity of the sampling station. This distinct periodicity was shown in one-celled hyaline spores, basidiospores and total spores. During periods of unfavorable environmental conditions, spore numbers were comparatively low and distinct periodic patterns were not evident.

DISCUSSION

There have been very few studies made of a comparison of the air spora of two contrasting ecological sites located near one another. The two sites selected for this study were approximately 1500 ft apart; one on a prairie hilltop, the other in a woodland ravine at the base of the hill. Generally, the concentration of spores collected at the prairie site was approximately twice that collected at the woodland site. This was in contrast to that of a somewhat similar study done by Lacey (1962) in England, who found 2.6 times more spores in the air at a site located near a stream surrounded by trees on three sides than at a nearby grassy hill site exposed to winds from the west and north-west.

The composition of the air spora also varied at the two sites in this study. There were proportionately larger numbers of basidiospores and ascospores at the woodland site while the conidia of the Deuteromycetes such as _Cladosporium_, _Alternaria_, and _Helminthosporium_ were more abundant at the prairie site. Lacey (1962) and Adams et al., (1968) also reported basidiospores to be more abundant in wooded areas in England than at locations with other types of vegetation.

The season of the year also had a pronounced influence on both the concentration and the composition of spores at each site. In Kansas during late summer and early fall, temperatures and moisture conditions are generally suitable for growth and sporulation of fungi.

However, spore concentrations can become extremely high during the summer if exceptional amounts of rain are received. Earlier studies of the air spora of Kansas by Kramer et al., (1959) showed that exceptionally high concentrations of spores in the air during the summer of 1958 could be correlated with above average rainfall over extended periods during that time. In these earlier studies as well as in the present study at both locations, by the first of November spore concentrations had reached minimum winter time levels.

Seasonal changes in the composition of the air spora were most pronounced at the woodland site. At this location, ascospores and conidia of Deuteromycetes were the most abundant components during the spring and summer, however, in the fall as the fleshy basidiomycetes began to appear, basidiospores became the dominant spore type. At the prairie site, conidia were the dominant spore type throughout the year, although basidiospores became proportionately more abundant during the fall. The collections made on the roof of a campus building by Kramer et al., (1959) and Pady et al., (1962) more closely resembled those at the prairie site than at the woodland site.

The composition and concentration of the air spora also varied from hour to hour throughout the day at both sites. However, distinct maxima of day spora and night spora were usually most pronounced at the woodland site. Because of the protected location of the woodland site, it is believed that a larger proportion of the air spora was comprised of spores produced and released in the near vicinity of the sampler and that the circadian patterns of spore release were more closely reflected in the hourly variations of the population of the air spora. At the exposed prairie site, daily maxima of the various spore types were not as distinct, indicating that a larger proportion of the air spora collected at that site had been transported in the atmosphere in "spore clouds" of varying sizes and concentrations from remote sources and thus tended to obscure circadian patterns of release of locally produced spores.

A comparison of the daily periodicities of the air spora during periods when environmental conditions were favorable for growth and sporulation of fungi in the areas surrounding the sampling station and during periods of unfavorable conditions from studies made by Kramer et al., (1963, 1964) and Pady et al., (1962), from 1959-1962 (Fig. 22). Distinct daily periodicities of the various spore types occurred only during periods favoring growth of fungi in the locale of the sampling station. During periods of unfavorable environmental conditions, spore numbers were comparatively low and distinct periodic patterns were not evident. Similar results were obtained in the present study. It is believed that these results indicate that during periods of favorable environmental conditions the large volumes of the various spore types released locally at certain times of the day reflect their release patterns in the spore catch. However, when such volumes of spores are not released locally, it is felt that the population of the air spora of the atmosphere in such an area consists primarily of spores transported from remote sources and thus do not reflect daily periodicities of release. In such cases the hour to hour variation is usually extreme and maxima may occur at any time of day.

The genus Cladosporium may serve to exemplify some of these ideas. At the prairie site, the spore trap was more openly exposed to the prevailing southwesterly winds and it is believed that a much higher percentage of the spores collected at this location were from remote sources being carried in the air mass passing over the site. Thus, due to the heterogeneity of the air spora within the air mass, as indicated by frequent extreme hour to hour variations, heavy concentrations (spore clouds) of Cladosporium spores might occur at the sampling site causing maxima (of varying magnitudes) at anytime of the day.

In contrast to this, at the woodland site Cladosporium spores generally occurred with maxima during the daytime. It is believed that because of the protected location the majority of Cladosporium spores collected were locally produced and this reflected the circadian pattern of spore release. In earlier studies in a wheat field where a K-C sampler was located near the ground among the plants and Cladosporium occurred abundantly on the lower leaves of the wheat plants, spore release occurred in the morning with rising winds and decreasing RH (Pady et al., 1969).

To a lesser extent these same differences were also characteristic of other spore types. Thus, generally collections at the woodland site tended to reflect the circadian patterns of spore release; while those at the prairie site depicted the variations in spore concentrations in the air masses as they passed over the collecting site.

There is general agreement that basidiospores and Cladosporium are the commonest fungi in the air and that basidiospores have nighttime maxima (Hirst, 1953; Gregory & Sreeramulu, 1958; Hamilton, 1959). At the woodland site, basidiospore numbers were 3-5 times those at the prairie site. A similar difference was found by Lacey (1962) between the stream site and exposed hill site in her studies in England. Adams et al., (1968) also reported that basidiospores were more abundant in woodlands than in any other type of habitat in England. These studies all indicated that in protected areas where basidiospores were trapped near their source of production, nighttime maxima occurred which reflected their circadian pattern of spore release. In the extensive study of basidiospore release in Hymenomycetes in the field, Haard and Kramer (1970) found that most species released their spores primarily at night.

Ascospores were the most irregular in regard to daily pattern of occurrence of all spore types. They were generally more abundant at night, but rainfall or heavy dew were also important in causing maxima of high magnitudes. Increases in ascospore numbers usually began within one to a few hours following a rain. In most cases, ascospores were more abundant at the woodland site. However, these differences apparently were not as great as in the study done by Lacey (1962) who reported 4.9 times more ascospores at the stream site near the woods than at the exposed prairie hill site.

In this study many fungi were too infrequent to indicate periodicity. Alternaria and hyphal fragments were abundant only during certain series and were included in the graphs only when sufficiently numerous. Alternaria exhibited an afternoon circadian rhythm at the prairie site throughout August and September. Previous studies (Hirst, 1953; Sreeramulu, 1959;

Adams, 1964) concluded that an afternoon periodicity was characteristic of Alternaria, because of the stronger afternoon winds which dislodge the conidia from the conidiophores.

SUMMARY

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 1968 and 1969. The concentration of spores collected at the prairie site was approximately twice the number at the woodland site. This was due to the prevalence of conidia of Deuteromycetes such as Cladosporium, Alternaria, and Helminthosporium. At the woodland site basidiospores and ascospores were usually more abundant than condia.

Daily periodicity in the occurrence of the various spore types was most pronounced at the woodland site. This indicated that a larger proportion of spores collected were from local sources and thus reflected their circadian patterns of release in the hourly collections. The greater hourly variation and the less distinct daily periodicities at the exposed prairie hilltop site indicated that a greater proportion of the spores collected were from remote sources being transported in the atmosphere.

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A COMPARISON OF THE AIR SPORA OF
TWO SITES NEAR
TUTTLE CREEK RESERVOIR,
POTTAWATOMIE COUNTY, KANSAS

by

DAVID LAWRENCE LONG

B. S., University of Wisconsin, 1967

AN ABSTRACT OF A MASTER'S THESIS

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requirements for the degree

MASTER OF SCIENCE

Department of Plant Pathology

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

ABSTRACT

There have been very few studies done in which a comparsion of the air spora of two contrasting ecological sites located near one another have been made. With this in mind it was decided to study the air spora on an hourly basis at various times of the year during periods of varying environmental conditions at two sites. These were a woodland ravine and a prairie hilltop located approximately 1500 ft apart near the Tuttle Creek Reservoir in Pottawatomie County, Kansas. Collections were made during 1968 and 1969 using Kramer-Collins Spore Samplers located 2 ft above ground.

The concentration of the spores at the prairie site averaged approximately twice the number at the woodland site. This was due to the high numbers of conidia of Deuteromycetes such as Cladosporium, Alternaria, and Helminthosporium at the prairie site.

Daily periodicities in the occurrence of the various spore types, eg. conidia, basidiospores and ascospores, were most pronounced during periods when environmental conditions of surrounding areas were most suitable for growth and sporulation of fungi. However, even during favorable conditions, periodic patterns were less distinct at the exposed hilltop site. This indicated that a larger proportion of spores collected were from local sources and thus reflected their circadian patterns of release in the hourly collections. The greater hourly variation and the less distinct daily periodicities at the exposed hilltop site indicated that a greater proportion of the spores collected were from remote sources being transported in the atmosphere.

Changes in the air spora from season to season were also most pronounced at the woodland site. At this location, ascospores and conidia of Deuteromycetes were the most abundant components during the spring and summer. However, in the fall as the fleshy basidiomycetes began to occur, basidiospores became the dominant spore type. At the prairie site, conidia were the dominant spore type throughout the year, although basidiospores became proportionately more abundant during the fall.

It might be concluded that the spore collections at the woodland site generally reflected the circadian patterns of spore release; while those at the prairie site depicted the variations in spore concentrations in the air masses as they passed over the collecting site.