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AIR SPORA OVER RICE CROP WITH SPECIAL REFERENCE TO *Piricularia oryzae* Cav.

BY

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THESIS

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C E R T I F I C A T E

This is to certify that the thesis herewith submitted contains the results of bonafide research work carried out by Kumari. S. Maheswari Amma under my supervision. No part of the work embodied in this thesis has been submitted earlier for the award of any degree.

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CONTENTS

INTRODUCTION

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Most pathogenic as well as non pathogenic fungi liberate their spores into the air under favourable conditions. A knowledge of the occurrence of the spores of pathogenic fungi in the air and of the factors which favour their production and liberation is essential for evolving criteria for forecasting crop diseases. Many earlier workers have attempted to sample the air and evaluate the spore content in the atmosphere. Pasteur (1861-'62), Cunningham (1873), and Miquel (1883) were pioneers in the field. These attempts were not very highly successful because an effective sampling device was not available to the earlier workers. The introduction of the automatic volumetric spore trap by Hirst (1952) however provided a fresh impetus to this line of work. With the help of this trap it is now possible to sample the air continuously during the 24 hours of the day and to assess the spore load at any given time.

Correlating of spore load with meteorological data is thus made possible.

Study of air spora with particular reference to a crop is comparatively a new line of work as far as India is concerned. We also do not have a properly organised forecasting service for many of our important crop diseases. Any contribution in this direction is therefore likely to be useful.

An attempt was therefore made in the present work to study the air spora over the rice crop covering a period of two cropping seasons. Eventhough a number of types of fungal spores and pollen grains were trapped, the present study was confined to seven easily identifiable spore forms belonging to Piricularia oryzae, Trichoconis padwickii, Helminthosporium spp., Alternaria spp., Curvularia spp., Nigrospora sp. and a basidiomycete. Of these the first three organisms cause serious diseases on rice in Kerala. The trap was worked during the entire period of study and the spore loads of the different organism during the different periods of the day and also the seasonal and diurnal periodicity of occurrence of these spore forms have been determined. An attempt was also made to correlate spore load with weather factors. In addition in the case of Piricularia oryzae the incidence of the disease in the field was also studied in order to correlate disease incidence with spore load.

REVIEW OF LITERATURE

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As early as 1861 Pasteur introduced a simple spore trap by the help of which he demonstrated the existence of the air spora. Salisbury (1833) investigated the air spora in connection with malaria in U.S.A. by exposing glass sheets and examining them. Maddox (1870-'71) invented a form of aeroconiscope for trapping spores in the atmosphere and this was later used by many investigators. Cunningham (1873) using this spore trap studied the air spora of Culcutta.

Meier *et al* (1933) collected spores over the Eastern United States in 1932 at altitudes ranging from 500 to 18000 ft. His studies investigated that certain agents of plant diseases might travel long distances in a viable condition before falling and starting new local infections. Above 8000 ft. the numbers usually declined considerably but viable *Pestalotia* spores were collected during March, 18000 ft. above Washington. Species of a number of genera were also identified. Pady *et al* (1950) showed the presence of spores of aerial pathogens on slides exposed from the planes in 1947 in arctic and subarctic regions.

Among the spores trapped were those of Puccinia graminis; P. triticina, Helminthosporium sativum; Helminthosporium sp. and smuts. Tervet and Cherry (1950) constructed a "Cyclone separator" for the collection of dry fungus spores of the atmosphere. Kelly et al (1951) described three methods for sampling air-borne bacteria and fungi from air craft flying at about 200 mph. The first is a qualitative method, using a sampling tube to hold a petri dish 12 metre in front of the air craft nose, yet permitting loading from the interior. With the second and third methods, which are quantitative, the samplers were located inside the air craft, air being brought to them by a rubber hose connected to 1 in. aluminium elbows in a side window.

Rajan et al (1952) during their study of the atmospheric fungal flora at Kanpur for one year from July 1945 used the culture plate method and recorded 38 fungus species. The organisms were more prevalent at a height of 8 ft. than at 4 ft. Gregory (1952) studied the spore content of the atmosphere near the ground at Rothamsted Experimental Station using the cascade impactor designed for sampling aerosols in the field. He sampled the air in dry weather at a height of 2 miles. Uredospores of Puccinia spp. were not abundant despite heavy infection of wheat with Puccinia glumarum, while conidia of Erysiphe graminis occurred in as much higher concentration. It is considered that these came from a heavily infected spring sown barley field 50 yds away. Spores of Ustilago avenae and probably of U.perennans occurring singly or in clumps formed a substantial portion of the total. Basidiospores of Ganoderma also occurred. Minute hyaline spores, many believed to be of Sporobolomyces spp. Reached a high concentration of 7000 per cubic metre, but disappeared soon after dawn as the day time spora became reestablished.

Hirst (1952) constructed an automatic volumetric apparatus consisting of an impactor unit, wind vane housing and motor housing for trapping air-borne spores. Kelly and Pady (1953) made estimation of the numbers of bacteria and fungi in the air on ten flights between Goosebay, Labrador & Fairbranks and Alaska, using agar plates and silicon coated slides. The results were correlated with definite air masses. The average number of bacteria and fungi was found to vary with the air mass and time of the year.

Gregory (1954) constructed and used a portable volumetric form of Hirst spore trap, which is light cheap and easy to operate. This trap can take only small samples at a time and the spore deposit is more sparse than with Hirst trap. It is suitable for measuring high spore concentrations.

Kelly and Pady (1954) made microbiological studies of air masses over Montreal from September 1950 to December 1951. Nine hundred and seventy eight exposures were made from the top of a building, 400 ft. above ground level to determine the numbers of bacteria and fungi in the air masses. Low counts of bacteria and fungi were obtained in all air masses from January to March. High fungus numbers were recorded from May to November covering a range from 5 to 86.3 per cu.ft. The counts from both continental polar and maritime polar air were higher when the mass had passed over considerable cultivated land than when moving direct to Montreal. Ogawa and English (1955) using an apparatus adapted from Tervet and Cherry's "Cyclone separator" at the University of California determined the relative concentration of Sclerotinia fructicola spores in peach orchards in two hourly periods.

The spores were collected either in a flask or in a vaseline-coated cover slip which replaced the flask at the base of the Cyclone. Spores from the flask were transformed to dilution plates containing potato dextrose agar adjusted to pH 2.2 by the addition of citric acid on which the pathogen had previously been found to grow well, while the growth rate of the other species was markedly depressed. In the orchards tests, small colonies of various fungi esp. Cladosporium, Alternaria and Penicillium sp. were found in profusion on the dilution plates but there was no evidence of S.fructicola. A few spores of this fungus were found on the cover slips, their concentration in the atmosphere of the orchard presumably being so low that their presence was marked by the other fungi.

Last (1955) studied the spore content of air within and above mildew infected cereal crops at the Rothamsted Experimental Station using a Portable Volumetric Spore trap. He demonstrated that in addition to Erysiphe graminis the most abundant spores in air over mildew infected wheat and barley crops were those of Cladosporium, Alternaria, Sporobolomyces, and Tilletiopsis.

Reddy & Vaheeduddin (1956) studied the trapping of spores of Piricularia oryzae. At sewage farm, where there were no standing crop, 115 spores were caught on 56 microslides coated on both sides with vaseline and exposed for 24 hrs. at an interval of one month near paddy hay stacks. More spores were trapped near the infected paddy stacks, than in surrounding areas, where there were standing paddy crops.
Chandwani et al (1960) reported that in a study of spore liberation of Helminthosporium oryzae over rice fields of Central Rice Research Institute, Cuttack it was found that the spores of this fungus were present in the air when there was no rice crop in the field.
Seshavataram (1965) studied spore content of air over paddy fields during threshing of paddy. Spores in dust liberated during threshing, determined by exposing vaseline-coated microscopic slides for 1 hour at ground level and 5 ft. above the fields were in the proportions Ustilaginoidea 45; Neovossia 4; Nigrospora 20; Helminthosporium 6; and hyaline fragments 10.
Chandrasekharan Nair (1965) studied the concentration of spores of Corynespora cassiicola using an improvised spore trap. Prasannakumaran (1966) studied air spora over a tomato field using a Hirst spore trap at Vellayani.

Major spores under study were Corynespora cassiicola, Helminthosporium sp., Alternaria sp., Curvularia sp., and yellow basidiospores.

Spore liberation.

Stepanov (1935) showed that while the spores of Ustilago tritici, Monilia sitophila, Botrytis cinerea, etc. are very easily detached from the sporophores and carried away by the lightest air currents; the aecidiospores of rusts and conidia from the aerial mycelium of Fusarium spp. are separated and carried through the air with difficulty, whereas the conidia from Fusarium, pionotes and sporodochia are not disseminated at all in the air. Dobbs (1942) classified the spore dispersal into two principal categories, namely, active dispersal in which the fungus supplies initial energy and passive dispersal which is achieved by the movements or activities of the organism or the surrounding medium.

Grainger (1954) found that spores of Helminthosporium avenae were liberated into the air in similar numbers per unit of leaf area during primary (seedling blight) and secondary phases of leaf spot disease of oats. No spores could be found in the surrounding air during the intervening period of disease free growth, when spores were found at ground level, and their numbers diminished with increasing height.

Gregory *et al* (1959) studied the 'Splash dispersal' of the spores of fungi, in the laboratory using spores of *Fusarium solani*, *Gloeosporium album*, *Colletotrichum lindemutheanum* and *Nectria cinnabarina* which are not normally dispersed by wind. They concluded that rain drops falling at terminal velocity and drops falling more slowly from vegetation may operate the splash dispersal mechanism. Splash in rain or drop from trees may act as a complete dispersal mechanism in still air, or as a take off mechanism leading to dispersal by wind.

Diurnal periodicity.

Hirst (1953) reported that the maximum concentration of Uredospores occurred in the air during the afternoon. The spores of *Phytophthora infestans*, and *Polythrincium trifoli*, were in abundance before 9 A.M., while the coloured basidiospores of Agaricales were common at night. Sreeramulu (1953) working at Rothamsted observed that the conidia of *Helminthosporium avenae*, occurred in maximum concentration in the afternoon. Higher numbers began to appear between 08.00 and 14.00 hrs. and the maximum concentration occurred by 20.00 hrs. The spores were almost absent during night. However, Grainger (1954) found spores of. Helminthosporium avenae in the air by night as well as by day. Last (1955) during the study on air spora at Rothamsted Experimental Station, found that Sporobolomyces and Tilletiopsis were numerous at 4 A.M., whereas Alternaria, Cladosporium and Erysiphe graminis occurred at 4 P.M.

Panzer et al (1957) referred Leptosphaeria, Epicoccum, Piricularia, Cladosporium, Diplodia and Ophiobolus to the 'night spora' with maximum between 18.00 and 09.00 hrs., and Nigrospora, Penicillium, Alternaria, Curvularia and Trichoconis to 'day spora' with maxima between 08.00 and 17.00 hrs.

Sreeramulu (1959) found that smut spores appeared in large numbers from 08.00 hrs., reached their maxima by about noon and then decreased to a minimum by midnight. Conidia of Erysiphe occurred in low concentration during the night and from 08.00 hour they began to appear in great numbers till noon. Their concentration gradually fell to a minimum in the evening. Further, he noted that spores of Ganoderma, Coniophora and other coloured basiodiospores were trapped in great concentrations between midnight and dawn.

Lacey (1961) reported Ganoderma spp. and certain ascomycetes as having night maxima. Atmospheric content of Nigrospora spores in Jamaican Banana Plantations was studied by Meredith (1961), who observed that the peak liberation of spores was between 08.00 and 10.00 hrs. Barksdale and Asai (1961) studied the release of spores from rice leaves infected with blast fungus and observed a 'nocturnal pattern' of spore liberation. When however, Piricularia oryzae was subjected to continuous darkness, spore discharge ceased after about twelve hours and did not assume again, until there was a prior period of illumination.

Sreeramulu et al (1962) reported that in normal dry weather Trichoconis padwickii, Nigrospora, Cladosporium, Cercospora, Botryodiplodia, and pollens showed the 'Forenoon pattern' with their peak concentration occurring before or at about noon. Spores of Helminthosporium oryzae, Helminthosporium type, Neovossia, Curvularia, Tetraploa, Aspergilli type etc. showed the afternoon pattern. Basidiospores and Pleospora type spores showed their daily peak after midnight and before dawn. He further reported Alternaria also as having an 'afternoon pattern' of spore liberation.

Ramalingam (1966) studied the spore dispersal of Piricularia oryzae over a paddy field near Visakhapatnam and found that the fungus exhibited 'nocturnal pattern" of diurnal periodicity. Peak concentrations occurred at 04.00 hr. in the main crop season and at 06.00 hr. in the second crop season. Prasannakumaran (1966) studied the concentration of spores of Corynespora cassiicola, Alternaria sp., Curvularia sp., Helminthosporium sp. and a yellow spored basidiomycete in the air over a tomato field at Vellayani and found that Corynespora cassiicola, Curvularia sp., Alternatia sp. and Helminthosporium sp. occurred during day time, whereas, basidiospores were present in the air during night.

Seasonal periodicity.

Hyde and Williams (1946) found that the spore liberation of Alternaria was confined to the months of June to September and that catches during this period varied very greately from day to day. Rajan et al (1952) during their study of the atmospheric fungal flora at Kanpur, found that the counts of Alternaria, Curvularia, Fusarium, Helminthosporium etc. were substantially lower from July to September and again in December and January than in the other months of the year, with the maximum incidence occurring in November and May. Pady (1957) made quantitative studies on fungus spores in the air and found that fungal spores were seasonal in distribution with peaks in july and August and low concentration in winter. In summer, numbers ranged from 50 to 700 per cu.ft. and in winter the figures were usually 5 to 20. Cladosporium spores were of definitely seasonal occurrence. In summer high spore load was found, while in winter numbers were low. Ustilago chlamydospores were present throughout the year. Puccinia uredospores were present in June and September and occasionally at other times. Alternaria spores were seasonal, the numbers ranging from 2 to 40 in summer, with a maximum of 97.8 on 7th July 1953 and generally absent in winter. Fusarium and basidiospores were definitely seasonal and appeared to be abundant after rain.

Maunsel (1958) & Hamilton (1959) found that the season affects the air spora prefoundly. Cladosporium and Alternaria showed pronounced seasonal periodicity. On the other hand, Penicillium showed little seasonal change. Frey and Durie (1960) observed that Alternaria spores were most common in January - February. Sreeramulu and Ramalingam (1963) studied the spore contents of air over paddy fields near Visakhapatnam from November, 1959 to January 9, 1960 and found that basidiospores, Fusarium and Trichoconis padwickii spores were caught in high numbers during the first half of November, while Alternaria, Curvularia and Helminthosporium were caught throughout November. Ramalingam (1966) studied dispersal of Piricularia oryzae conidia in air over a paddy field near Visakhapatnam for a period of two years and found that the fungus showed a marked seasonal periodicity, with high concentration during two periods in each year, one from middle of February to April in the second crop season and the other during September to October in the main crop season.

Effect of weather on spore load.

Keitt and Jones (1926) showed that, the liberation of ascospores of the apple scab fungus Venturia inaequalis could be correlated with rain. Hirst (1953) showed that, the pollens and spores of Cladosporium, Erysiphe, Alternaria, smuts and rusts are mostly removed by prolonged rain, which however soon liberate into the air a characteristic damp air spora. Hamilton (1957) studied the correlation between spore concentration of twenty eight fungal types and the weather. She found that rainfall had no effect on the atmospheric concentration of hyaline basidiospores. The concentration of pollen and most types of spores decreased with rain, but all ascospore types and *Helicomyces* increased with rain. In half of the types studied, concentration were significantly increased by increase in temperature, dew point or humidity. Increased wind significantly decreased the concentration of *Alternaria*, some basidiosopores, *Botrytis*, *Cladosporium* etc. Gustiness was associated with increases in *Alternaria*, filiform ascospores and *Ustilago*.

Gregory and Sreeramulu (1958) found that, hyaline basidiospores favoured by high humidity and low wind speed reached the maximum at early morning. Larger hyaline basidiospores appeared only after rain. Hamilton (1959) recorded the temperatures, at which various spore types were in the air in maximum numbers; for yellow basidiospores 12.8° - 15° C, *Alternaria* 23.9° - 26.1°C; *Helminthosporium*, Yellow and brown basidiospores 26.7 - 28.9°C and for hyaline basidiospores 29.4°- 31.7°C.

Meredith (1961) recorded that rainfall and irrigation increased the atmospheric spore content of *Nigrospora*. Ramalingam (1966) found that spore load of *Piricularia oryzae* was higher in the day following the rainy day, than in the rainy day. Prasannakumaran (1966) recorded that high humidity and low temperature favoured the liberation of yellow basidiospores, whereas spores of Corynespora cassiicola Alternaria sp., Curvularia sp., and Helminthosporium sp. were liberated in large numbers during hours of low humidity and high temperature. He also found that, rain had a pronounced effect on the spore liberation of all the above mentioned fungi, the higher spore load being on the day following rainy day.

MATERIALS AND METHODS

MATERIALS AND METHODS

The Crop.

The rice crops were raised during 1966-67 in the garden land of the Agricultural College and Research Institute, Vellayani. The plot selected was located about 100 metres away from the wet fields. The first crop in the experiment was raised during October-January and the second crop during January-May. The former is referred to as the first crop and the latter as the second crop in this thesis.

Three strains of paddy *viz.* Tainan-3, ADT-27 and Kaoshiung-18, were used for the present study.

Lay out.

The experimental area was divided into two blocks, leaving a strip of land two metres wide in between. Each block was subdivided into three plots, each plot with a net area of 9.45 square metres, to accomodate the three varieties. The spore trap was located in the narrow strip in between the two blocks (Fig.1).

LAYOUT OF THE EXPERIMENTAL PLOT

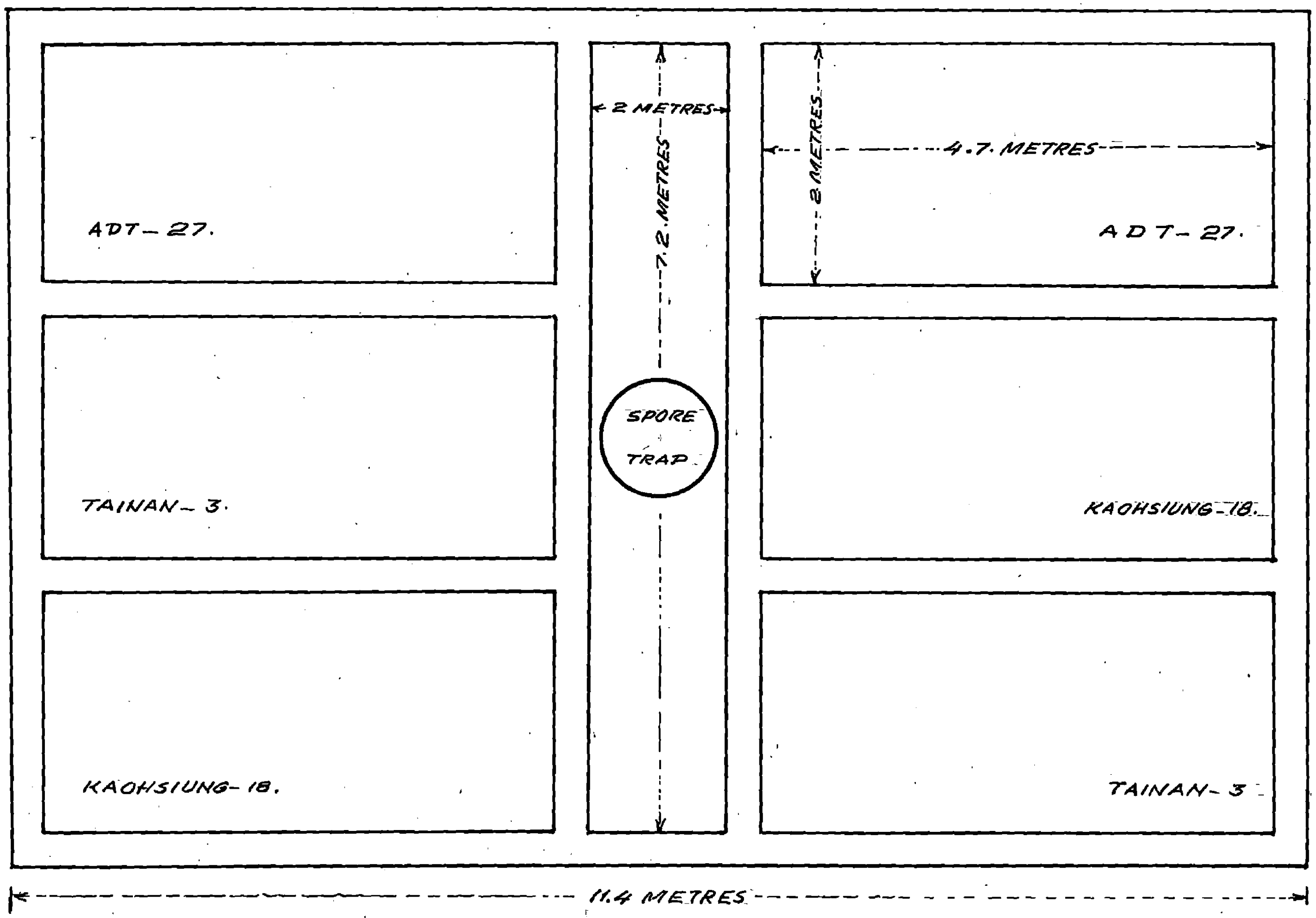


FIG 1

PLATE 1. Lay out of the plot showing spore trap in the centre

PLATE 2. Closer view of the plot showing spore trap and Stevenson's Screen.

The crop was heavily manured as per details given below, to ensure the incidence of diseases.

Farm yard manure	-	35 Kg. per plot (14520 Kg/Acre)
Ammonium sulphate	-	1 Kg. per plot (415 Kg/acre) to supply 83 Kg. N_2 /acre.
Superphosphate	-	1 Kg. per plot (415 Kg/acre) to supply 75 Kg. P_2O_5/acre.
Muriate of potash	-	½ Kg. per plot (208 Kg/acre) to supply 104 Kg. K_2O/acre.

The entire quantity of farm yard manure, superphosphate, muriate of potash and 1/3 of ammonium sulphate were applied as basal dose. The rest of ammonium sulphate was given in two equal doses, after three and six weeks of sowing.

Seeds were dibbled on seventh October 1966 and 22nd January 1967, for first and second crops respectively.

The plants were spaced 10 cm apart within the row and 15 cm between the rows. 24 cm of land was left out near the borders. After thinning, two seedlings were left in each hill.

The crop was kept free of weeds and irrigated as and when required.

Two prophylatic sprayings with endrin (0.03%) were given, when the crop was three and six weeks old.

Spore trapping.

Hirst's automatic volumetric spore trap was used for sampling the air and estimating the daily spore load in the atmosphere. This is a suction trap, in which air enters through an orifice 2 mm x 14 mm.

The trap has a wind vane mounting, which allows continuous rotation of the impactor, so that the orifice faces the wind and also provides a cover, to prevent the rain from falling on the orifice.

The trap is mounted on a tripod, and when resting on the ground, the orifice is about 20 inches above ground level. All the plants, which obstructed the free movement of trap, were removed.

Suction is achieved by means of an electrically operated pump. A sticky microscopic slide moves upwards past the orifice at the rate of two mm an hour, by means of a clock. Slight variations may occasionally occur, but the rate of movement of the slides could be calculated from the duration of exposure and length of the trace. Every part of the slide is exposed for an hour.

The rate of flow of air through the orifice is adjusted by means of a valve. During the present experiment, the rate of air intake was maintained at 10 litres per minute.

The trap increases the efficiency of impaction, by artificially accelerating a narrow air stream towards a sticky surface. Movement of the sticky surface at a constant speed past the orifice, through which the air stream flows, produces a trace showing changes of atmospheric spore content with time.

The spore trap was set up on the first crop on 1-11-1966 and continued to be there till 31-1-1967. When the crop was harvested, it was moved to the second crop on 1-2-1967.

The slides were changed, daily at 9 A.M.

Preparation of slides.

Ordinary microscopic slides of 75 x 25 mm in size, were used in the trap. They were first cleaned and dried and then dipped in alcohol and flamed. A mixture of molten vaseline and paraffin wax in the ratio 9:1 was spread over 2/3 of the length (about 55 mm) on one side of the warm slide, to form a thin coating. The uncoated portion of the slides were used for labelling.

Scanning the slides.

The slides were scanned, with a Spencer microscope, having a graduated mechanical stage. Hourly scans of each slide were made, by using a high power objective (magnification x 430) of the microscope. A trace of about 0.38 mm wide could be brought into the field of the microscope at a time. A vertical scan of about 0.38 mm wide was made for every hour. This represents about 19 percent of the area exposed during an hour and total area scanned was 19 percent of the entire trace.

The fungal spores under study

Spores of a number of fungi and also dust particles and pollen were noted in the trap slide. But the following identifiable spôres were counted and recorded.

1. *Piricularia oryzae* Cav.
2. *Trichoconis padwickii* Ganguly
3. *Helminthosporium* spp.
4. *Curvularia* spp.
5. *Nigrospora* spp.
6. *Alternaria* spp.
7. Yellow basidiomycetes.

Recording weather data.

Temperature and humidity were recorded from the month of December to the end of the period of study using a Cassella thermohygrograph, which was located near the spore trap.

Recording of Blast incidence.

The incidence of diseases in the crop was recorded. But in the case of blast, the progress of the disease in the second crop was also recorded, in order to determine whether there is any correlation between spore load and severity of disease incidence.

The observations were taken at weekly intervals. In each plant the second leaf of all the tillers were taken for recording the number of spots.

The extent of leaf infection based on the number of spots was converted into numerical scores as follows: 1-3 spots = score 1; 4-15 spots = score 2; 16-30 spots = score 3; 31-50 spots = score 4; 51-80 spots = score 5; and above 80 spots = score 6. The average of numerical scores obtained in each variety was taken as the numerical score for that variety.

Plants from which the observations were taken, were selected at random from each plot using a rectangular frame of size 30 x 30 cm.

RESULTS

R E S U L T S

I. Incidence of diseases.

ADT-27 was severely affected by blast in both the crops. Kaohsiung-18 was also affected but not so severely. Tainan-3 was the least affected. Stack burn and Helminthosporium leaf spot were present in all the varieties.

Varieties ADT-27 and Kaohsiung-18 showed symptoms of blast earlier than Tainan-3. Incidence of blast was observed on the leaves during the seedling stage itself. But the maximum spread of the disease was observed during the tillering stage in all the three varieties. ADT-27 plants were almost completely damaged due to heavy infection of blast before the plants attained flowering stage.

2. Fungal spores over the rice crops.

Spores of *Piricularia oryzae*, *Trichoconis padwickii*., *Helminthosporium* spp., *Alternaria* spp., *Curvularia* spp., *Nigrospora* sp., and unidentified basidiomycete occurred commonly over the rice crops. The concentrations of spores of these fungi in the atmosphere, however, varied during the different periods. All the spores exhibited a definite diurnal periodicity in their occurrence.

(i) <u>*Piricularia oryzae*</u>

Spores of Piricularia oryzae were found in large numbers over the first crop. The average for this period was 404.00 spores per cubic metre of air. The spore load was comparatively low over the second crop being 15.3. spores per cubic metre of air (Table 1).

The highest spore load was noted in November. The total number of spores trapped during this month was 484654 which works out at the rate of 1126.8 spores per cubic metre of air. The lowest spore load occurred in January. Tbtal number of spores trapped during this month was 446 which works out at the rate of 0.9 spores per cubic metre of air. The spore load in February was also low, being, 2.4 spores per cubic metre of air. This rose sharply in March to 36.4 spores per cubic metre of air. The spore load again fell in April to 6.3 spores per cubic metre of air. Spores were not present during May.

Highest spore load for any single day was recorded on 12th November 1966 being 66842. This works out at the rate of 4641.7 spores per cubic metre of air. The lowest spore load was 8 which is equivalent to 0.41 spores per cubic metre of air and this occurred on 9th, 15th, 16th and 26th of January, 6th of February, and 16th, 18th and 19th of March.

Highest spore load for an hour was 16700 spores which works out at the rate of 2783.3 spores per cubic metre of air and this occurred at 00.00 hour on 17th November 1966.

Diurnal periodicity

A definite periodicity in the liberation of spores was exhibited by *Piricularia oryzae*. During October-January the highest spore load always occurred during night hours (Table 2). Spores began to appear in the atmosphere at 20.00 hrs. and were present till 05.00 hrs. The peak load was noted after midnight usually around 02.00 hrs (Table 3)(Fig 2) The spores were present in small numbers during day time also (Table 2). The total spore load in the night during November between 18.00 and 06.00 hrs. was 420457 which works out at the rate of 1946.5 spores per cubic metre of air. The total spore load during the day time between 06.00 and 18.00 hrs. in November was only 64197 which works out at the rate of 297.2 spores per cubic metre of air. Similarly the night spore load in December was 39670 which is equivalent to [illegible] spores per cubic metre of air. The total spore load during the day time for the month was 10493 which is equivalent to 47.01 spores per cubic metre of air.

TABLE 1

Piricularia oryzae - Total monthly spore load over the rice crops

Date of sowing	Months	Total spore load	No. per cubic metre of air
7-10-1966	November	484654	1126.8
	December	50163	112.3
	January	446	0.9
	Total for the season	535263	404.00
22-1-1967	February	972	2.4
	March	15731	36.4
	April	2729	6.3
	May	-	-
	Total for the season	19432	15.3

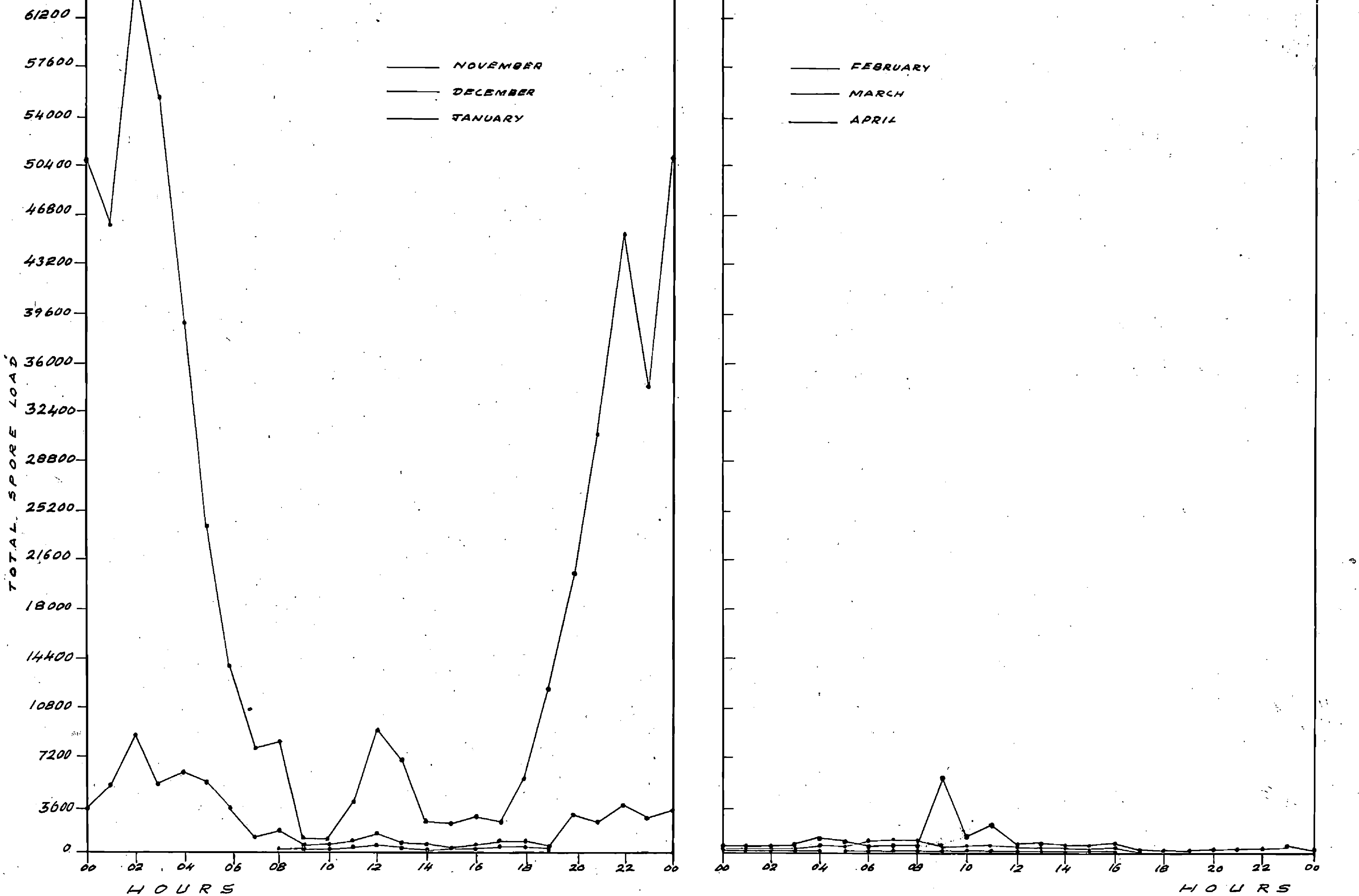
TABLE 2

Piricularia oryzae - Total spore load during day time and night in different months

Months	Day time 06.00 - 18.00 hrs.		Night 18.00 - 06.00 hrs.	
	Total spores	No. per cubic metre of air	Total spores	No. per cubic metre of air
First crop				
November	64197	297.2	420457	1946.5
December	10493	47.01	39670	177.7
January	384	1.8	62	0.3
Second crop				
February	520	2.5	452	2.2
March	10982	50.8	4749	21.9
April	1836	8.5	849	4.06
May	Nil	Nil	Nil	Nil

Table -3 <u>Piricularia Oryzae</u> - Spore lad on hourly basis for each month from Noember 1966 - May 1967.

rs / ns	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
mber	46037	73158	55123	30956	23766	13835	7696	7829	934	929	3244	8765	6714	2067	2618	3133	2689	4480	12948	20143	30113	45286	34108	52[illegible]74
mber	4510	6195	4593	5735	4763	3081	950	1003	441	423	566	1407	723	553	192	275	640	441	231	2624	1929	3415	2444	3025
uary	-	24	-	-	-	-	-	-	16	16	82	50	32	16	40	116	40	8	-	8	-	8	-	-
ruary	25	16	108	40	41	150	-	42	108	73	74	-	16	40	117	34	16	-	8	24	8	8	8	16
ch	231	383	264	1007	973	693	514	697	5213	1281	1999	399	433	192	182	249	124	83	96	82	40	90	189	249
il	16	90	74	83	208	317	163	642	74	214	224	99	48	32	107	8	-	16	8	8	16	38	16	32
	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-



PIRICULARIA ORYZAE — TOTAL SPORE LOAD

FIG:

The spore load fell sharply from January onwards and the diurnal periodicity was also altered. The night maxima shifted to a day maxima, the highest spore load occurring during the day time. The total day spore load for the month was 384 as against 12 only for the night. This position continued in February, March and April also. The average spore load in March during day time was 50.8 spores per cubic metre of air and that during the night was only 21.9. Similarly in April the average spore load during the day time was 8.5 spores per cubic metre of air while that during the night was only 4.06 (Table 2).

(ii) *Trichoconis padwickii*.

Spores of *Trichoconis padwickii* began to appear from the first week of November. Spore load of this fungus was low when compared to that of *Piricularia oryzae*. The total spore load for November was 1375 which is equivalent to 3.2 spores per cubic metre of air. The average spore loads during December and January were also more or less similar to that of November being 3.0 and 2.7 spores per cubic metre of air respectively. There was a sharp fall in the spore load during February which was maintained during March also. There was an average of 0.56 and 0.72 spores per cubic metre of air during February and March respectively. There was a rise in the spore load in April bringing up the average spore load to 2.6 spores per cubic metre of air. There was a slight fall in the spore load during May, the average concentration of spores being 2.09 spores per cubic metre of air. (Table 4).

Diurnal periodicity.

It was found that irrespective of the season spores of Trichoconis padwickii appeared mostly during day time with a few spores appearing at night (Table 5). Spores began to appear at 08.00 hrs. and continued to be in air till 17.00 hrs. The highest spore load was observed between 09.00 and 12.00 hrs (Table 6)(Fig 3)The total spore load during day time in November was 1187 which is equivalent to an average of 5.6 spores per cubic metre of air whereas the total spore load during night in November was 188 which work out at the rate of 0.9 spores per cubic metre of air. The average spore loads for day time during the other months were 5.6, 4.6, 0.9, 1.3, 5.2, and 4.1 for December, January, February, March, April and May respectively and those for the night were 0.4, 0.7, 0.2, 0.07, 0.03, and 0.03 respectively (Table 5).

TABLE 4

Trichoconis padwickii - Total monthly spore load over the rice crops.

Date of sowing		Months	Total spore load	No. per cubic metre of air.
7-10-1966		November	1375	3.2
		December	1250	3.0
		January	1146	2.7
	Total for the crop.		3771	2.9
22-1-1967		February	233	0.56
		March	313	0.72
		April	1135	2.60
		May	901	2.09
	Total for the crop		2582	1.5

TABLE 5

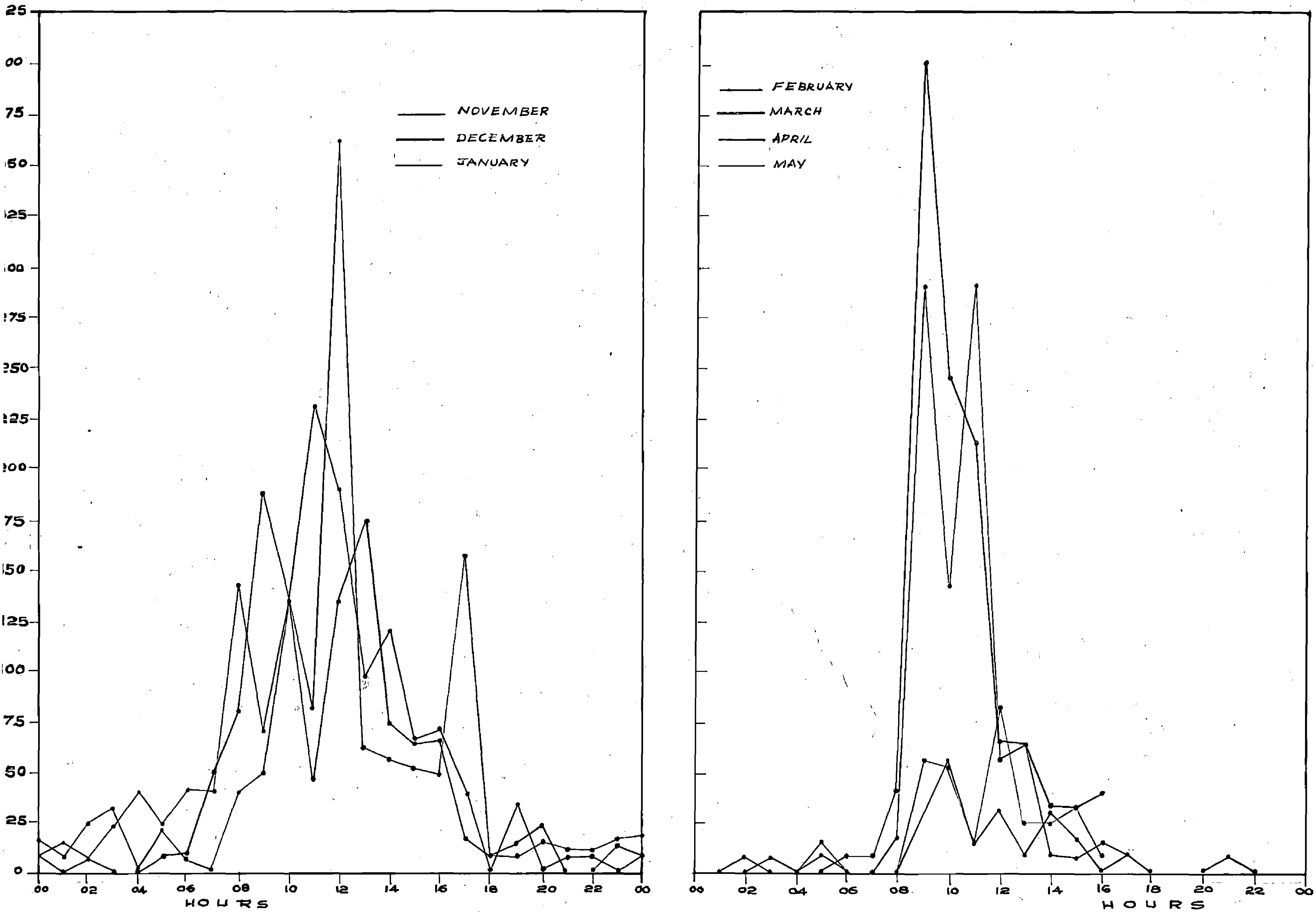
Trichoconis padwickii - Total spore load during day time and night in different months.

Months	Day time 06.00 - 18.00 hrs		Night 18.00 - 06.00 hrs.	
	Total No. of spores	No. per cubic metre of air.	Total No. of spores	No. per cubic metre of air.
First crop				
November	1187	5.6	188	0.9
December	1161	5.6	89	0.4
January	994	4.6	152	0.7
Second crop				
February	201	0.9	32	0.2
March	297	1.3	16	0.07
April	1127	5.2	8	0.03
May	893	4.1	8	0.03

Table 6.

<u>Trichoconis padwickii</u> – Spore load calculated on hourly basis for each month from November 1966 – May 1967.

Hours / Months.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
November	16	8	24	32	16	32	32	141	72	131	229	188	96	122	64	72	40	–	32	–	8	8	–	8
December	–	8			8	8	49	80	189	133	48	131	173	74	65	65	16	8	16	25	–	–	16	8
January	8	24	32	–	24	8	–	40	49	131	81	305	64	57	56	48	156	8	8	16	8	8	–	16
February	–	8	–	–	8	–	–	–	32	57	16	32	8	32	16	–	8	–	–	–	16	–	–	–
March	–	–	–	–	16	–	–	–	57	56	16	80	24	24	32	8	–	–	–	–	–	–	–	–
April	–	–	–	–	–	8	8	41	400	245	212	64	65	32	32	40	8	–	–	–	–	–	–	–
May	–	–	8	–	–	–	–	16	290	142	290	57	66	8	8	16	–	–	–	–	–	–	–	–



TRICHOCONIS PADWICKII —— TOTAL SPORE LOAD
CALCULATED ON HOURLY BASIS FOR EACH MONTH — NOV. 1966 — MAY. 67

FIG 3

(iii) Helminthosporium spp.

The concentration of the spores of Helminthosporium spp. in the air was low when compared with that of Piricularia oryzae and Trichoconis padwickii.

The spores of this fungus were noticed in the slides from 1st November onwards. During this month the spore load in the atmosphere was comparatively higher than that of the other months. A total of 2404 spores were trapped during November which is equivalent to 5.7 spores per cubic metre of air. The spore load began to fall in December and this trend was continued till March. The average spore load per cubic metre of air calculated for the months of December, January, February and March were 1.1, 0.5, 0.4, and 0.4 respectively. A slight increase in the spore content was observed in April and the concentration of spores during this period was 1.9 per cubic metre of air. Then there was again a fall in the spore load in May to 0.8 spores per cubic metre of air. (Table 7).

Diurnal periodicity.

The spores of Helminthosporium spp. were found to have a day maxima. Very few spores were trapped at night (Table 8). The spores began to appear regularly from 09.00 hrs. and continued to be present till 18.00 hrs. Comparatively high spore load was noted between 10.00 and 16.00 hrs. The hours of peak spore load varied in each month (Table 9)(Fig4)The total spore loads for day time between 06.00 and 18.00 hrs. were found to be 2147, 416, 204, 138, 170, 821 and 366 respectively for the months of November, December, January, February, March, April and May; the corresponding concentrations being 10.4, 2.2, 0.9, 0.6, 0.78, 3.8 and 1.6 spores per cubic metre of air respectively. The total spore loads for nights in November, December, January, February and March were 257, 40, 32, 32, 40 respectively which work out at the rate of 1.2, 0.19, 0.14, 0.14, 0.18 respectively. In April and May no spores were trapped at night. (Table 8).

(iv) *Alternaria* spp.

The average concentration of *Alternaria* spores was low during the month of November being only 1.57 spores per cubic metre of air. The spore load increased in December to 3.25 and fell to 2.44 in January and then to 1.01 in February. In March the spore load rose to 3.13 and in April to 7.71. In May the spore load again fell to 1.4 spores per cubic metre of air. (Table 10).

TABLE 7

Helminthosporium spp. — Total monthly spore load over the rice crops.

Date of sowing	Months	Total spore load	No. per cubic metre of air.
7-10-1966	November	2404	5.7
	December	456	1.1
	January	236	0.5
	Total for the crop	3096	2.4
22-1-1967	February	170	0.4
	March	210	0.4
	April	821	1.9
	May	366	0.8
	Total for the crop	1567	0.8

TABLE 8

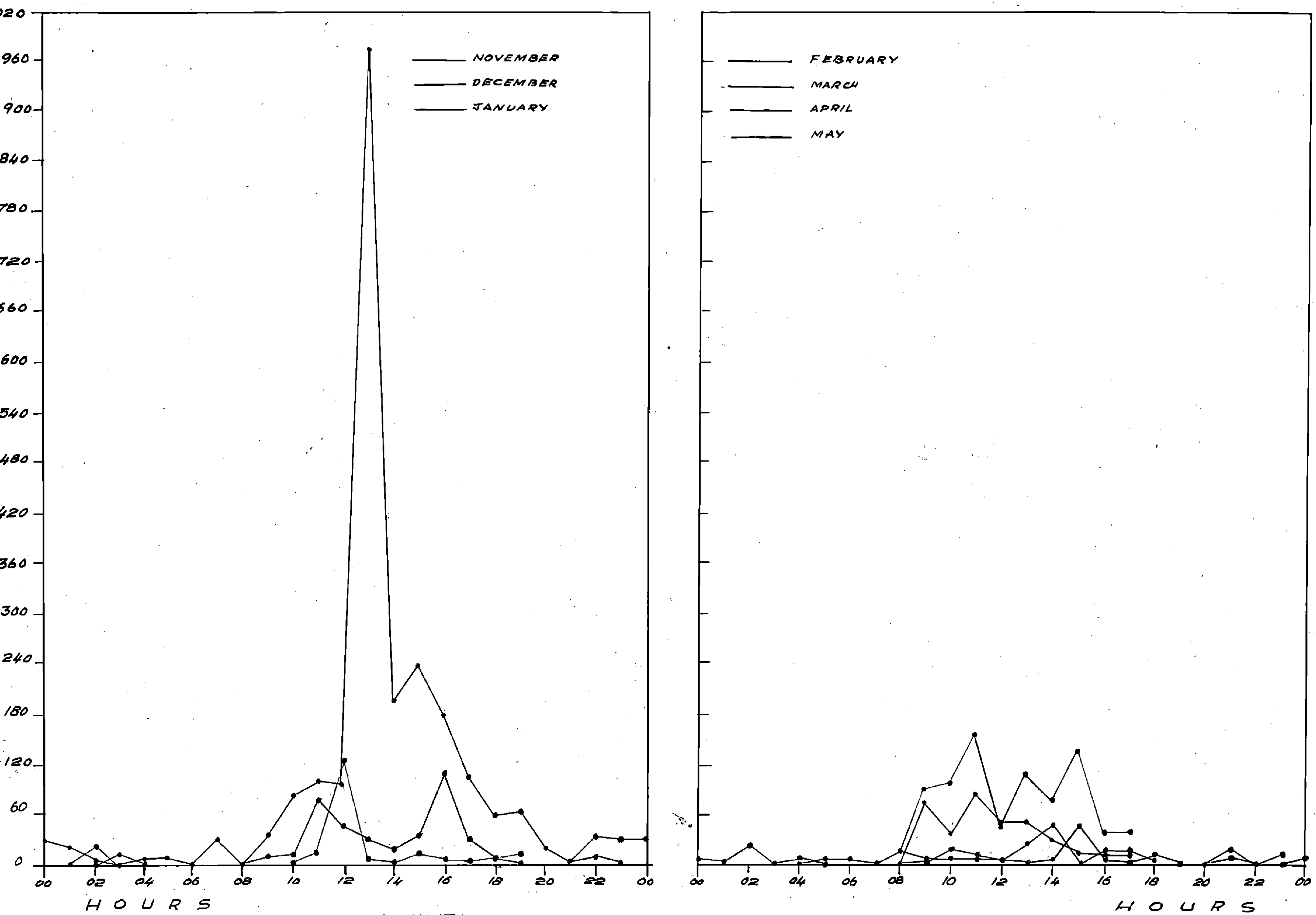
Helminthosporium sp. - Spore load during day time and night in different months.

Months	Day time 06.00 - 18.00 hrs		Night 18.00 - 06.00 hrs	
	Total spore load	No. per cubic metre of air.	Total spore load	No. per cubic metre of air.
First crop				
November	2147	10.4	257	1.2
December	416	2.2	40	0.19
January	204	0.9	32	0.14
Second crop				
February	138	0.6	32	0.14
March	170	0.78	40	0.18
April	821	3.8	0	0
May	366	1.6	0	0

Table 8

Helminthosporium sp. Spore load calculated on hourly basis for each month from November 1960 - May 1967.

Hours / Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
November	24	8	-	8	8	-	32	-	41	89	106	98	987	199	242	182	107	64	72	24	8	40	33	32
December	-	24	-	-	-	-	-	-	16	16	82	50	32	16	40	116	40	8	-	-	8	8	-	-
January	-	-	16	-	-	-	-	-	-	16	16	124	8	-	16	8	8	8	16	-	-	-	-	-
February	8	-	-	8	-	-	-	-	8	24	16	8	-	8	50	16	-	8	-	-	8	-	-	8
March	-	-	-	-	8	8	-	16	8	8	8	8	25	49	-	16	16	8	-	-	16	-	8	-
April	-	-	-	-	-	-	-	-	90	99	159	48	113	80	139	41	42	-	-	-	-	-	-	-
May	-	-	-	-	-	-	-	-	73	40	82	49	49	33	16	16	8	-	-	-	-	-	-	-



HELMINTHOSPORIUM SPP. — TOTAL SPORE LOAD

CALCULATED ON HOURLY BASIS FOR EACH MONTH — NOV. 1966 — MAY '67

FIG: 4

Diurnal periodicity.

It was found that Alternaria spores were present in comparatively larger numbers in the atmosphere during day time. At night very few spores were trapped. The spores generally began to appear at 07.00 hrs. The maximum spore content was observed between 09.00 and 16.00 hours with a peak between 12.00 and 15.00 hrs (Table 12)(Fig 5) The total spore loads for day time between 06.00 and 18.00 hrs. were found to be 470, 1180, 943, 274, 1113, 2372 and 574 respectively for the months of November, December, January, February, March and April respectively, the corresponding concentrations being 2.25, 5.75, 4.36, 1.35, 5.07, 10.98 and 2.65 spores per cubic metre of air. The total spore loads during night in November, December, January, February, March, April and May were 186, 154, 114,136, 240, 962 and 32 respectively, the corresponding concentrations being 0.89, 0.75, 0.52, 0.67, 1.11, 4.45 and 0.14 spores per cubic metre of air (Table 11).

(v) Curvularia spp.

The spores of Curvularia spp. were present in the atmosphere throughout the period of study. The highest spore content in the atmosphere was during November when 3829 spores were trapped and this is equivalent to 9.16 spores per cubic metre of air.

TABLE 10

Alternaria spp. - Total monthly spore load over the rice crops.

Date of sowing	Months	Total spore load	No. per cubic metre of air.
7-10-1966	November	656	1.57
	December	1334	3.25
	January	1057	2.44
	Total for the crop	2947	2.33
22-1-1967	February	410	1.01
	March	1353	3.13
	April	3334	7.71
	May	606	1.40
	Total for the crop	5703	3.36

TABLE 11

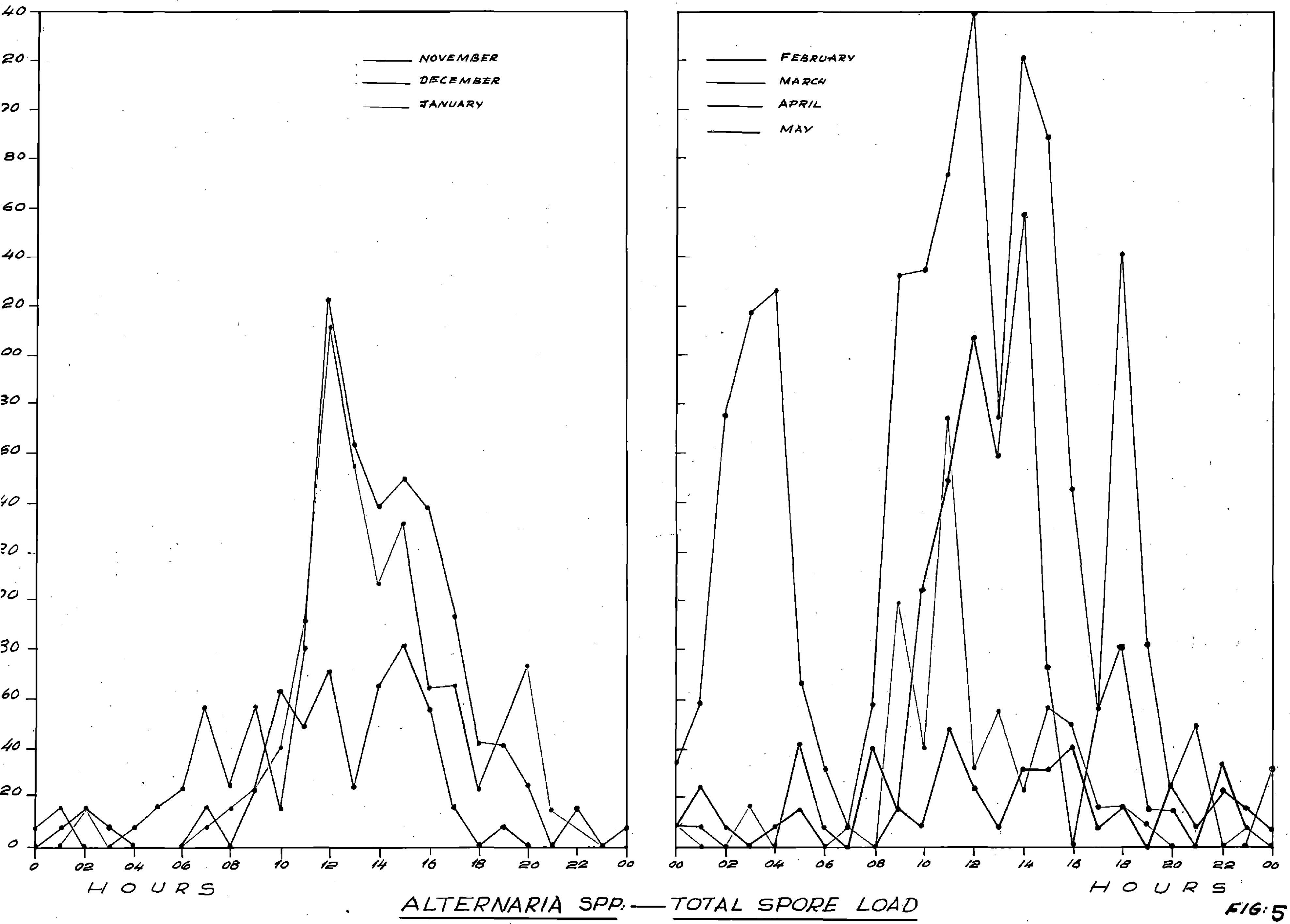
Alternaria spp. - Total spore load during day time and night in different months.

Months	Day time 06.00 - 18.00 hrs.		Night 18.00 - 06.00 hrs.	
	Total spores	No. per cubic metre of air.	Total spores	No. per cubic metre of air.
First crop				
November	470	2.25	186	0.89
December	1180	5.75	154	0.75
January	943	4.36	114	0.52
Second crop				
February	274	1.35	136	0.67
March	1113	5.07	240	1.11
April	2372	10.98	962	4.45
May	574	2.65	32	0.14

Table 12.

<u>Alternaria</u> sp. – Spore load calculated on hourly basis for each month from November 1966 – May 1967.

Months \ Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
November	8	16	8	–	–	–	–	–	24	64	49	72	24	66	83	56	16	–	8	121	25	–	–	–
December	16	–	–	8	16	24	57	25	57	16	80	222	163	138	150	137	93	42	41	25	–	16	–	8
January	–	16	–	–	–	–	8	16	24	41	92	216	155	107	131	64	65	24	74	–	16	8	–	–
February	24	8	–	8	16	–	–	40	16	8	49	24	8	32	32	41	8	16	–	24	8	24	16	8
March	8	–	–	–	42	8	–	–	16	115	148	207	158	257	73	57	82	–	16	16	–	34	8	8
April	58	175	217	226	66	32	8	58	232	230	273	339	175	321	289	145	56	241	82	24	50	–	–	32
May	–	–	16	–	–	–	8	–	99	40	174	33	56	24	58	50	16	16	8	–	–	–	8	–



ALTERNARIA SPP. — TOTAL SPORE LOAD

CALCULATED ON HOURLY BASIS FOR EACH MONTH — NOV. 1966 — MAY 67

FIG: 5

A slight fall was seen in December and January, the total number of spores trapped during these months being 2509 and 2345 respectively. These work out at the rate of 6.11 and 5.42 spores per cubic metre of air for December and January respectively. A sharp fall in the spore load was observed during February and March, the spore loads during these months being 0.79 and 0.78 respectively per cubic metre of air. A rise in the spore load to 4.65 was noticed in April followed by a fall in May to 0.84 spores per cubic metre of air (Table 13).

Diurnal periodicity.

The spores of *Curvularia* spp. were present in the atmosphere in comparatively larger numbers only during day time. Only very few spores were present in the atmosphere during night. The total number of spores trapped during day time in November, December, January, February, March, April and May were 3396, 2341, 1974, 241, 307, 1663 and 366 which work out at the rate of 16.26, 12.47, 9.13, 1.19, 1.42, 7.79, and 1.69 respectively. Total number of spores during nights in November, December, January, February, March, April

TABLE 13

Curvularia spp. - Total monthly spore load over the rice crops.

Date of sowing	Months	Total spore load	No.per cubic metre of air.
7-10-1966	November	3829	9.16
	December	2509	6.11
	January	2345	5.42
	Total for the crop	8683	6.88
22-1-1967	February	321	0.79
	March	339	0.78
	April	2009	4.65
	May	366	0.84
	Total for the crop	3035	1.78

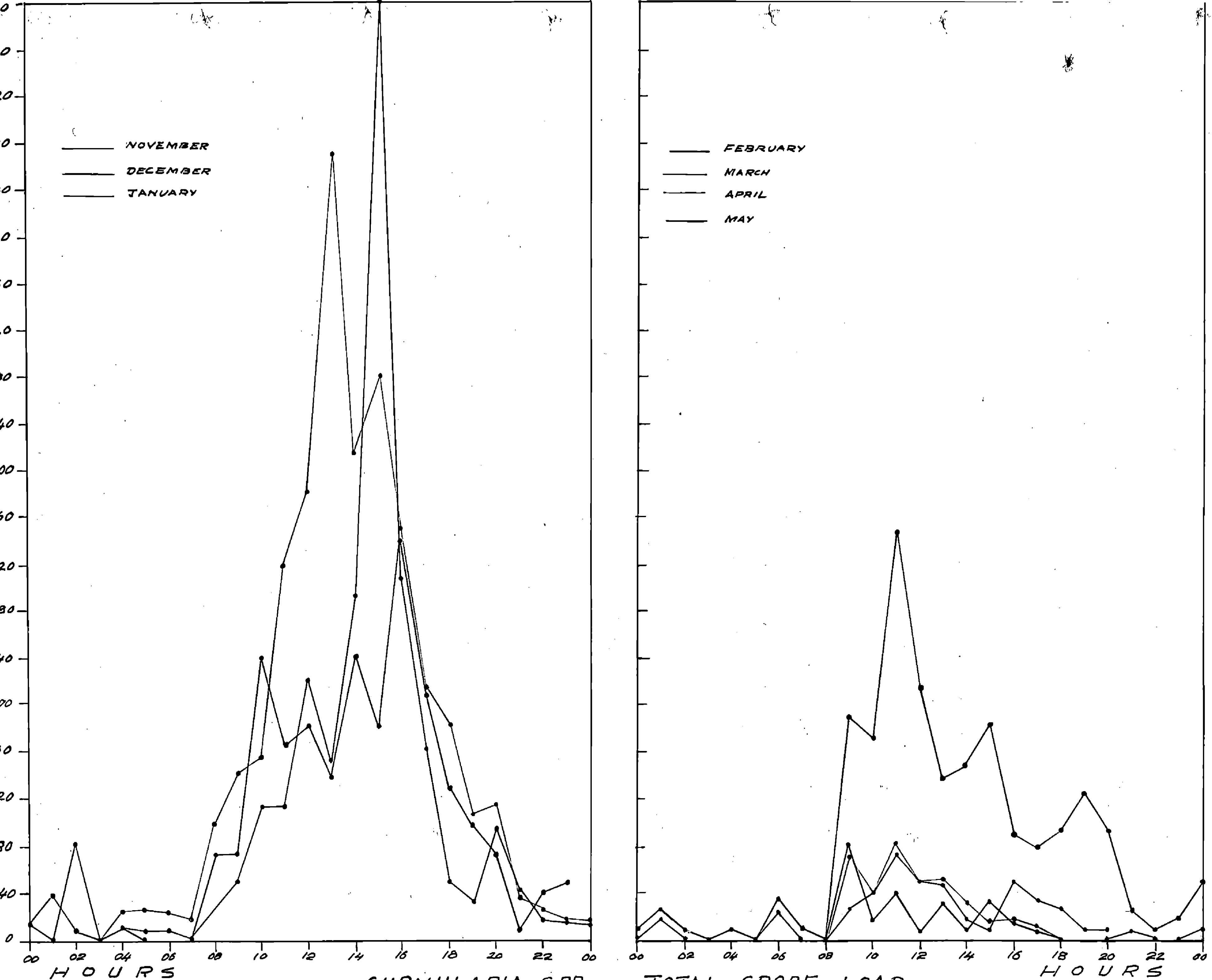
TABLE 14

Curvularia spp. - Total spore load during day time and night in different months.

Months	Day time 06.00 - 18.00 hrs.		Night 18.00 - 06.00 hrs.	
	Total spores	No. per cubic metre of air	Total spores	No. per cubic metre of air.
First crop				
November	3396	16.26	433	2.07
December	2341	12.47	168	0.81
January	1974	9.13	371	1.71
Second crop				
February	241	1.19	80	0.39
March	307	1.42	32	0.14
April	1663	7.69	336	1.55
May	366	1.69	-	-

Table 15. <u>Curvularia</u> sp. - Spore load calculated on hourly basis for each month November 1966 - May 1967

Months \ Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
November	40	8	-	24	25	24	16	94	141	156	318	381	670	414	481	338	213	174	107	115	83	25	16	16
December	-	-	-	8	-	-	-	24	48	114	113	222	139	292	841	297	163	48	32	96	40	-	16	16
January	-	82	-	8	8	8	-	74	74	241	167	182	138	242	182	337	207	130	96	93	8	40	48	-
February	24	8	-	8	-	24	-	-	81	16	40	8	32	8	32	16	8	-	-	-	8	-	-	8
March	16	-	-	-	-	-	-	-	25	40	75	49	48	16	8	49	33	25	8	8	-	-	-	-
April	-	-	-	-	-	34	-	-	191	172	347	213	138	148	184	90	80	92	124	91	24	8	16	49
May	-	-	-	-	-	-	8	-	73	40	82	49	49	33	16	16	16	8	-	-	-	-	-	-



CURVULARIA SPP. — TOTAL SPORE LOAD

CALCULATED ON HOURLY BASIS FOR EACH MONTH — NOV. 1966 — MAY '67

FIG 6

and May were 433, 168, 371, 80, 32, 336 and 0, which work out at the rate of 2.07, 0.81, 1.71, 0.39, 0.14, 1.55 and 0 respectively (Table 14).

(vi) *Nigrospora* sp.

Nigrospora spores were present in large numbers throughout the period of the experiment. There was no appreciable variation in the number of spores present in the atmosphere during November, December and January, the total number of spores trapped during these months being 34549, 37227 and 37644 respectively. These work out at the rate of 70.46, 83.39 and 86.90. spores per cubic metre of air for the months of November, December and January respectively. There was a sharp fall in the spore load in February. The total number of spores trapped during this month was 12253 which is equivalent to 30.38 spores per cubic metre of air. A rise in the spore load was noticed from the beginning of March till the end of April. In May again a slight fall in the spore load was observed. The average spore loads during the months of March, April and May were 106.69, 95.03 and 83.61 respectively per cubic metre of air (Table 16).

Diurnal periodicity

Maximum number of spores of *Nigrospora* sp. was trapped during day time especially during the forenoon. Spore load during night was comparatively low.

Spores began to appear by 05.00 hrs. and continued to be present in considerable numbers till 20.00 hrs. Maximum number of spores was obtained between 07.00 and 16.00 hrs. and the peak load was seen between 08.00 and 11.00 hrs (Table 18).(Fig: 7)

The total number of spores trapped during the day time in November, December, January, February, March, April and May were 33364,35998, 35687, 10744, 36125, 36078, and 35828 respectively and the corresponding spore loads per cubic metre of air were 159.78, 175.42, 82.6, 53.29, 167.24, 167.00 and 165.87. The total number of spores trapped during nights were 1185, 1229, 1957, 1509, 9974, 4979 and 294 respectively and the corresponding spore loads per cubic metre of air were 5.4, 5.5, 8.7, 7.4, 46.17, 23.05 and 1.36 (Table 17).

(vii) Basidiomycete spores.

Yellow coloured spores which were traced to a gill bearing basidiomycete were trapped in large numbers from the second week of November onwards. The

TABLE 16

Nigrospora sp. - Total monthly spore load over the rice crops

Date of sowing	Months	Total spore load	No. per cubic metre of air
7-10-1966	November	34549	70.46
	December	37227	83.39
	January	37644	86.90
	Total for the crop	109330	86.76
22-1-1967	February	12253	30.38
	March	46099	106.69
	April	41057	95.03
	May	36122	83.61
	Total for the crop	135525	79.87

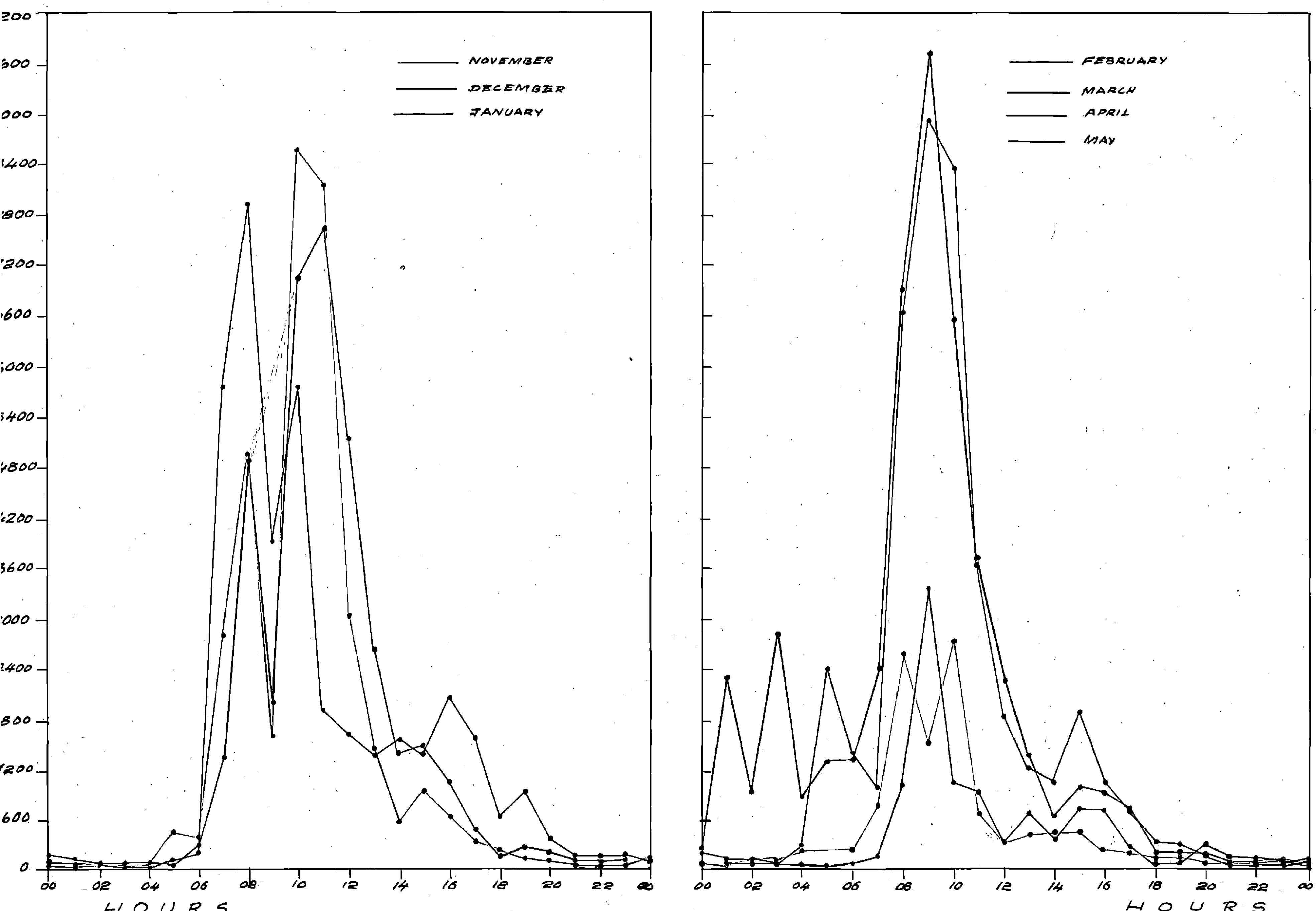
TABLE 17

Nigrospora sp. - Total spore load during day time and night in different months

Months	Day time 06.00 - 18.00 hrs.		Night 18.00 - 06.00 hrs.	
	Total spores	No. per cubic metre of air	Total spores	No. per cubic metre of air
First crop				
November	33364	159.78	1185	5.4
December	35998	175.42	1229	5.5
January	35687	82.60	1957	8.7
Second crop				
February	10744	53.29	1509	7.4
March	36125	167.24	9974	46.17
April	36078	167.00	4979	23.05
May	35828	165.87	294	1.36

Table -18 *Nigrospora sp.* Spore load calculated on hourly basis for each month from November 1966 - May 1967.

Hours / Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
November	-	-	25	-	417	367	2784	4967	1617	8602	8192	3184	1391	539	926	616	314	242	150	117	42	-	42	25
December	40	48	40	24	49	249	1351	4857	2575	7018	7717	5123	2648	1398	1473	1128	483	225	241	204	73	74	123	64
January	40	74	8	16	90	233	5740	7928	3840	5752	1890	1599	1393	1514	1357	2083	1571	634	908	331	178	148	157	74
February	56	48	65	204	238	234	790	2678	1467	2716	664	389	448	439	454	255	238	196	246	88	97	73	112	48
March	2319	850	2837	825	1299	1381	2299	7593	9776	6517	2764	2292	1382	658	1023	931	672	212	180	48	56	81	16	82
April	72	40	56	284	2374	1416	907	6260	8946	8246	3635	1813	1213	1056	1883	1099	700	350	306	172	88	67	48	56
May	-	-	16	8	-	33	100	1093	3370	1012	931	439	677	444	788	767	298	99	116	33	8	8	32	40



NIGROSPORA SPP: — TOTAL SPORE LOAD

CALCULATED ON HOURLY BASIS FOR EACH MONTH — NOV: 1966 — MAY '67

FIG: 7

total spore catch during this month was 788264 which works out at the rate of 1887.65 spores per cubic metre of air. A gradual fall in the spore load was observed from December, onwards and no spores could be trapped during February. The total spore catch for December, January and February were 340926, 5667 and 0. respectively and the corresponding spore loads per cubic metre of air were 830.71, 13.11 and 0. In March the spores again began to appear and their number gradually increased till May. The total spore catch during March, April and May were 438, 109762, 229486, respectively and the corresponding spore loads per cubic metre of air were 0.98, 254.08 and 514.08 (Table 19).

Diurnal periodicity

Basidiomycete spores were found in large numbers during night between 18.00 and 06.00 hrs. Comparatively low spore load was observed during day time. Peak load was observed between 21.00 and 02.00 hrs (Table 21)(Fig 8) The total number of spores trapped during nights in November, December, January, February, March April and May were 518969, 178090, 4692, 0, 388, 92292 and 185033 respectively and the corresponding spore loads per cubic metre of air were 2402.63, 802.37, 21.72, 0, 1.92, 427.27, 829.00. The spore loads decreased by

TABLE 19

Basidiomycetes - Total monthly spore load over the rice crops

Date of sowing	Months	Total spore load	No. per cubic metre of air
7-10-1966	November	788264	1887.65
	December	340926	830.71
	January	5667	13.11
	Total for the crop	1134857	856.62
22-1-1967	February	-	-
	March	438	0.98
	April	109762	254.08
	May	229486	514.08
	Total for the crop	339248	196.32

TABLE 20

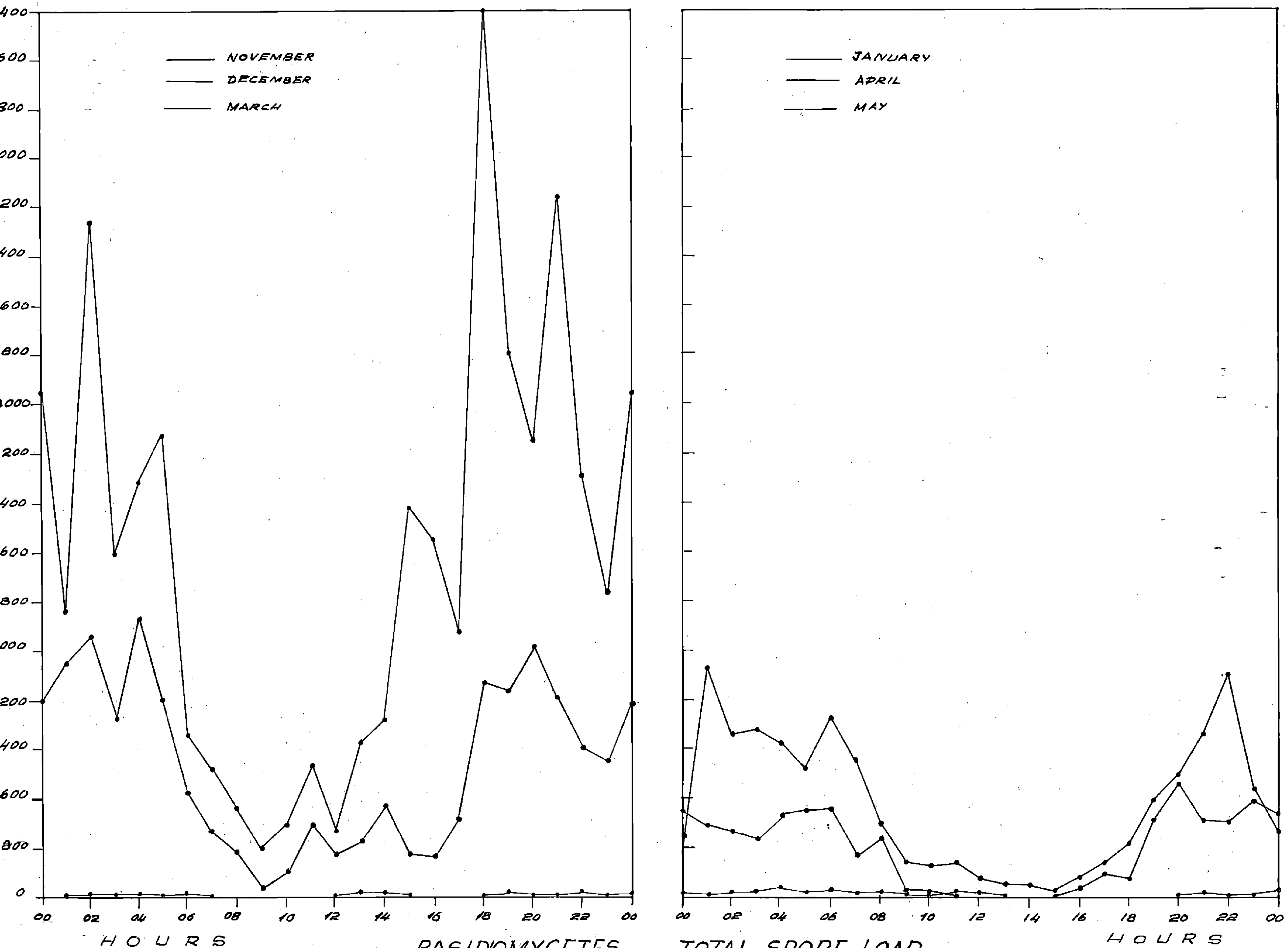
Basidiomycetes - Total spore load during day time and night in different months

Months	Day time 06.00 - 18.00 hrs.		Night 18.00 - 06.00 hrs.	
	Total spores	No. per cubic metre of air	Total spores	No. per cubic metre of air
First crop				
November	269295	1246.68	518969	2402.63
December	162836	729.54	178090	802.37
January	975	4.36	4692	21.72
Second crop				
February	Nil	Nil	Nil	Nil
March	50	0.23	388	1.92
April	17470	80.87	92292	427.27
May	44453	191.19	185033	829.00

Table -21

Basidiomycetes. Sporeload calculated on hourly basis for each month from November 1966 - May 1967.

Months \ Hours	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
November	28370	65614	33342	40136	46825	15707	11624	8417	4730	7351	13107	7945	14972	17174	37866	35496	25024	86589	53148	44474	68115	41084	29715	49341
December	22398	46959	17922	27609	19505	10120	6057	4607	958	2751	6898	4295	4403	9275	4957	36800	6417	20023	20565	24491	19680	14550	13396	19131
January	417	382	583	664	476	558	475	150	33	34	108	58	-	25	-	42	-	50	151	132	259	240	241	759
February	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
March	16	41	192	16	42	-	-	-	-	-	-	-	25	25	-	-	-	-	16	-	-	42	90	24
April	6670	6298	5595	7205	7887	8520	3952	6597	467	667	350	399	24	92	33	383	2205	1801	7266	10403	7365	7317	9339	8492
May	22916	15292	16617	14252	11724	17372	13015	7719	3789	3257	3547	1975	1176	1009	565	1384	2090	4887	9417	11551	15869	21981	10144	7998



BASIDIOMYCETES — TOTAL SPORE LOAD

CALCULATED ON HOURLY BASIS FOR EACH MONTH— NOV. 1966—MAY '67

FIG: 8

07.00 hr. and very few spores were trapped during mid day. The total spore catch during day time between 06.00 and 18.00 hours for the months, November, December, January February, March, April and May were 269295, 162836, 975, 0, 50, 17470 and 44453 respectively and the corresponding spore loads per cubic metre of air were 1246.68, 729.54, 4.36, 0, 0.23, 80.87 and 191.19 (Table 20).

3. Effect of Temperature and humidity on the spore load.

Maximum concentration of spores of *Piricularia oryzae* in the air was noted during the period of high humidity and low temperature. The concentration of spores of this fungus was low during the period of high temperature and low humidity. Generally the spores began to appear in small numbers in the evening when the temperature fell and humidity began to rise. The peak concentration of *Piricularia* spores occurred at a temperature range of 23°-26°C and relative humidity between 89-99 percent. (Fig. 10-12)

In December generally the humidity began to rise and temperature began to fall around 19.00 hrs. and this low temperature and humidity were usually maintained during the night till 07.00 hrs (Table 22). Spores were present throughout this period but the peak load occurred six to seven hours after the temperature began to fall and humidity began to rise, namely at 2.00 hrs (Fig 9). In March the temperature began to fall and humidity began to rise around 23.00 hrs. (Table 23) and the peak spore load occurred after 8 hrs. in the morning (Fig. 9.).

Similarly spores of basidiomycetes also began to appear in the evening when the humidity increased and temperature fell. The spore load decreased in the morning when the humidity fell and temperature rose. The highest spore load was noted when the temperature range was 20 - 25°C and the humidity range was 95 - 99 percent. (Fig.18)

Spores of the other fungi, namely, Trichoconis padwickii, Helminthosporium spp., Alternaria spp., Curvularia spp. and Nigrospora sp. were liberated when the humidity began to fall and temperature began to rise. (Fig. 13-17)

Maximum liberation of Trichoconis spores was observed when the temperature range was 25 - 30°C and relative humidity range was 75 - 95 percent.

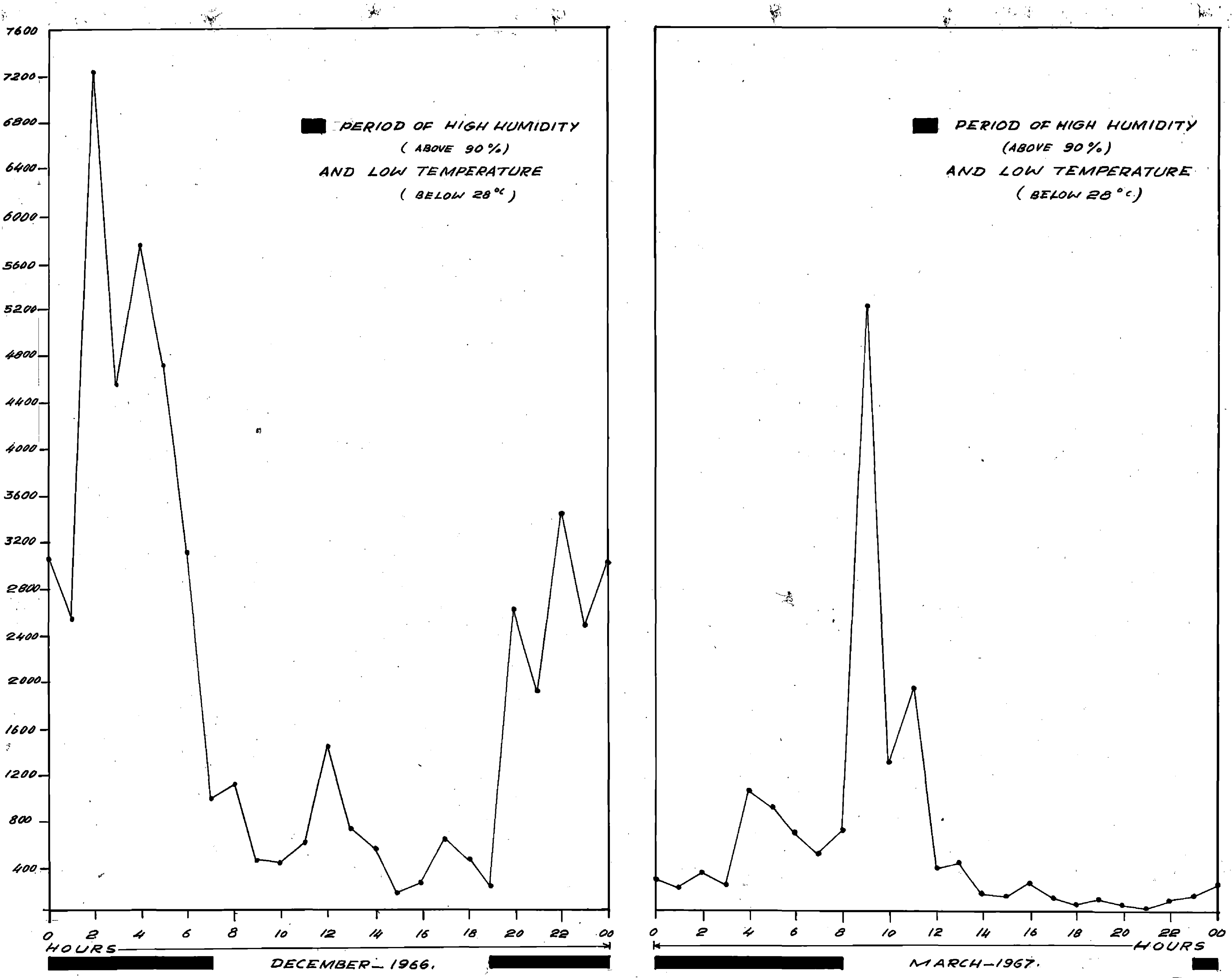
Maximum number of Helminthosporium spores were observed when the temperature was 29-35°C and a humidity between 60-75 percent.

Table 22. Duration of high humidity and low temperature in relation to spore load of *Piricularia oryzae* in December.

Date	Time of fall of temp.& rise in humidity	Time of rise in temp. & fall in humidity	Duration of high humidity & low temp.	Total spore load.	Time of peak load.
1st 9 A.M.-2nd 9 A.M.	20.00 hrs.	07.00 hrs.	11 hrs.	615	03.00 - 05.00 hrs.
2nd..-3rd..	19.00 ..	07.00 ..	12 ..	-	-
3rd..-4th..	21.00 ..	09.00 ..	12 ..	-	-
4th..-5th..	18.00 ..	07.00 ..	13 ..	139	02.00 hrs
5th..-6th..	19.00..	07.00 ..	12 ..	12538	01.00-06.00 ..
6th..-7th..	17.00 ..	08.00 ..	15 ..	9426	02.00-05.00 ..
7th..-8th..	19.00 ..	07.00 ..	12 ..	2600	02.00-05.00 ..
8th..-9th..	19.00 ..	07.00 ..	12 ..	3290	01.00-05.00 ..
9th..-10th.	19.00 ..	07.00 ..	12 ..	1833	02.00 hrs
10th..-11th..	19.00 ..	07.00 ..	12 ..	1642	02.00 ..
11th..-12th.	21.00 ..	07.00 ..	10 ..	73	06.00 ..
12th..-13th..	20.00 ..	08.00 ..	12 ..	73	06.00 ..
13th..-14th..	22.00 ..	08.00 ..	10..	223	03.00 ..
14th..-15th..	19.00 ..	08.00 ..	13 ..	189	04.00 ..
15th..-16th..	20.00 ..	07.00 ..	11 ..	123	04.00 ..
16th..-17th..	20.00 ..	08.00 ..	12 ..	48	02.00 ..
17th..-18th..	20.00 ..	08.00 ..	12 ..	105	03.00 ..
18th..-19th..	19.00 ..	07.00 ..	12 ..	221	03.00 ..
19th..-20th..	19.00 ..	08.00 ..	13 ..	3318	02.00 ..
20th..-21st..	13.00 ..	06.00 ..	17 ..	5333	02.00 ..
21st..-22nd..	19.00 ..	07.00 ..	12 ..	1524	02.00 ..
22nd..-23rd..	20.00 ..	08.00 ..	12 ..	116	02.00 ..
23rd..-24th..	20.00 ..	07.00 ..	11 ..	97	03.00 ..
24th..-25th..	20.00 ..	08.00 ..	12 ..	680	04.00 ..
25th..-26th..	20.00 ..	08.00 ..	12 ..	146	02.00 ..
26th..-27th..	21.00 ..	07.00 ..	10 ..	208	04.00 ..
27th..-28th..	19.00 ..	07.00 ..	12 ..	16	02.00 ..
28th..-29th..	21.00 ..	07.00 ..	14 ..	56	02.00 ..
29th..-30th..	22.00 ..	07.00 ..	9 ..	16	-
30th..-31st..	20.00 ..	07.00 ..	13 ..	-	-

Table 23. Duration of high humidity and low temperature in relation to spore load of <u>Piricularia</u> <u>oryzae</u> in March.

Date	Time of fall in temp.& rise in humidity	Time of rise in temp. & fall in humidity	Duration of high humidity & low temp.	Total spore load	Time of peak load
1st 9 A.M.- 2nd 9 A.M.	22.00 hrs.	07.00 hrs	9 hrs.	33	11.00 hrs.
2nd..-3rd..	23.00 ..	07.00 ..	8 ..	342	10.00 ..
3rd..-4th..	23.00 ..	07.00 ..	8 ..	57	09.00 ..
4th..-5th..	23.00 ..	07.00 ..	8 ..	891	09.00 ..
5th..-6th..	23.00 ..	07.00 ..	8 ..	209	09.00-11.00 ..
6th..-7th..	23.00 ..	07.00 ..	8 ..	807	09.00-11.00 ..
7th..-8th..	23.00 ..	07.00 ..	8 ..	160	09.00-11.00 ..
8th..-9th..	22.00 ..	07.00 ..	9 ..	3774	09.00 hrs.
9th..-10th..	23.00 ..	07.00 ..	8 ..	1030	04.00-06.00 ..
10th..-11th..	24.00 ..	07.00 ..	7 ..	849	09.00 hrs.
11th..-12th..	23.00 ..	07.00 ..	8 ..	548	10.00 ..
12th..-13th..	23.00 ..	07.00 ..	8 ..	417	06.00 ..
13th..-14th..	23.00 ..	07.00 ..	8 ..	99	07.00 ..
14th..-15th..	23.00 ..	07.00 ..	7 ..	164	09.00 ..
15th..-16th..	24.00 ..	07.00 ..	7 ..	8	-
16th..-17th..	23.00 ..	07.00 ..	8 ..	83	08.00 ..
17th..-18th..	02.00 ..	07.00 ..	5 ..	8	-
18th..-19th..	01.00 ..	07.00 ..	6 ..	8	-
19th..-20th..	01.00 ..	07.00 ..	6 ..	50	09.00 hrs
20th..-21st..	01.00 ..	07.00 ..	6 ..	-	-
21st..-22nd..	01.00 ..	07.00 ..	6 ..	65	10.00 hrs.
22nd..-23rd..	22.00 ..	07.00 ..	9 ..	199	08.00 ..
23rd..-24th..	24.00 ..	07.00 ..	7 ..	305	09.00 ..
24th..-25th..	18.00 ..	09.00 ..	15 ..	1014	09.00 ..
25th..-26th..	23.00 ..	07.00 ..	8..	74	09.00 ..
26th..-27th..	22.00 ..	07.00 ..	9..	3156	09.00 ..
27th..-28th..	23.00 ..	07.00 ..	8 ..	458	05.00 ..
28th..-29th..	22.00 ..	07.00 ..	9 ..	131	08.00 ..
29th..-30th..	22.00 ..	07.00 ..	9 ..	171	08.00 ..
30th..-31st..	22.00 ..	07.00 ..	9 ..	-	-



PIRICULARIA ORYZAE – SPORE LOAD IN RELATION TO PERIOD OF HIGH HUMIDITY AND LOW TEMPERATURE. Fig. 9

Alternaria spores were found in considerable numbers when the temperature was 29°-$33^{\circ}C$ and the humidity was 60-80 percent.

Higher concentration of *Curvularia* spores in the atmosphere was noted when the temperature ranged between 28°-$33^{\circ}C$ and humidity between 60-80 percent.

In the case of *Nigrospora* sp., spores were found to be liberated when the temperature was between 23°-$34^{\circ}C$ and the humidity range was 55-90 percent.

Effect of rain.

The concentration of spores of *Piricularia oryzae* and of the basidiomycetes was found to be greater on days following rains (Table 24 and 25).

5. Correlation between spore content in the air and blast infection.

A correlation was noted between the concentration of spores of *Piricularia oryzae* in the atmosphere and severity of infection in the second crop for which only the observations were made.

Spores of *Piricularia* could be trapped prior to the detection of blast disease in the young crop. The spores could have come from the remnants of the harvested first crop nearby or from grasses. It was

TABLE 24.

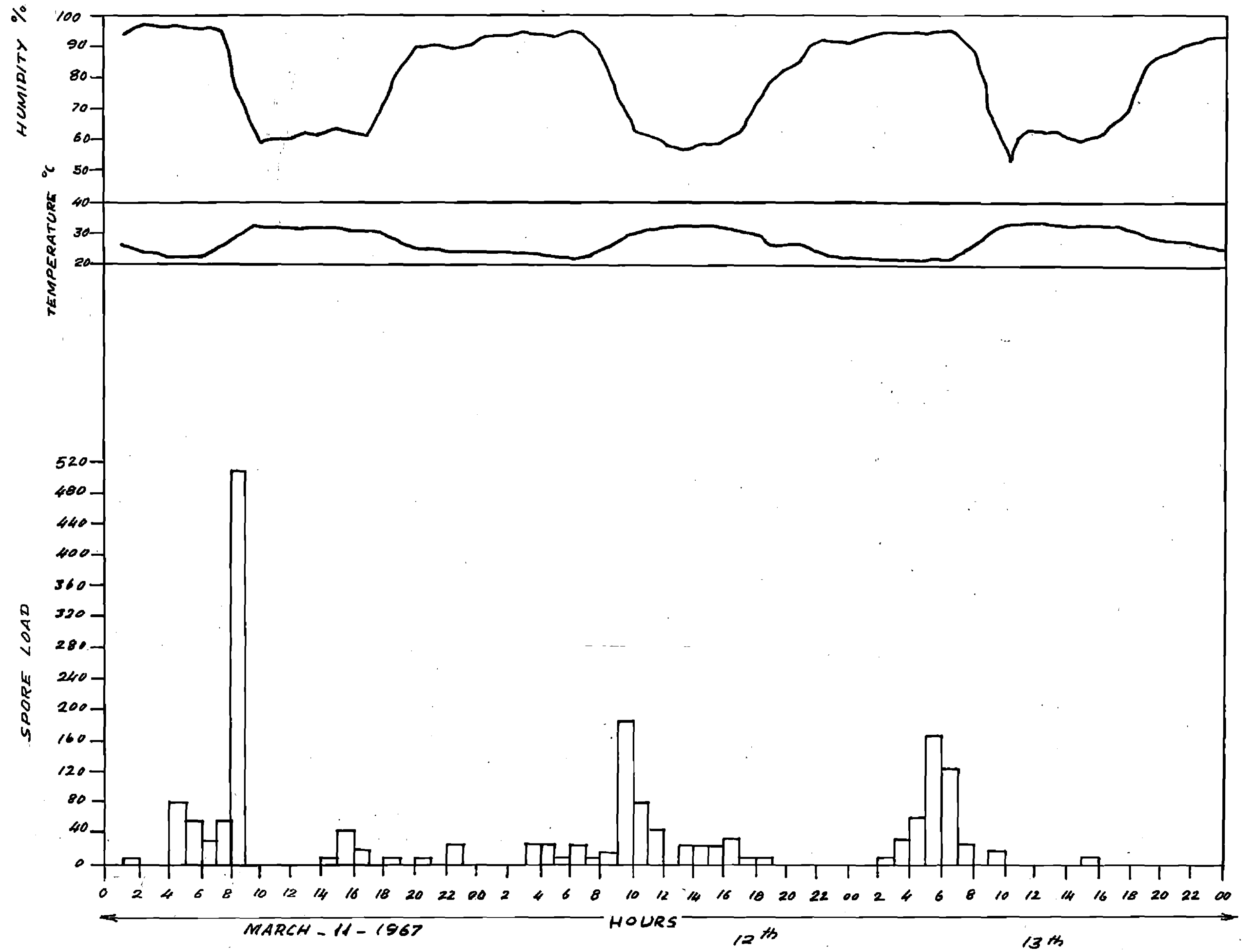
Influence of rain on spore load of *Piricularia oryzae*.

Date of rain fall.	Spore load	Spore load on the day following rain
3-11-1966	357	1919
8-11-1966	4451	18021
10-11-1966	2602	13105
11-11-1966	13105	66842
18-11-1966	11878	14566
19-12-1966	221	3318
20-12-1966	3318	5333
18-2-1967	No spores	1014
25-3-1967	75	1014
12-4-1967	50	248
23-4-1967	No spores	8

TABLE 25.

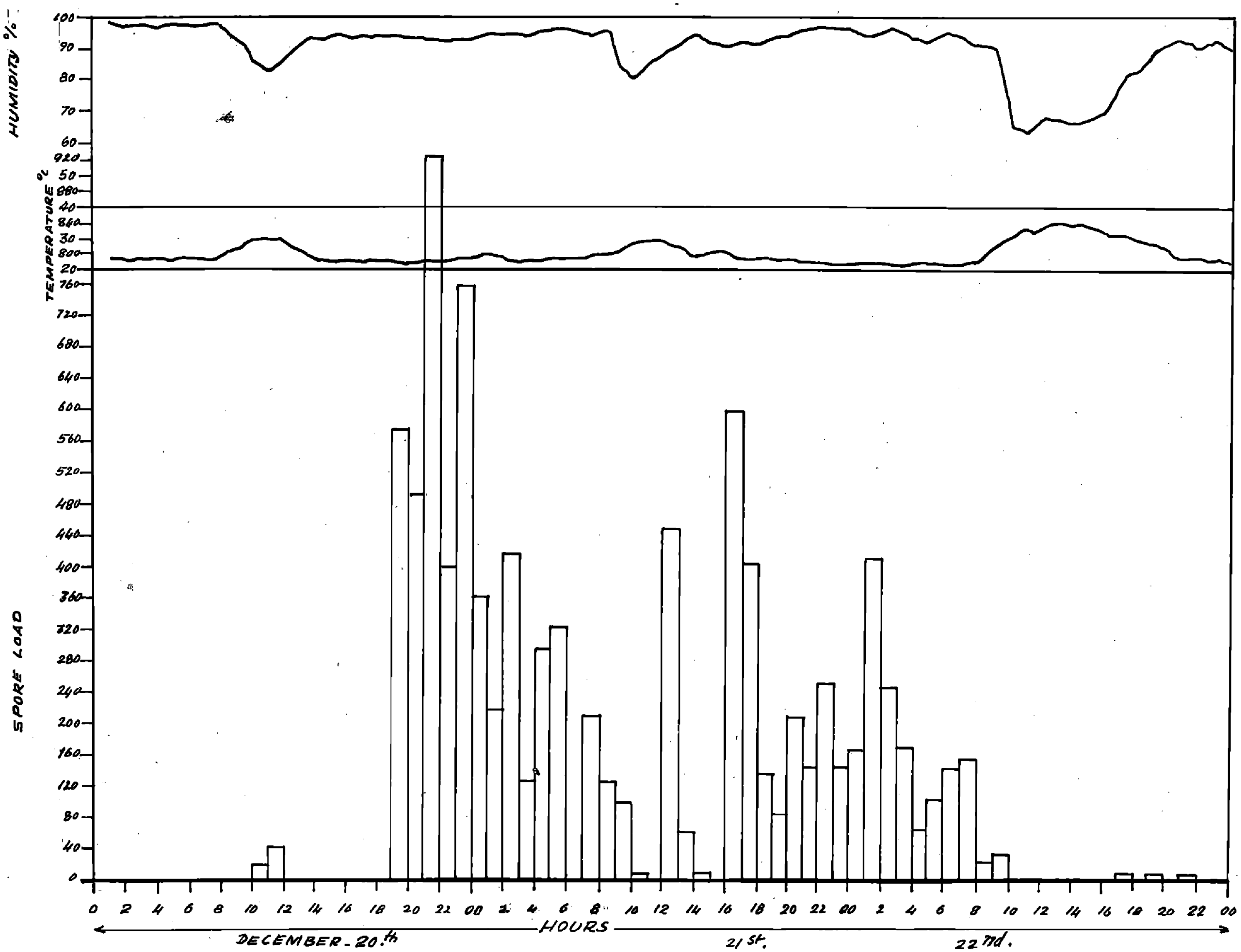
Influence of rain on the spore load of Basidiomycetes.

Date of rain fell	Spore load	Spore load on the day following rain.
10-11-1966	No spores	26515
11-11-1966	26515	74569
18-11-1966	1751	2031
19-12-1966	1165	1662
20-12-1966	642	6374
18-2-1967	No spores	8
12-4-1967	515	613
23-4-1967	250	3560
9-5-1967	2368	4229
10-5-1967	4229	4345
15-5-1967	7009	14261
17-5-1967	22814	29846
21-5-1967	5101	8190



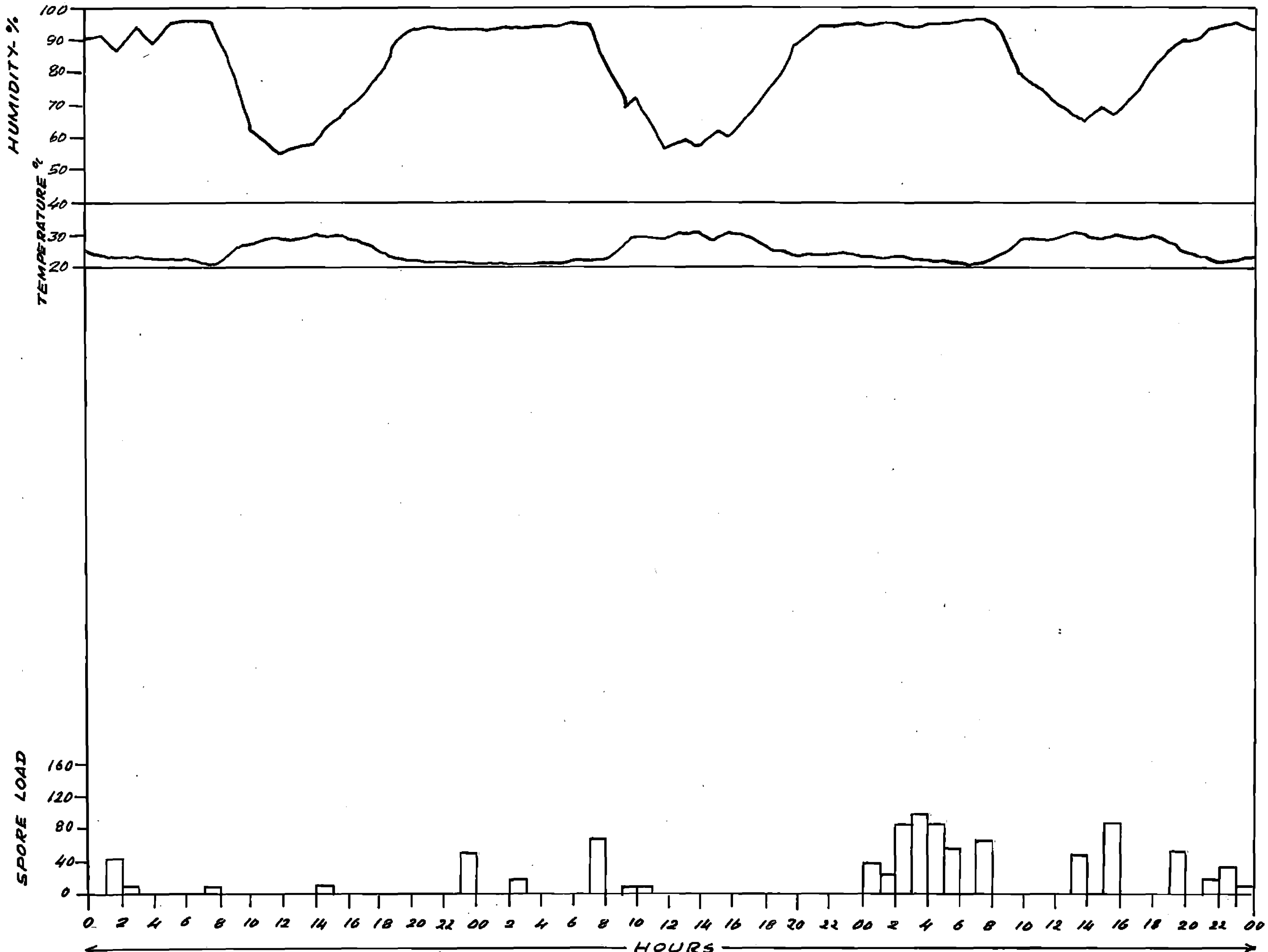
PIRICULARIA ORYZAE - SPORELOAD IN RELATION TO WEATHER CONDITIONS.

FIG: 10



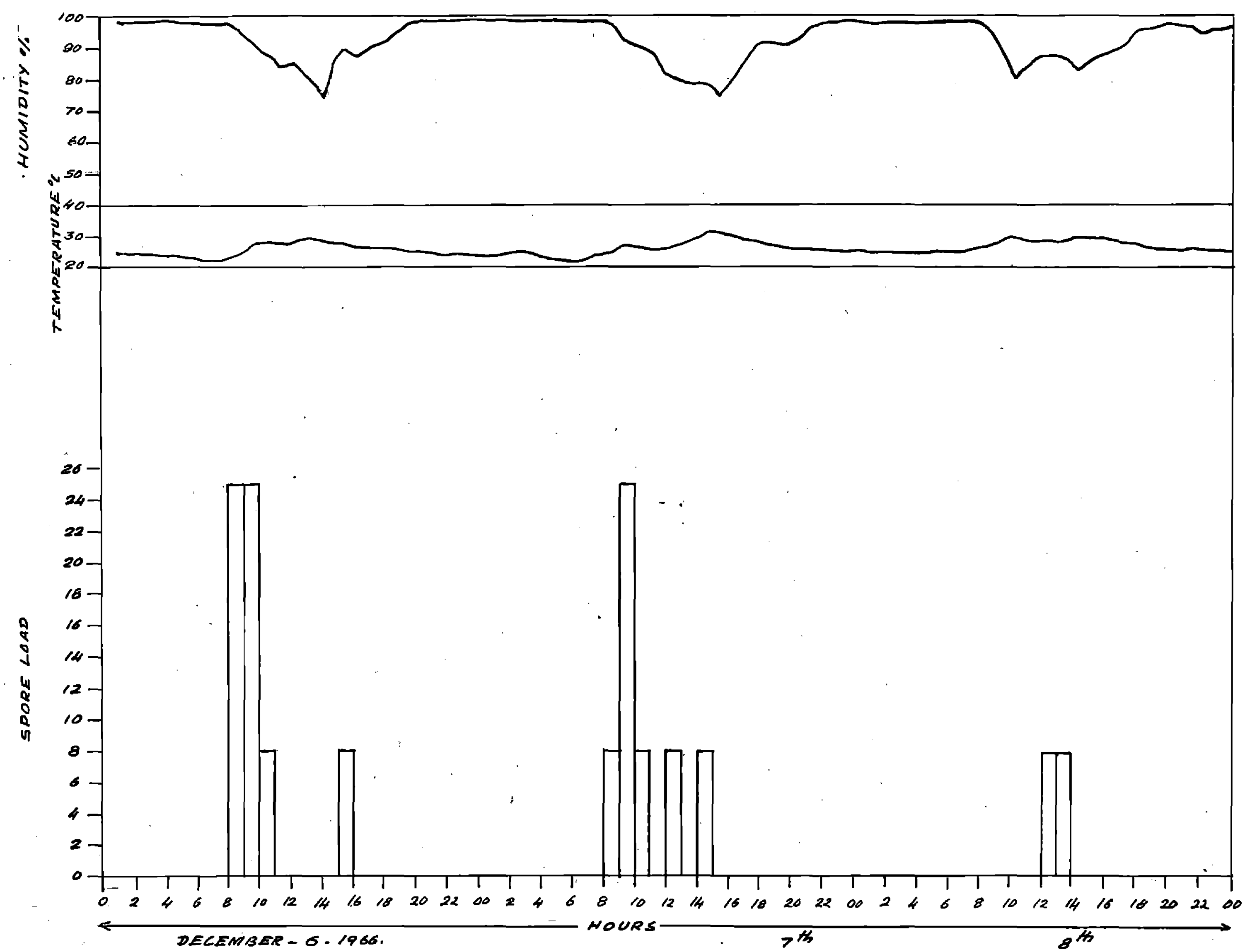
PIRICULARIA ORYZAE - SPORE LOAD IN RELATION TO WEATHER CONDITION.

FIG. 11

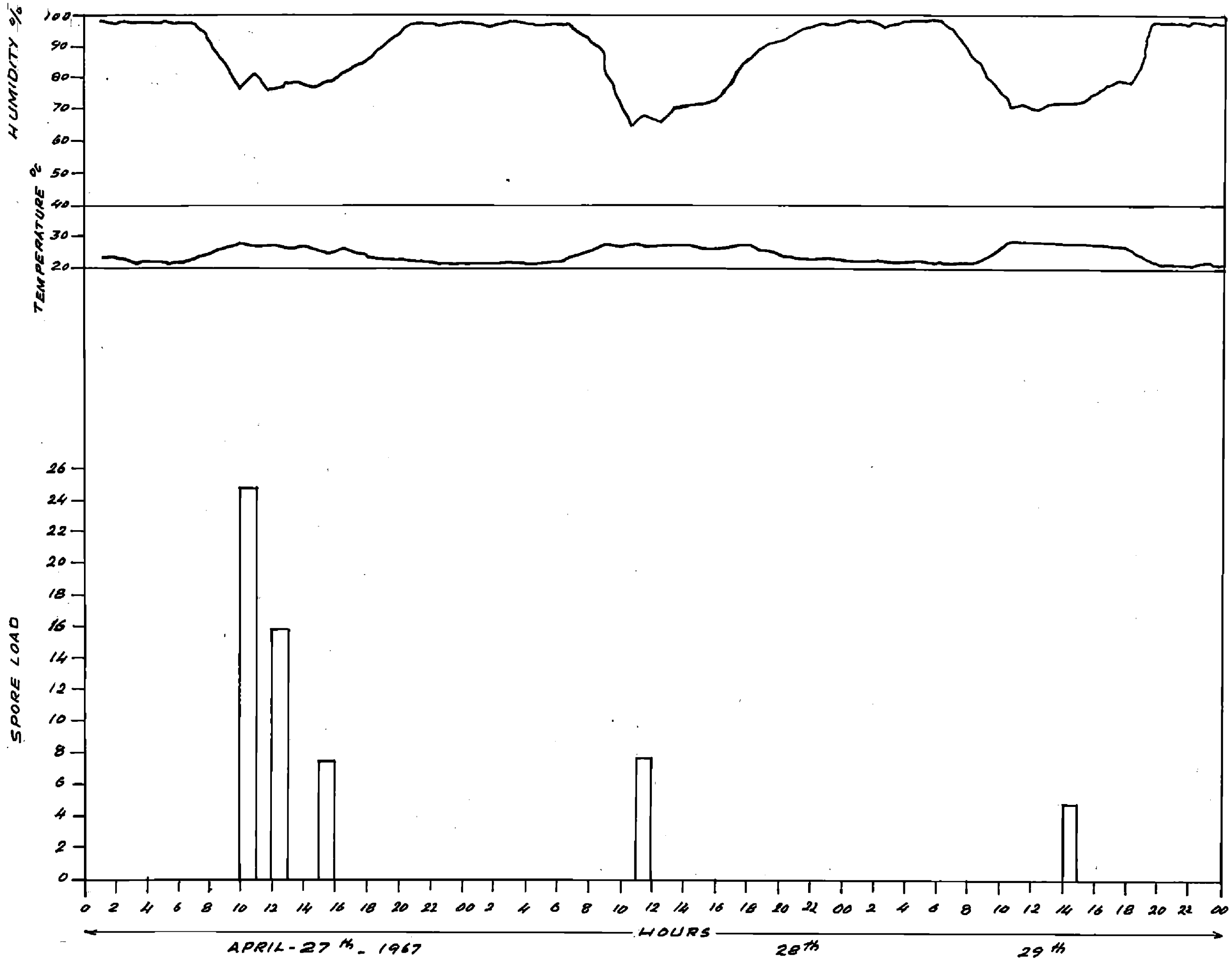


PIRICULARIA ORYZAE- SPORE LOAD IN RELATION TO WEATHER CONDITION.

FIG: 12

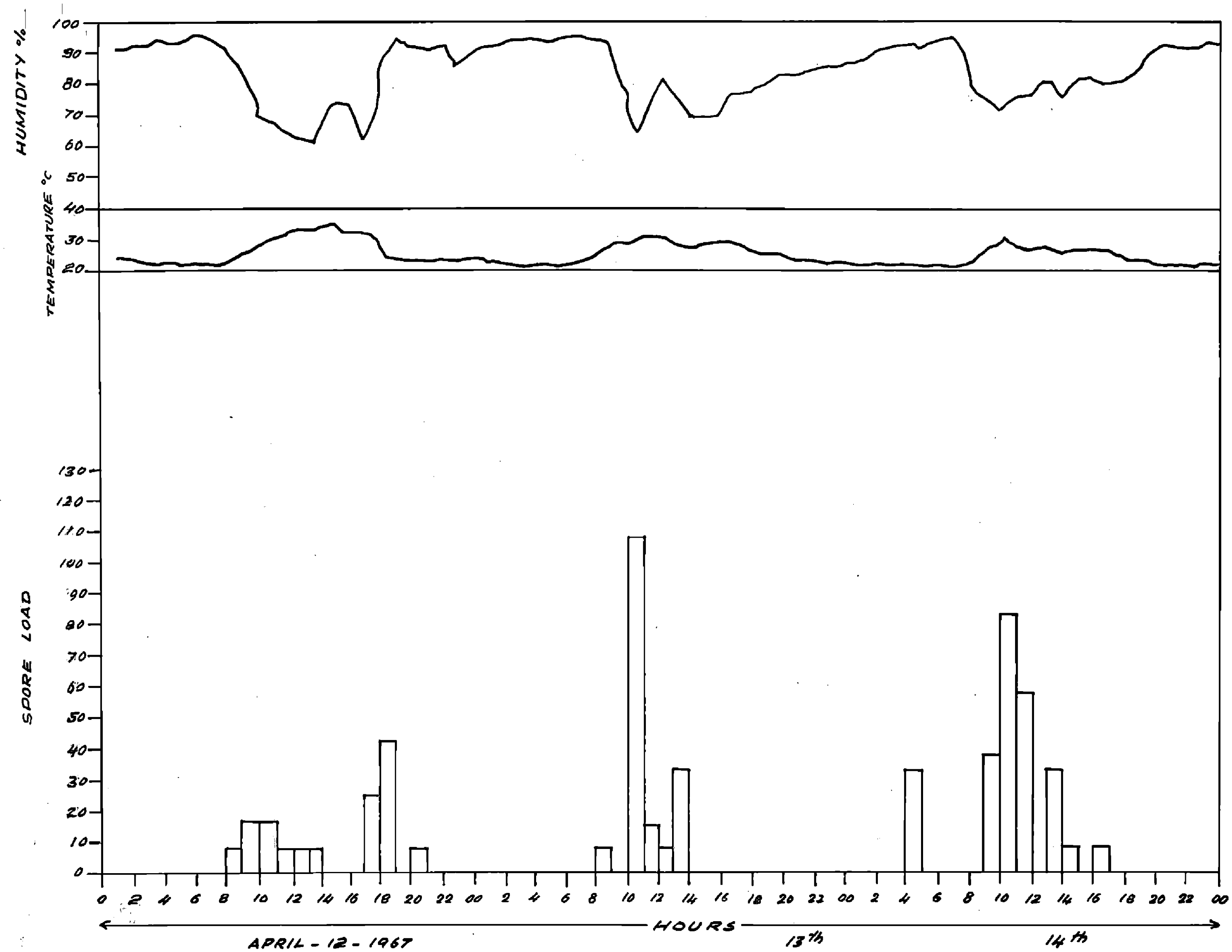


<u>TRICHOCONIS</u> <u>PADWICKII</u> – SPORE LOAD IN RELATION TO WEATHER CONDITIONS. FIG: 13



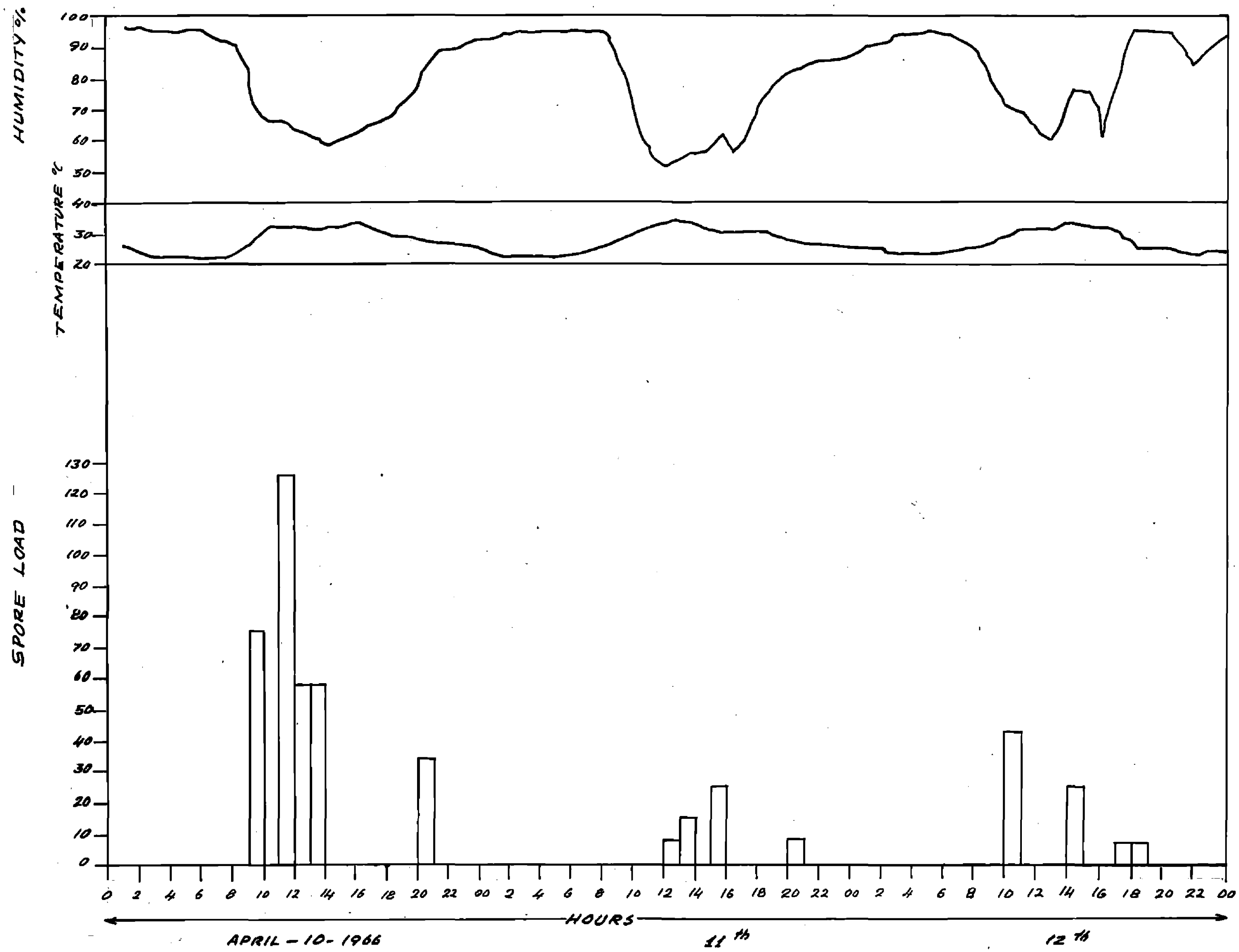
HELMINTHOSPORIUM Spp: — SPORE LOAD IN REATION TO WEATHER CONDITIONS.

FIG: 14



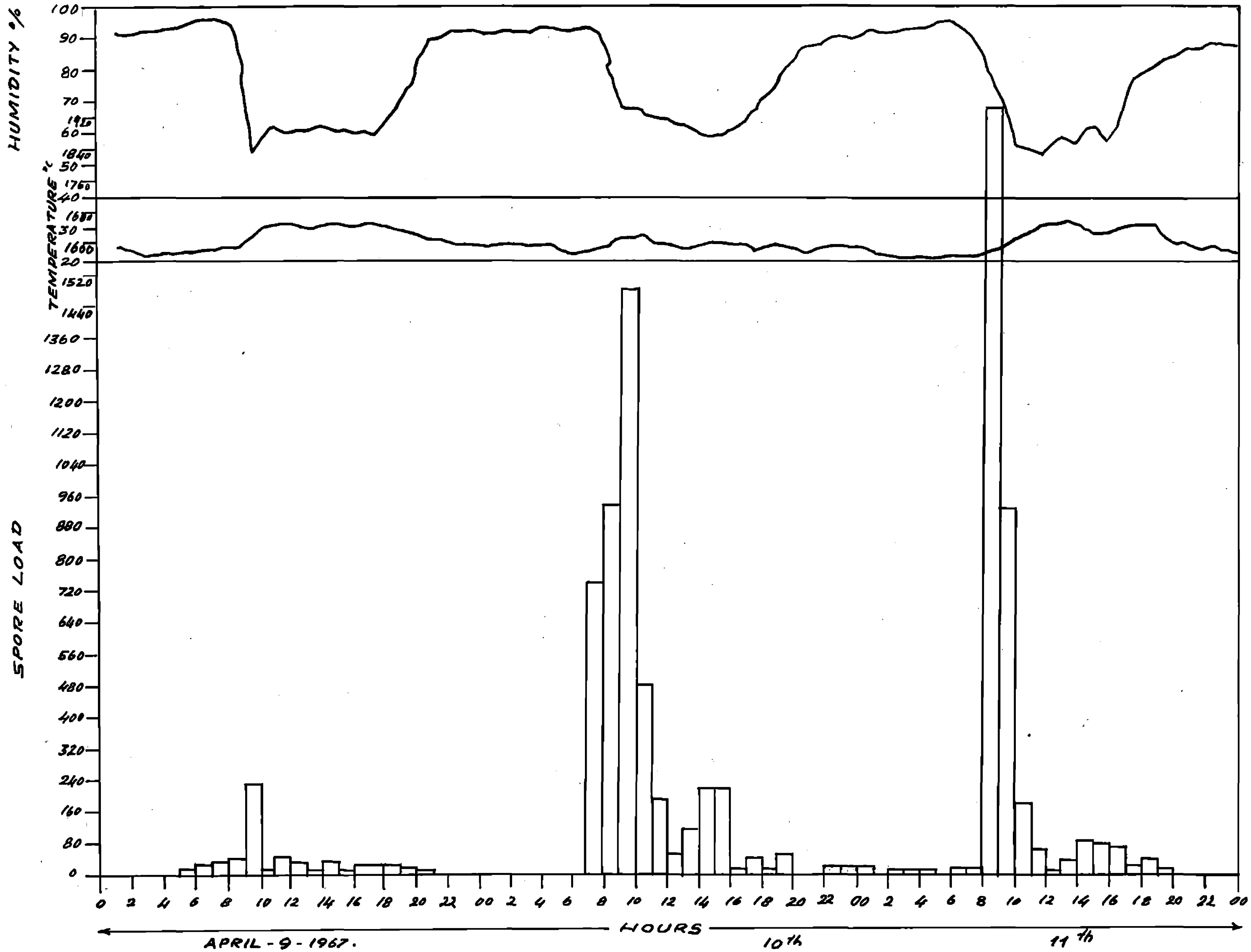
CURVULARIA Spp: – SPORE LOAD IN RELATION TO WEATHER CONDITIONS.

FIG: 15



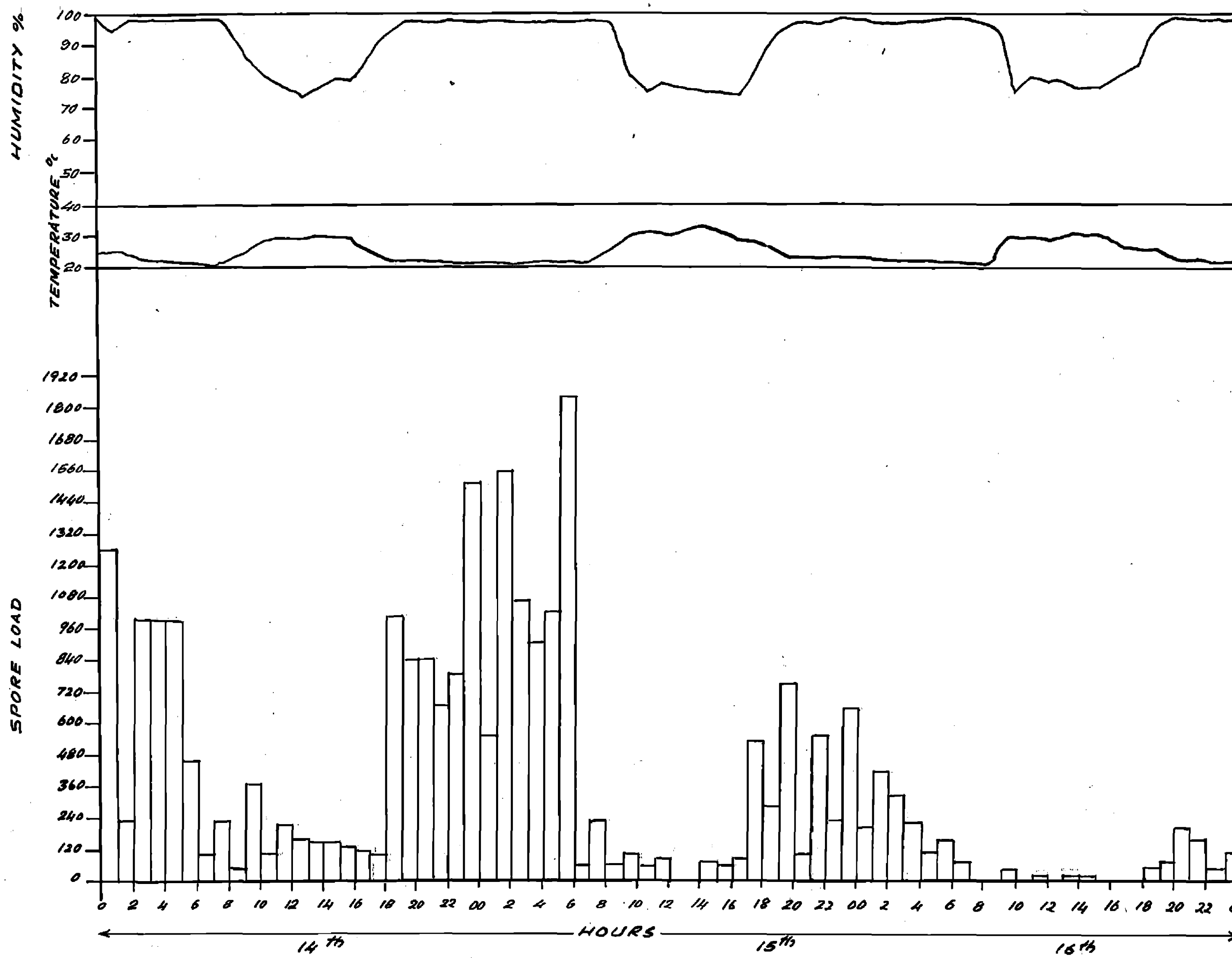
ALTERNARIA Spp:- SPORE LOAD IN RELATION TO WEATHER CONDITIONS.

FIG: 16



NIGROSPORA Spp. - SPORE LOAD IN RELATION TO WEATHER CONDITIONS.

FIG: 17



BASIDIOMYCETES – SPORE LOAD IN RELATION TO WEATHER CONDITIONS

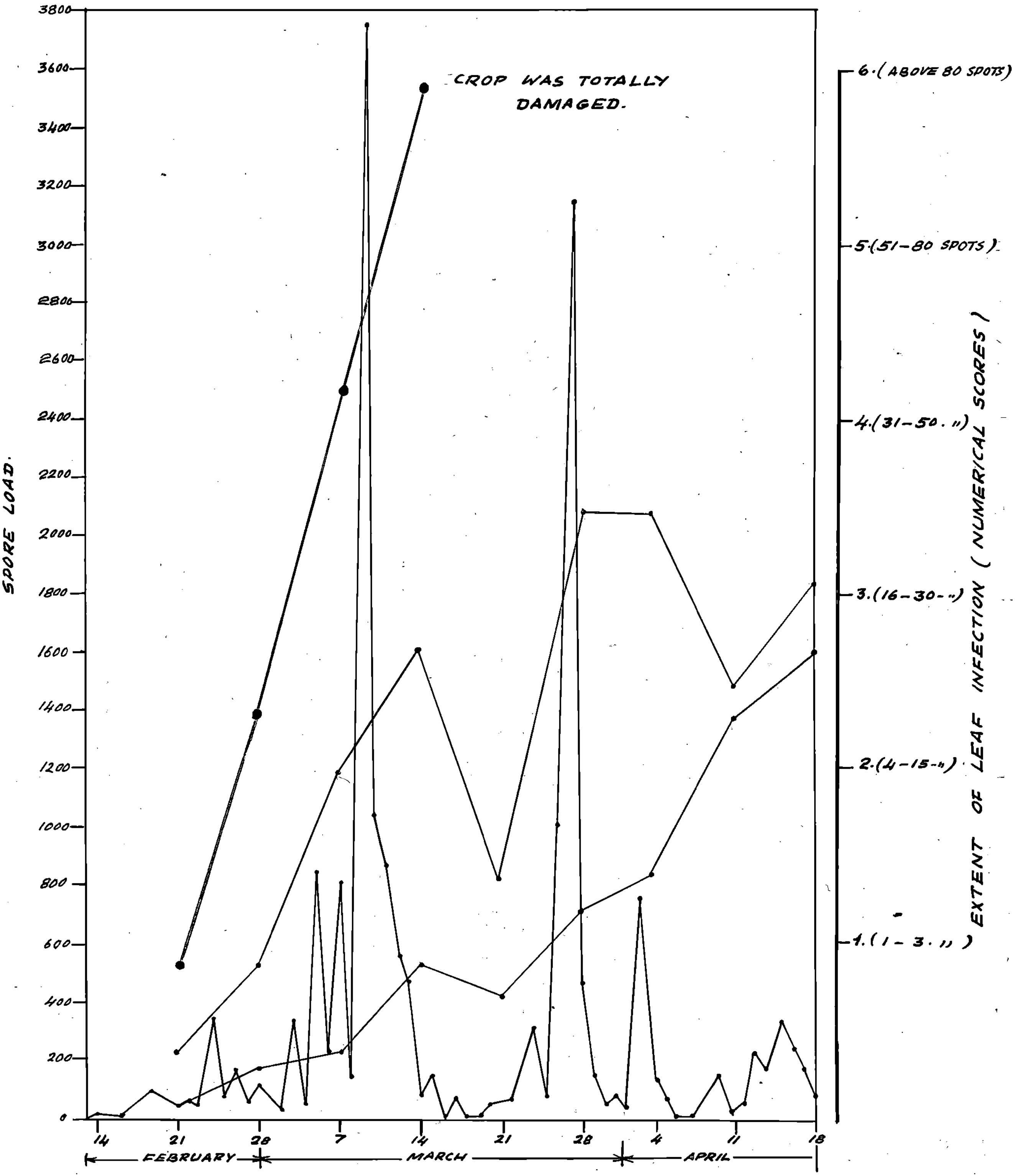
FIG: 18

found that an increase in the spore load in the atmosphere was followed within 3 to 7 days by increased leaf infection (Table 26). There was an increase in the spore load during week ending 28-2-1967 and this was attended by an increase in the severity of infection (Fig. 19). From then on, the spore load showed a tendency to increase and the infection also continued to increase. During the week ending 14-3-1967 there was a marked increase in the spore load and this was attended by a very sharp rise in infection also. ADT.27 was so severely affected by the disease that the crop was almost completely damaged at this stage. Only the other two varieties survived. A sharp fall in the spore load was noted during the week ending 21-3-1967 and a fall in infection was also noticeable during this period. The spore load in the succeeding week ending 28-3-1967 again showed a marked rise. A sharp rise in infection was also noticeable during this period especially in the variety Kaohsiung-18. A slight rise in the spore load was again noticed during the week ending 18-4-1967 and an increase in infection was also noticeable during this period (Fig. 19).

Table 26. Blast - weekly recrod of the disease incice and daily spore load from February 14th to Apr 18th.

Varieties / Dates		21-2-67	28-2-67	7-3-67	14-3-67	21-3-67	28-3-67	4-4-67	11-4-67	18-4-67
Tainan-3.	average No. of scores obtained.	0.15	0.3	0.4	0.9	0.7	1.2	1.4	2.3	2.7
Kaohsiung-18		0.4	1.2	2.0	2.7	1.4	3.5	3.5	2.5	3.1
ADT-27		0.8	2.30	4.2	5.9	-	-	-	-	-
Stages of growth		Seedling stage					Tillering stage			

Dates	Spore load.
14-2-67	0
15-2-67	0
16-2-67	8
17-2-67	0
18-2-67	0
19-2-67	74
20-2-67	0
21-2-67	0
22-2-67	55
23-2-67	0
24-2-67	349
25-2-67	48
26-2-67	174
27-2-67	58
28-2-67	106
1-3-67	84
2-3-67	33
3-3-67	342
4-3-67	57
5-3-67	891
6-3-67	209
7-3-67	807
8-3-67	160
9-3-67	3774
10-3-67	1030
11-3-67	848
12-3-67	548
13-3-67	467
14-3-67	99
15-3-67	164
16-3-67	8
17-3-67	83
18-3-67	8
19-3-67	8
20-3-67	50
21-3-67	0
22-3-67	65
23-3-67	199
24-3-67	305
25-3-67	74
26-3-67	1014
27-3-67	3156
31-3-67	0
1-4-67	93
2-4-67	48
3-4-67	776
4-4-67	114
5-4-67	73
6-4-67	0
7-4-67	0
8-4-67	24
9-4-67	8
10-4-67	175
11-4-67	32
12-4-67	50
13-4-67	248
14-4-67	192
15-4-67	357
16-4-67	214
17-4-67	191
18-4-67	157



RELATIONSHIP BETWEEN SPORELOAD OF

PIRICULARIA ORYZAE IN THE AIR AND DISEASE INCIDENCE IN THE FIELD

——— TAINAN-3. ——— KAOHSUING-18. ——— ADT-27.

Fig. 19.

DISCUSSION

DISCUSSION

Of the spores of various fungi trapped over the rice crop, those of Piricularia oryzae can be considered to have been dispersed mainly from the rice crop, and to a small extent from the graminaceous weeds like panicum repens, Rhynchelytrum repens that are commonly seen affected by the fungus in this area. This may be the case with the spores of Helminthosporium also since leaf spots caused by this fungus are common on weeds like Euphorbia geniculata. Further, two distinctly different types of Helminthosporium spores have been trappedo on the slides during most of the periods. Trichoconis is not known to affect any plant other than rice in this area and hence the spores trapped are presumed to have been liberated exclusively from the rice crop. Alternaria has been observed on rice grains and also on other host plants and dead plant materials. The conidia trapped might have, therefore, come from more than one substratum and belong to more than one species. Nigrospora sp. was noticed on old and dry rice leaves while Curvularia was noticed on rice grains as well as on dead plant materials. The yellow coloured basidiospores could be traced to a small mushroom growing on decaying organic matter in and around the experimental plots.

Seasonal as well as diurnal periodicity in spore liberation have been observed for all the above fungi. High spore load of <u>Piricularia oryzae</u> was obtained during March-April in the second crop. These coincide with the period of maximum blast infection in the crop. The spore load of November was over 30 times that of March and the spore load of December was nearly 4 times that of March. This may be attributable to the differences in the weather conditions which prevailed during these periods. The weather data for November is not available. The weather data for December indicate that high humidity and low temperature prevailed for longer periods on most of the nights during these months. This might have favourably influenced the production of spores. In March on the other hand the above conditions were obtained only for much shorter periods and the spore load was also low. The occurrence of frequent rains and also dew formation in November and December would have contributed towards the production of greater number of spots during these months. Barksdale and Asai (1961) have observed that the lesions of <u>Piricularia oryzae</u> on leaves kept in high relative humidity for longer periods produced comparatively larger number of spores.

The spores of Piricularia oryzae showed a night maxima during the first crop season, the highest spore load occurring between 02.00 and 04.00 hrs. This changed to a day maxima during the second crop season, the highest spore load occurring between 08.00 and 11.00 hrs. Thus the nocturnal pattern of diurnal periodicity was altered as a result of the seasonal influence. Panzer et al (1957) referred Piricularia to the 'night spora' with maximum between 18.00 and 09.00 hrs. Barksdale and Asai (1961) found that the spores of this fungus were released only at night. A definite nocturnal pattern of spore dispersal of this fungus has been noted by Ramalingam (1966A) also. He, however, found that under the conditions obtained at Visakhapatnam the peak spore load in the 1st crop season during September-October occurred at 04.00 hrs, while in the second crop season during February-April, it occurred at 06.00 hrs. Thus a change in the period of peak spore load was noticeable in his work also. The shift in the period of spore liberation noted in the present study was however much more marked. It is quite likely that this shift in the diurnal pattern of spore liberation noted in the experiment could have been influenced by temperature and humidity. While the fall in temperature and rise in humidity commenced between 18.00 and 19.00 hrs. in December, it occurred only around 23.00 hrs. in March. Perhaps this forward shift of the favourable conditions might have influenced the forward shift in the period of maximum liberation of spores. Barksdale and Asai (1961) who provided dew periods artificially, found that spores of Piricularia oryzae began to be released 6-8 hrs. after the start of this period and that the release stopped soon after dawn. In the present work, however, the release was found to continue during the day time also in the second crop season. Barksdale and Asai (1961) studied only the effect of light, moisture and humidity on the production and liberation of spores of Piricularia oryzae, under laboratory conditions. They have not taken into consideration, other factors like temperature and air currents. A proper understanding of the shift in the diurnal periodicity noted in the present work will be possible only by future work.

The spore dispersal of Piricularia oryzae seems to be governed by high atmospheric humidity and low temperature. Ingold (1965) had observed that the spores of *Piricularia oryzae* can be set free only if the air is saturated or nearly so. This factor and also the nature of attachment of the conidia to the conidiophore has made him infer that there is an active discharge mechanism in *Piricularia oryzae*. While this may be so, the trapping of spores of the fungus during day time in the second crop season indicates that, possibly the drying up of the substratum and wind erosion may also be able to discharge the spores of this fungus.

With regard to the other fungi, only the seasonal periodicity was found altered. The diurnal periodicity was not altered by the change in season. While *Helminthosporium*, *Alternaria*, and *Curvularia* showed an "afternoon pattern" *Trichoconis* and *Nigrospora* exhibited "forenoon pattern" and the yellow coloured basidiospores showed "night pattern" of spore liberation. These results are more or less in close agreement with that obtained by earlier workers like Rajan *et al* (1952), Panzer *et al* (1957), Sreeramulu *et al* (1962), Sreeramulu and Ramalingam (1963) and Prasannakumaran (1966).

The exact mechanism, by which the spores of the above fungi are liberated, is not known.

Hirst (1953) has suggested that spores which are commonest in the forenoon depend on hygroscopic changes during drying to liberate their spores and those commonest in the afternoon are passively dispersed by shaking and wind erosion from dry surfaces. *Trichoconis padwickii* and *Nigrospora* may belong to the former category while *Helminthosporium*, *Alternaria*, and *Curvularia* may belong to the latter category. It may not, however, be correct to assign anyone of the above species exclusively to one category, since spores of all these organisms were present in numbers in the forenoon and also in the afternoon, eventhough the highest spore load occurred in the forenoon or afternoon. It is therefore likely that both the mechanisms of spore liberation suggested by Hirst may be present in all the five species though in each species one of the mechanisms may be predominant. The gill fungi are considered to have a definite discharge mechanism of their spores which are known to depend on wind only for dissemination but not for liberation. The night maxima observed in the case of yellow coloured basidiospores may be attributable to the desposition of free water as a result of precipitation which occurs during night time.

Rain was found to influence on the spore load of *P. oryzae* and basidiomycetes on the day after the rain. The spore load of these fungi on the day following rain were comparatively high. This can be due to the favourable conditions provided by rain for the production of greater number of spores in *Piricularia* and for the maturity of the fruit body in the gill bearing fungus.

A correlation was noted between the periods of high spore load of *P. oryzae* and severity of infection by this organism. Heavy infection usually followed a period of high spore load. The three varieties of rice behaved differently with reference to the infection under identical conditions. While the most susceptible variety succumbed to the infection the other two varieties survived.

SUMMARY

S U M M A R Y

Air spora over the rice crop was studied during two seasons using the Hirst automatic volumetric spore trap. Blast, Helminthosporium leaf spot and stackburn diseases were present in both crops.

A large variety of fungal spores and also pollen grains were usually seen on the trap slides. But the present study was confined to seven easily identifiable spore forms which are considered to belong to Piricularia oryzae, Trichoconis padwickii, Helminthosporium spp., Alternaria spp., Curvularia spp., Nigrospora sp. and basidiomycete.

All the spore forms exhibited a definite pattern of seasonal and diurnal periodicity in their occurrence. Spores of P. oryzae were more abundant during November and December in the first crop season than during February to May in the second crop season. No spores were present during May. The spores of Trichoconis padwickii, Helminthosporium spp., Curvularia spp. and of the basidiomycetes were abundant during November December, April and May. Spores of Alternaria spp. and Nigrospora sp. were abundant during December, January, March and April. The spores of all these organisms

except those of the basidiomycetes were present in smaller numbers during the other months also.

Spores of P.oryzae showed "night maxima" during November and December; the highest spore load occurring around 02.00 hrs. A shift in the 'nocturnal pattern' of diurnal periodicity to a 'forenoon pattern' was noted in this organism during the second crop season, the peak spore load occurring around 09.00 hrs. It is considered likely that this shift was brought about by changes in humidity and temperature.

Spores of basidiomycete showed night maxima and those of Trichoconis padwickii, Helminthosporium spp, Curvularia spp., Alternaria spp., and Nigrospora sp. showed 'day maxima' throughout. Trichoconis padwickii and Nigrospora sp. showed a forenoon pattern of spore dispersal while Helminthosporium spp., Curvularia spp., and Alternaria spp. showed an 'afternoon pattern'.

It is inferred that an active mechanism of spore liberation is present in P.oryzae, Trichoconis padwickii and Nigrospora. While in Helminthosporium spp., Curvularia spp and Alternaria spp. which have got an "afternoon" pattern of dispersal the spores are passively dispersed.

The dispersal of spores of *P. oryzae* appears to be governed by low temperature, high humidity and free moisture. The spore loads of *Piricularia oryzae* and of the basidiomycete were comparatively higher on days following rain.

A correlation was noted between the periods of high spore load of *P. oryzae* and severity of infection in this organism. Heavy infection usually followed a period of high spore load. Three varieties of rice were used in the present studies and these behaved differently with regard to severity of infection under identical conditions. While the most susceptible variety ADT-27 succumbed to the infection, the other two varieties namely, Kaohsiung-18 and Tainan-3 survived.

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