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PATHOGEOGRAPHIC STUDIES OF SUGARCANE DOWNY MILDEW IN TAIWAN IV. A COMPARISON OF CLIMATIC CONDITIONS IN FOUR PATHOGEOGRAPHIC REGIONS AND A STUDY ON THE RELATIONSHIP OF CLIMATIC FACTORS AND DISEASE ON DIFFERENT VARIETIES

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摘　　要

潘崇儀[1]、呂理榮[2]、劉清[3] (1982)　臺灣甘蔗露菌病病害地理之研究Ⅳ病害地理區域氣象因子之比較及品種發病與氣象因子之關係　植保會刊 24：121～129　(1.國科會生物組。現通訊地址：美國夏威夷東西文化中心資源系統研究所。2.臺灣植物保護中心植物病理組。3.農業試驗所農藝系。)

虎尾（偶發病區）、新營（主要受害地區）、屏東（邊際受害地區）及臺中（非流行病區）等糖廠區域自 1965 至 1978 年氣象條件之比較顯示：(1)各區之氣象因子之年平均或各月份之氣象相大致相似。(2)病害與氣象之變遷並不吻合。(3)根據歷年資料之定性分析，初期發病月份之氣象趨勢亦與常年無太大偏差。(4)相關分析之結果顯示，F160品種之發病似與日照量有關，而 F155 之發病則與溫度高低及低濕度有關。因爲露菌對氣象因子極爲敏感，故從大氣象資料無法洞測氣象因子與發病之關係，微氣象與發病之關係較爲密切，而且露菌病寄主因子可能較氣象因子爲重要。

(關鍵字：氣象因子，病害地理區域，品種發病情形。)

ABSTRACT

The climatic conditions of four pathogeographic regions of sugarcane downy mildew as represented by Huwey (sporadic region), Hsinying (main damage region), Pingtung (marginal damage region) and Taichung (nonepidemic region) were compared. No striking difference in the annual means of different climatic factors and the climatic patterns for the different months can be identified to account for the difference in disease intensities in the pathogeographic regions.

The dynamic disease patterns of the period studied (1965-1978) does not correspond to the dynamic of climatic conditions. In a qualitative analysis of the records, none of the weather variables of the four months (the disease onset period) studied can be used to distinguish epidemic and nonepidemic years and no distinct climatic trend can be found in epidemic years that deviate from the climatic conditions of normal years. Quantitative analysis of the relationship between infection on F160 and F155 and climatic factors in Pingtung was conducted. Disease on F160 appeared to be associated with the amount of sunshine while high temperature and low humidity appeared to be associated with lower level of disease on F155. Failure to identify the relationship between climate and disease was attributed to the irrelevancy of macroclimatic data since the downy mildew pathogen is highly sensitive to microenvironment which is crucial to disease development. It is also suggested that host factor may play a more important role other than the climatic factors in the sugarcane downy mildew disease.

(Key words: climatic factors, pathogeographic regions, varietal infection)

INTRODUCTION

Epidemiological studies on the relationship of climate and disease have led to formulation of predictive systems which can forecast the occurrence of infection or disease, facilitating effective disease management. There are two major approaches to epidemiological studies and disease prediction: namely empirical and fundamental. Empirical or deductive systems focus on studying and comparing records of disease occurrence and concurrent weather conditions in the same or approximate locality. Fundamental, inductive or logical systems are those developed from data obtained experimentally in the laboratory or field regarding the relationships of biological and environmental conditions governing the host-pathogen interactions.[6] Most studies adopt the fundamental approach because of the unreliability of the records. However such records may serve to identify the general trend. The empirical approach is adopted here. Weltzien claimed that "the causes of the distribution patterns of disease can only be found in environmental factors".[18] Ecological and climatological mapping of the limits of favorable temperature, moisture and soil conditions for host and pathogen and of the occurrence of alternative hosts and reservoirs are usually conducted to characterize the pathogeographic regions. The sugarcane growing regions in Taiwan were classified into four pathogeographic regions based on records in another paper.[11] The objective of this paper is to compare the climatic conditions of four pathogeographic regions as represented by Huwey (sporadic region), Hsingying (main damage region), Pingtung (marginal damage) and Taichung (nonepidemic region) sugar factory districts and to identify the weather variables associated with disease incidence in those regions by means of climatograms, qualitative and

quantitative analysis of historical disease records and macroclimatic data. The approach and methods used are similar to those described below in other disease systems.

By means of climatograms, regional comparisons of climatic conditions in regions of varying disease intensity have been conducted in citrus blast and blackpit disease in Florida, Israel and California,[4] apple scab in different locations in the state of Washington,[1] and sugarbeet powdery mildew in different disease zones of Germany.[17] Diagrams of dynamics of disease and climatic conditions in different locations are also informative for regional characterization. Analysis of disease records and of January temperature at five locations in the southeastern region of U.S. showed that yearly fluctuations in the intensity of tobacco blue mold disease followed closely the deviation from the normal of January temperature for the years 1931 through 1949[9,10]. Qualitative analysis of the relationships between climate and disease is useful for identifying distinct trends if they exist. Under the assumption that fire blight epidemics are induced by subsequent weeks, qualitative analysis of 75 years data from both Southern San Joaquin Valley and Sacramento Delta showed a direct correlation between these criteria and a high incidence of fire blight.[18] In another study which is based on past disease records and weather data of over 38 years, the weather variables, temperature and rainfall, of epidemic and nonepidemic years for oat crown rust were compared and attributes distinguishing epidemic and nonepidemic years were identified.[14] Correlation analysis has been commonly employed for quantitative analysis of the relationship of disease and climatic factors. Epidemiological studies have been carried out to identify the meteorological variables that relate virus disease incidence on pepper in Niagara Peninsula. Good correlations were found with degree days, bright sunshine hours in April and a combination of the two preceding factors and virus disease incidence.[5] Similar studies were conducted on the epidemiology of tomato buckeye rot. The correlation between disease incidence and prevailing meteorological conditions was studied. It was found that rainfall and temperature were the main factors involved in the causation of the disease.[15]

MATERIALS AND METHODS

The period studied in this paper extends from 1965 to 1978 including Taichung, Huwey, Hsinying and Pingtung sugar factory districts. Data on disease and planting acreages of the different sugar factory districts were obtained from Taiwan Sugar Corporation. Only Taiwan Sugar Corporation farms were considered, contract farms were not considered because the sugarcane plantings in these farms fluctuate from year to year. Disease intensity is computed in terms of total infection per cent in all four districts and infection per cent of F155 and F160 in Pingtung. (Infection per cent = disease acreage/planting acreage × 100). Pingtung was selected for further characterization because of the distinct difference in disease intensity between epidemic and nonepidemic years which seem to indicate that climate may be the determining factors of disease intensity in the region. Weather data of meteorological stations located at

the sugar factory were obtained from the Laboratory of Agricultural Meteorology, Department of Agronomy, Sugar Research Institute. The weather variables studied were sunshine (hours), relative humidity, temperature (minimum, maximum and average), and rainfall (amount and duration). Comparative studies were conducted on the climatic conditions of the different pathogeographic regions by sketching climatograms of the following: 1) the annual means (cumulative averages of the past years), 2) monthly means (cumulative averages of the past years), 3) annual means (from 1965-1978). Qualitative and quantitative analysis were conducted on weather data of March, April, June and July from 1965-1978. Those four months were chosen because they are the months of disease onset, the weather conditions of the latter months do not seem to affect disease intensity of the year significantly. The weather data were classified in the following categories: sunshine hours (number of days with 0-3, 4-7 and 8-11 hours), maximum temperature (number of days with temperature ranging from 9-14, 15-20, 21-26, 27-32 and above 33°C), rainfall (number of days with total amount of rainfall in the following categories: trace-5.0, 5.1-10.0, 10.1-20.0, 20.1-30.0, 30.1-50.0, 50.1-100.0, and above 100 mm), and the (number of times where rain falls for 1 day or consecutively for 2, 3-4, 5-7, and 8-14 days). In the qualitative analysis, climatic conditions in epidemic years from normal years were examined. In the quantitative analysis, correlation coefficients of variety infection per cent and the weather variables were calculated.

RESULTS

Climatograms

There is no significant difference in the annual means (cumulative averages) of the climatic factors in the different regions except for sunshine and rainfall (Table 1). The sunshine duration is longest in Taichung (this might be less favorable for disease), similar in Pingtung and Huwey, and shortest in Hsinying. Rainfall is particularly abundant in Pingtung, less but similar in the other regions. It has been proved that heavy rain inhibit-

Table 1. Annual means (cumulative averages of over 20 years) of the climatic factors, sunshine, relative humidity, temperature and precipitation in the four pathogeographic regions.

Climatic factors	Pathogeographic regions			
	Taichung	Huwey	Hsinying	Pingtung
Sunshine duration (hours)	2219.3	2058.4	1904.0	2049.2
Relative humidity (%)	82	79	79	83
Average temperature (°C)	22.4	22.1	23.3	24.2
Maximum temperature (°C)	27.1	27.2	28.8	30.0
Minimum temperature (°C)	18.8	18.5	19.3	19.9
Amount of precipitation (mm)	1511.0	1417.0	1670.0	2343.7
Number of days with precipitation	83	93	87	118

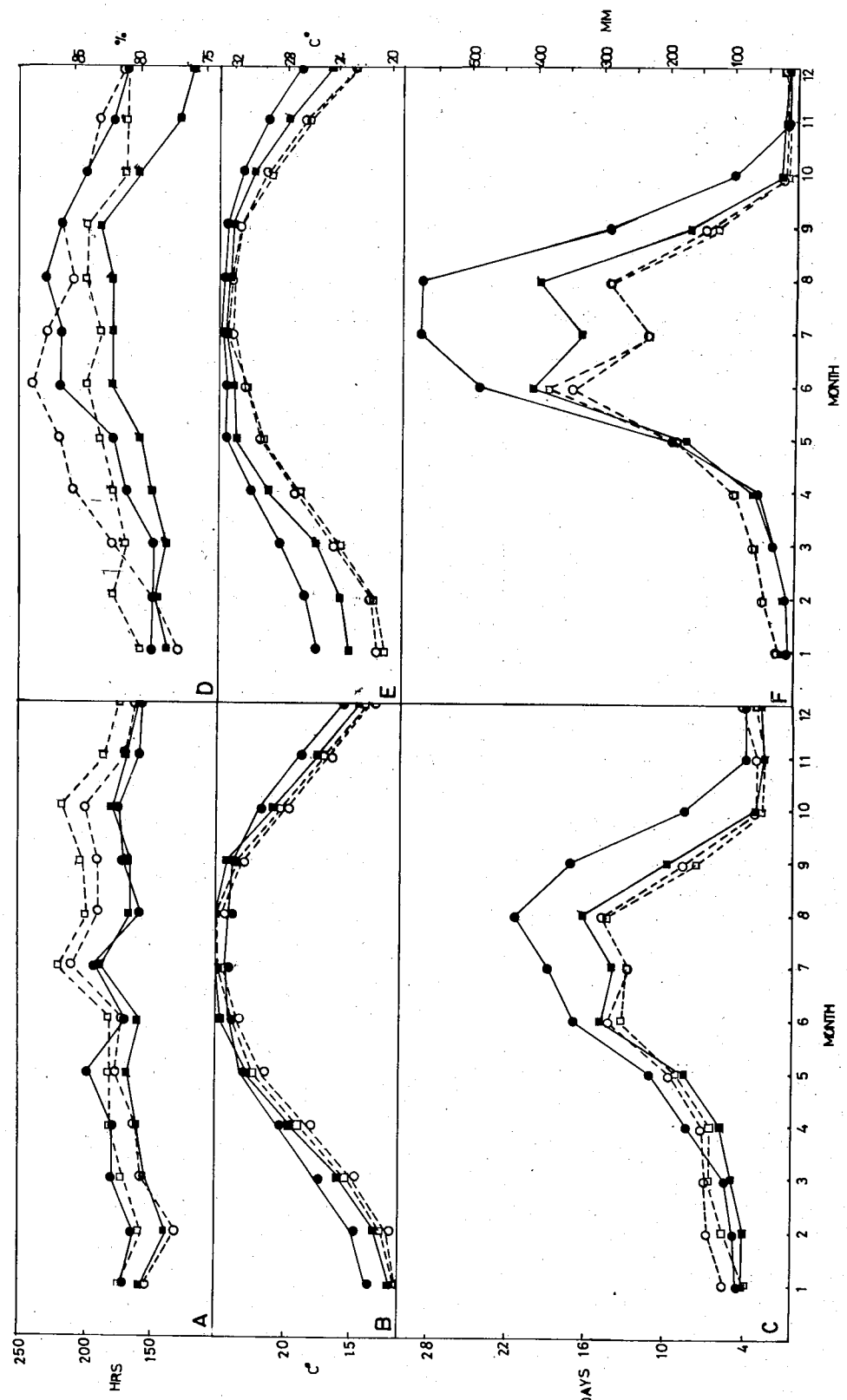


Fig. 1. The distribution patterns of various climatic factors for different months in four pathogeographic regions. A. sunshine (monthly total), B. minimum temperature (monthly mean), C. days with precipitation (monthly total), D. relative humidity (monthly mean), E. maximum temperature (monthly mean), F. amount of precipitation (monthly total). All values are cumulative averages of over 20 years. Taichung, ■; Huwey, □; Hsinying, ○; Pingtung, ●.

ed sporulation.[7] This might partly account for lower disease intensity in Pingtung as compared to Hsinying despite of its more favorable climatic conditions. The distribution patterns of various climatic factors for the different months in the four pathogeographic regions are very similar (Fig. 1). During the period studied from 1965-1978, the dynamic disease pattern does not correspond to the dynamic of climatic conditions (Fig. 2). Nor can one explain the pathogeographic classification of the four rgions in accord with their climatic patterns except for temperature. However the limited difference in temperature of the different regions do not warrant a logical explanation.

Qualitative analysis

None of the weather variabies studied

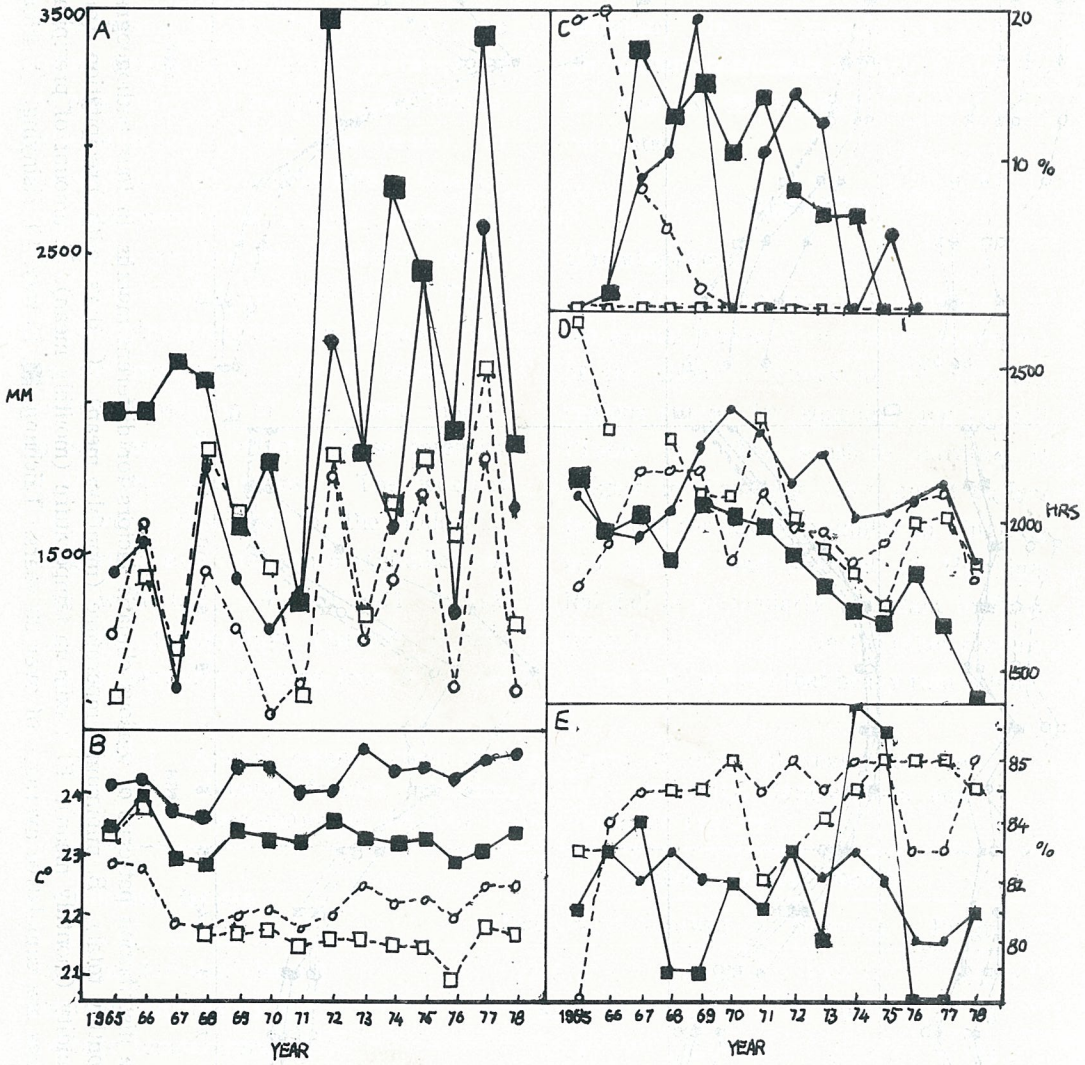


Fig. 2. The disease and climatic patterns of four pathogeographic regions from 1965-1978. A. amount of precipitation (annual total), B. mean temperature (annual mean), C. infection%, D. sunshine (annual total), E. relative humidity (annual mean). Taichung, ●; Huwey, ○; Hsinying, □, Pingtung, ■.

can be used to distinguish epidemic and nonepidemic years and no distinct climatic trend can be found between epidemic and normal years.

Quantititave analysis

1. The relationship between infection on F160 and climatic factors in Pingtung:

No meaningful relationship seems to exist between F160 infection and the climatic factors studied except for sunshine. There is a negative tendency for the relationship between number of days with 0-3 hours sunshine and disease intensity on F160. Disease is less severe when there are many days with limited sunshine. This can be explained by the light requirement for plant growth which in turn provides better host tissue for infection. There is significant positive correlation ($r=0.53$) and the number of days with 8-11 hours of sunshine ($r=-0.55$) in May correlate fairly well with disease. This may indicate that a certain amout of light is required for good sporulation but excessive light is inhibitory and thereby affecting disease development. This agrees well with findings in literature which suggests that high light intensity and long duration of light exposure my be inhibitory to sporulation, but a minimal amount of light is required.[2,8,16] The effect of sunshine on host growth should also be taken into consideration since F160 is a fast growing variety at early planting stage, therefore ample sunshine for photosynthesis is essential.

2. The relationship between infection on F155 and climatic factors in Pingtung:

Negative relationship exists between disease on F155 and the number of days with relative humidity below 75% in March, April, May, June and their sum. This suggests that relative humidity below 75% is unfavorable for disease. Although laboratory studies on corn and sugarcane have found 86% to be the minimal relative humidity required,[19] on atmospheric relative humidity of 75% in the field may in reality be much higher in sugarcane due to the canopy effect. Also irrigation is not required for F155, the relative humidity in the sugarcane canopy would be lower than the irrigated fields, therefore the atmospheric relative humidity would be a limiting factor for the proliferation of the downy mildew pathogen. A negative tendency also seems to exist for disease on F155 and the number of days above 33°C and 27~32°C in March, April, May and June. This indicates that high temperature is unfavorable for disease. In literature, it was reported that above 31°C, germination and sporulation of the downy mildew pathogen is restricted.[3,19] However, the microclimatic conditions may be different, temperature in the canopy is different from the atmospheric temperature. No other meaningful relationship was found with other climatic conditions.

DISCUSSION

The epidemic and nonepidemic years in different pathogeographic regions cannot be distinguished by means of the climatic criteria studied. Failure to find good association of disease and climatic factors lead one to consider the possibility that climatic factors play secondary role in promoting epidemics of this disease and host factors may play a more important role since good correlation was found with some host factors and disease incidence as reported in another paper.[12]

Better associations may be found by selecting different climatic criteria or adopting a different classification system of the weather data. It is also likely that 14 years of data may not be adequate to unveil meaningful relationships of climate and disease since great climatic variation from year to year is common. The downy mildew pathogen is very sensitive to the environmental fluctuation, therefore macroclimatic data may be unable to reveal the true relationship. The selection of climatic criteria in this paper was based on laboratory studies of the fungus itself or greenhouse studies of the individual plants. The situation is quite different in the field because the microenvironment in the plant population may be distinctly different from that of the individual plant. The macroclimatic data need to be transformed in the proper way to simulate microclimatic conditions. However, fundamental as well as empirical studies should be conducted in the laboratory, the greenhouse and the field. It is suggested that future direction of research on the downy mildew disease should be focused on the microenvironment of the crop in the field and its relationship to disease. Although no conclusive evidence has been obtained with the relationship of disease on different varieties and climatic conditions, the results do indicate that the effect of climatic factors on resistance as well as on pathogen development vary with different varieties. Disease on F160 appeared to be associated with the amount of sunshine while high temperature and low humidity appeared to be associated with lower level of disease on F155, this is probably due to the difference in agronomic characteristics of the two varieties.

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