植保會刊 24：111～119 (1982)
Plant Prot. Bull. (Taiwan, R.O.C.) 24：111～119 (1982)

PATHOGEOGRAPHIC STUDIES OF SUGARCANE DOWNY MILDEW IN TAIWAN III. A COMPARATIVE STUDY OF VARIETAL DISEASE PATTERNS IN THREE PATHOGEOGRAPHIC REGIONS

E. S. Poon[1], L. S. Leu[2], and C. Liu[3]

1. Formerly with National Science Council, ROC, Present address: Resource Systems Institute, East-West Center, Honolulu, Hawaii USA.
2. Plant Protection Center, Taiwan, Wufeng, Taiwan, ROC.
3. Department of Agronomy, Taiwan Agricultural Research Institute, Taichung, Taiwan, ROC.

(Accepted for publication: June 8, 1982)

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Ⅲ病害地理區域甘蔗發病情形之比較 植保會刊 24：111～119. (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)

取自臺糖公司 1965 至 1978 年來之病害調查資料，比較三個不同病害地理區域即虎尾（偶發病區）、新營（主要受害區）及屏東（邊際受害區），其中七個主要甘蔗品種 (F155, F156, F146, F160, F161, F167 及 NCo310) 之露菌病發病情形。根據歷年發病資料估計之品種抗感病等級，大致與田間試驗測定之結果相等。F155 極爲感病。F156, F161 及 F146 均爲抗病，影響各品種發病之主因似爲該品種所佔之栽種百分比，其他因子如助長發病之品種栽種百分比，潛在之發病源、品種之感病性及環境可能亦有影響。各區之 F160, F167 及 NCo310 之發病情形不一。該等品種之發病主要可能受環境影響，各品種及助長發病品種之栽種百分比亦有影響，故推測影響各區發病情形之主因大致如下：(1)虎尾：助長發病之寄主組織及潛在感染源之多寡；(2)新營：品種之栽種百分比；(3)屏東：環境因子。

（關鍵字：品種發病相，病害地理區域。）

ABSTRACT

The downy mildew disease patterns of 7 major sugarcane varieties in 3 pathogeographic regions were compared based upon the disease survey records from 1965-1978. The varieties studied were F155, F156, F146, F160, F161, F167 and NCo310. The regions compared were Huwey (a region of sporadic occurence), Hsinying (a region of severe disease) and Pingtung (a region of

marginal damage). The attributes to disease development pattern considered are the amount of disease-conducive varieties which determines an infection spectrum as well as the inoculum source in the population. Susceptibiliy and resistance of the variety are conditioned by environmental influence in the different regions. It was found the susceptibility rating of varieties based on historical records was similar to that based on field testing. F155 was found highly susceptible. F156, F161 and F146 were found resistant. The primary factor associated with disease on these varieties appeared to be per cent of the planted area. Other factors such as per cent of disease conducive varieties planted, potential inoculum, susceptibility of the variety and environment may play secondary role. Infection of F160, F167 and NCo310 in the different regions varied. It is speculated that disease intensity on these varieties depend on environment, while per cent of the variety planted and per cent of disease-conducive varieties planted were secondary factors. The primary factors associated with variety infection in Huwey was the availability of disease-conducive variety and potential inoculum; in Hsinying, the per cent of the variety planted; and in Pingtung, environment seemed to play the primary role.

(Key words: varietal disease patterns, pathogeographic regions.)

INTRODUCTION

The disease dynamics of sugarcane downy mildew has been reported to be affected by varietal change,[1] but the reason for such an association has not been closely examined. A change in varietal composition of wheat throughout the Indo-Gangetic plain has been reported to delay and lessen development of brown and yellow rust. The change was speculated to reduce the amount of oversummering inoculum in the hills, to reduce the chance of the same race spreading from the northeastern to the northwestern zone and thereby delaying or preventing epidemic development, and to decrease the number of primary infection centers present in the eastern region owing to changes in the cultivar distribution resulting in less disease development.[2] There is limited information on the races or biotypes of downy mildews in sugarcane, corn and sorgum. Comparative virulence and gross morphology of isolates of *Sclerospora philippinensis* Weston on corn has been examined,[4] but no studies on virulence has been conducted on the sugarcane downy mildew pathogen in Taiwan. Therefore, under the present circumstances, it is not possible to explain disease dynamics in terms of a change in race composition due to the selection pressure exerted by varietal shifts. However the explanation offered by inoculum and infection center is worth considering. In another paper,[3] it was found that per cent of disease conducive sugarcane varieties planted of the disease potential index of the sugarcane population are closely associated with disease intensiy in the region. Percent of disease conducive varieties planted is an indicator of the amount of disease conducive host

tissue available for the propagation and proliferation of the pathogen whereas the disease potential index is an indicator of both the susceptibilty of the variety planted and the amount of disease conducive host tissue available. However both attributes are cumulative values of the entire host population. In this paper, the authors examine further the attributes of the components of the population, in terms of 7 major varieties (F155, F156, F146, F160, F161, F167 and NCo310) on which disease surveys records have been kept for 14 years in 3 pathogeographic regions, namely, Huwey (area of sporadic attack), Hsinying (area of main damage) and Pingtung (area of marginal damage). The attributes considered are the amount of disease conducive sugarcane host tissue available in the region, which determines the variety infection spectrum as well as the inoculum in the population; and the susceptibility and resistance of the variety as conditioned by environmental influence in the different pathogeographic regions. A subjective evaluation of the factors most closely associated with disease on the variety in different locations is also attempted.

MATERIALS AND METHODS

Data on disease acreage of variety and their total planting acreage from 1965 -1978 were obtained from the Division of Agricultural Technology, Taiwan Sugar Corporation. Only Taiwan Sugar Corporation farms were considered, contract farms were not considered because of the great fluctuation in sugarcane planting in those farms from year to year. Cumulative annunal means of 14 years data in Huwey, Hsinying and Pingtung were computed for the following: per cent of varietal infection (variety disease acreage/variety planting acreage), percent of total infection (total disease acreage / total planting acreage), per cent of total infection of the variety (variety disease acreage/total disease acreage), disease conducive index (per cent of total infection of the variety/per cent of total planting acreage of the variety), per cent of the variety planted (variety planting acreage/total planting acreage) and potential inoculum source (sum total of infection per cent of varieties in the region other than the variety in question). Correlation analysis was conducted to determine the association of the data collected.

RESULTS

Infection patterns of varieties in different regions

Fig. 1 shows the infection per cent of the major disease conducive varieties in three pathogeographic regions. The major varieties infected with downy mildew were F156, F146 and F155 during 1965-1970. Infection on F146 was mild and also less severe on the other two varieties when compared to infection of the same varieties in Hsinying and Pingtung. The predominant varieties infected in Hsinying were F155 and F160. There was also considerable infection on F161, F167 and F146 when compared to infection of those varieties in other regions. F155 and F160 were the predominant varieties infected in Pingtung. Infection was severe on F155, but mild on other varieties. Comparison of different regions indicates that varieties planted in Hsinying were most conducive to disease, Pingtung was next and Huwey least.

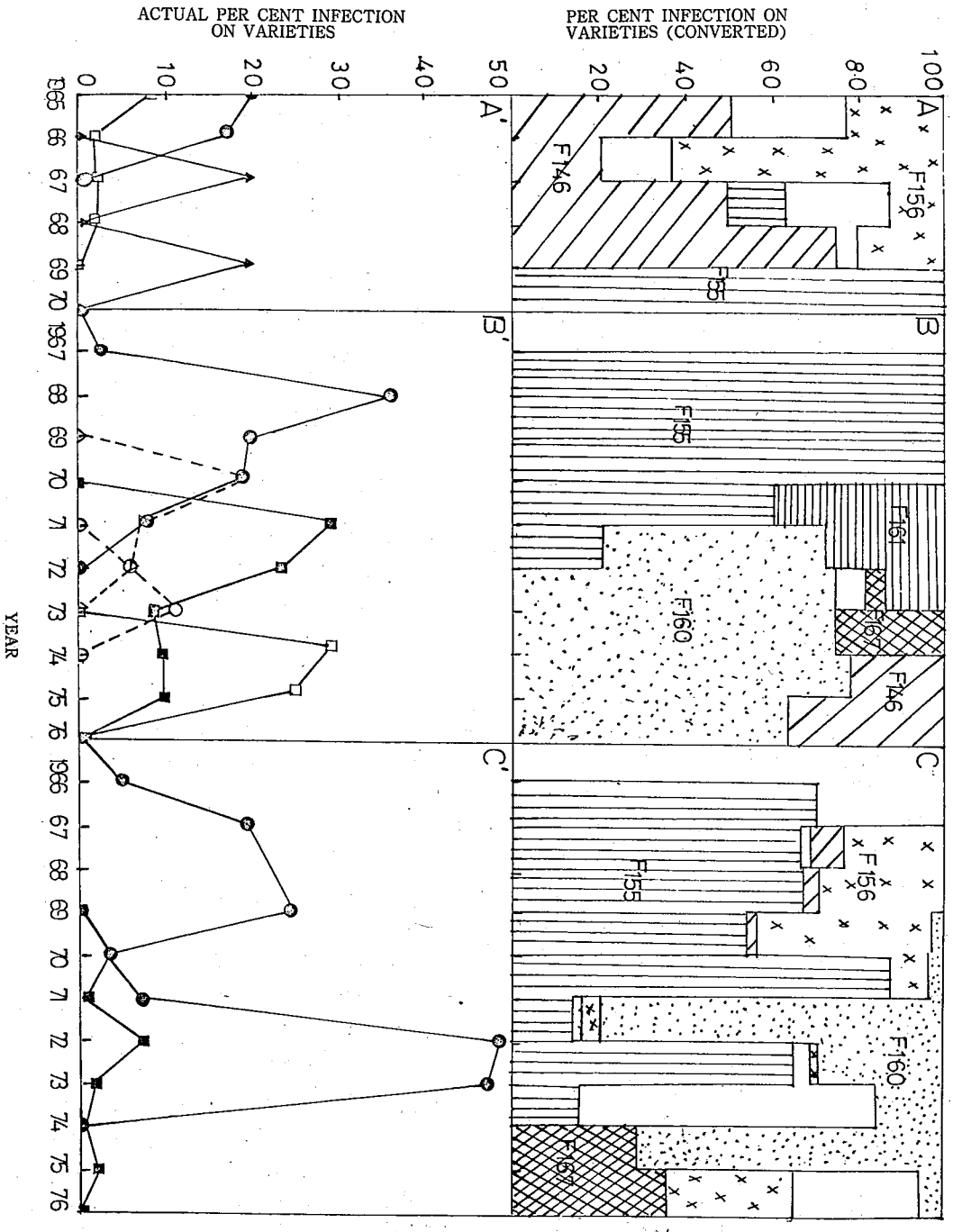


Fig. 1. Per cent infection of major infected sugarcane varieties in different regions from 1965-76. A-C, per cent infection on varieties (converted); A′-C′, actual per cent infection on varieties; A, A′, Huwey; B, B′, Hsinying, C, C′, Pingtung. F155 □, ●; F156 □, ▲; F160 □, ■; F161 □, △; F167 □, ○; F146 □, □. Other disease conducive varieties or in total or the year of 1966 and 1965 in Hsinying and Pingtung, respectively, in which varieties were not recorded are shown with blank.

Table 1. A comparison of variety infection and variety composition in three pathogeographic regions.[a)]

Pathogeographic regions	Disease conducive varieties in total	Major varieties						
		F155	F156	F160	F161	F167	F146	NCo310
HUWEY[b)]								
Planting acreage (ha)	798.31	—	—	—	—	—	—	—
Infection %	0.99	2.87	2.80	0	0	0	1.086	0.0033
Disease conducive index[c)]	—	13.8	10.58	0	0	0	0.72	0.32
% planted	47.93	0.58	14.47	26.87	0.061	13.91	19.59	4.046
HSINYING[d)]								
Planting acreage (ha)	380.56	—	—	—	—	—	—	—
Infection %	6.56	6.11	0	5.72	2.34	1.20	3.86	0
Disease conducive index	—	1.73	0	1.00	0.62	0.44	0.17	0
% planted	78.30	15.77	0.67	24.70	9.37	4.79	23.77	5.049
PINGTUNG[•)]								
Planting acreage (ha)	2609.35	—	—	—	—	—	—	—
Infection %	1.48	12.74	0.51	1.22	0	0.38	0.66	0
Disease conducive index	—	8.52	0.25	0.75	0	0.88	0.42	0
% planted	75.93	3.71	35.21	9.32	0.00086	5.45	1.99	10.77

[a)] All values are cumulative annual means of 14 years (1965—1978).

[b)] Sporadic region.

[c)] Per cent of total infection/per cent of total planting acreage.

[d)] Main damage region.

[•)] Marginal damage region.

Among varieties F155 was the most intense in all three regions, F160 was next and in decreasing order of F146, F156, F161 and F167. Table 1 shows the cumulative annual means of the infection per cent, disease conducive index and the per cent of the 7 varieties in the sugarcane population in the 3 regions. Huwey was characterized as sporadic region with disease-conducive varieties constituted only half of the total population. Hsinying was characterized as main damage region although less acreages of disease-conducive varieties in total but they still constituted over two-thirds of the total population. Pingtung was characterized as marginal damage region with large acreage of disease conducive sugarcane varieties which constituted also about two-thirds of the total population. In Huwey, F155 was severely infected, F156 also showed relatively high infection per cent due to high per cent of the variety planted. On F160 and F167 no infection occurred even high per cent of the varieties was planted. Limited infection of NCo310 was probably due to its resistance and relatively small acreage. In Hsinying, there were considerable infection on both F155 and F160 due to their large per cent acreage. No

infection on NCo310 and low disease intensity on F156 was probably due to their small acreage. Limited infection on F161 and F167 was probably due to their high resistance and low per cent planted. However infection on F146 was limited even though large per cent was planted, probably due to its high resistance. In Pingtung, F155 was severely infected and F160 was infected probably due to the susceptibility of the former and the relatively large planting acreage of both varieties. Limited infection occurred on F156 even though large per cent was planted. Infection on F167 and F146 were limited due to limited per cent planted. No infection occurred on NCo310 even though large per cent was planted, while extremly small per cent of F161 planted probably account for its zero disease record.

Correlation analysis of 14 years data on the variety infection and per cent of the variety planted, per cent of disease conducive varieties planted in total and potential inoculum which is represented by the infection per cent on varieties (Table 2). Good correlation was found with disease and disease conducive index on all varieties in all three regions except for F155 in Hsinying. One possible explanation is that F155 was susceptible and

Table 2. Correlation coefficients of infection per cent and other varietal attributes (disease conducive index, availability of host tissue and potential inoculum index) of major varieties in three pathogeographic regions.

Location	Major varieties						
	F155	F156	F160	F161	F167	F146	NCo310
HUWEY							
Disease conducive index	0.79***	0.99***	—	—	—	0.84***	0.98***
% planted a)	0.49	0.48	—	—	—	0.56*	0.46
b)	0.56*	−0.04	—	—	—	0.44	0.66**
Potential inoculum index[a)]	−0.11	0.10	—	—	—	0.62*	0.64*
HSINYING							
Disease conducive index	0.37	—	0.96***	0.98***	0.97***	0.99***	—
% planted a)	0.53*	—	0.38	0.40	0.27	0.06	—
b)	0.87***	—	0.29	0.78***	0.45	−0.30	—
Potential inoculum source	−0.19	—	0.14	0.22	0.03	−0.14	—
PINGTUNG							
Disease conducive index	0.52*	0.86***	0.79***	—	0.72***	0.97***	—
% planted a)	0.50*	0.38	0.40	—	0.18	0.22	—
b)	0.46	0.22	0.30	—	0.35	0.27	—
Potential inoculum index	0.37	0.54	0.23	—	0.08	0.22	—

*** Significant at 0.001 level, ** Significant at 0.01 level, * Significant at 0.1 level.

a) Per cent of the variety planted.

b) Per cent of disease conducive varieties planted in total.

[a)] Sum of infection per cent of varieties other than the variety in question.

inoculum source was readily available in Hsinying area due to corn interplanting, and that the limiting factor in this region was the per cent of disease conducive varieties in the sugarcane population and the per cent of variety planted instead of its susceptibility. In Huwey, good correlation was found with disease on F155 and per cent of the variety planted; disease on F146 and per cent of disease conducive varieties planted as well as the per cent of the variety planted, disease on F161 and per cent of the variety planted. In Pingtung area, good correlation was found with disease on F156 and potential inoculum index.

DISCUSSIONS

Taking into account the above results and the original data, varietal susceptibility and factors closely associated with variety infection in the 3 pathogeographic regions were speculated and summarized (Table 3). The susceptibility rating of varieties based on 14 years records and on field testing in the Nantou downy mlidew disease nursery is agreeable. This shows the present system for evaluating downy mildew resistance is reliable. High disease intensity on the variety F155 in all 3 regions can be accounted for by its susceptibility. However in Hsinying, per

Table 3. Factors closely associated with variety infection in three pathogeographic regions.

	Major varieties						
	F155	F156	F160	F161	F167	F146	NCo310
Susceptibility rating[a)]							
A.	S	R	R	R	HR	HR	R
B.	S	R	MS-R	R	R-HR	R	HR-R
Key factors in different regions							
Huwey	S	V,SH,I	S	V	S	S,SH	S,I
Hsinying	S,SH	V	S,V	S,V	V	V	S
Pingtung	S	S,V	S,V	V	S,V	S,V	S
Overall key factors[b)]							
Primary	S	V	E	V	E	V	E
Secondary	V	SH,I,E	S,V	S	V,S	E	S,V,I

[a)] S, susceptible, MS, mildly susceptible, R, resistant, HR, highly resistant, A. Field test rating, B. based on disease-conducive index and planting acreage calculated from 14 years records in different regions. (Mean index of 1.5 or above is considered susceptible; 1.0 or above, moderately susceptible; 0.5 or above, mildly susceptible; above 0, resistant; 0, highly resistant). If a variety is mildly infected in region where low planting acreage, it is considered mildly susceptible. A variety is considered susceptible when infection occurred regardless of whether high or low acreage of the variety is planted.

[b)] Infection level of the variety associated with the following factors; S=susceptibility of the variety, V=per cent of the variety planted, SH=per cent of disease conducive varieties planted, I=potential inoculum source, E=environment.

cent of disease conducive varieties planted and the per cent of the variety planted also affect disease intensity on the variety. Infection on F160 was reported in both Hsinying and Pingtung, but not in Huwey where the variety composed as high as around 20% of the total population. Therefore different environmental conditions in the 3 regions result in different degrees of susceptibility of F160. According to field testing, F160, F156 and F161 were rated as resistant. F161 constituted negligible proportion of the sugarcane population planted in Huwey and Pingtung, but some disease occurred on the limited proportion of the variety planted in Hsinying; so disease on F161 seems to be affected by the per cent of the variety planted. Disease on F156 appeared to be less intense than F160. As in the case of F161, the per cent of the variety planted affected disease intensity on F156. F146 was rated as highly resistant according to field testing, but when large per cent of the variety was planted, the disease intensity reached as high a level as on F156. Again per cent of the variety planted appears to be an important factor affecting disease on the variety. F167 was rated as highly resistant in field test, and low level of infection was found on the variety based on records. NCo310 was rated as resistant and no infecton in Hsinying or Pingtung, but very limited infection in Huwey. Therefore the variety NCo310 was generally resistant to the disease but appeared to be conditioned by the environment since the proportion of the variety planted in all 3 regions was similar.

To summarize, F155 was highly susceptible; F156, F161 and F146 were resistant, therefore mild infection was reported on these varieties. The primary factor associated with disease on these varieties appeared to be per cent of the variety planted. Other factors such as per cent of disease-conducive varieties planted, potential inoculum source, susceptibility of the variety and environment may play secondary role. F160, F167 and NCo310 infection in the 3 regions varied, probably depending on environment. Secondary factors affecting disease on these 3 varieties include per cent of the variety planted and per cent of disease conducive varieties planted.

A comparison of the characteristics of the 3 pathogeographic regions in relation to varietal infection pattern indicates that Huwey was characterized by low disease intensity, limited planting acreage of the highly susceptible variety F155 and lower per cent of disease conducive varieties planted. The primary factors associated with variety infection in Huwey was the availability of disease conducive host tissue and potential inoculum source because the common practice of corn interplanting in Hsinying and large sugarcane planting acreage in Pingtung. In general, high per cent of disease-conducive variety was planted in both regions. However proportion of F155 planted in Hsinying was higher than Pingtung. This may partly account for the higher disease intensity in Hsinying. The primary factor associated with disease in Hsinying appeared to be per cent of the variety planted whereas environment seemed to play the primary role in Pingtung because per cent of disease conducive varieties planted and disease potential index in epidemic and nonepidemic years did not

differ greatly. In conclusion, the varietal composition is a major component of the plant pathosystem of the region, therefore the variety planting scheme should be designed according to the pathogeographic history of the region. Varietal response in terms of resistance and susceptibility may vary from region to region, therefore evaluation of varietal resistance in different environments before the release of new variety is essential.

ACKNOWLEDGEMENT

The authors wish to thank Dr. W. H. Hsieh (Taiwan Sugar Research Institute) for his generous assistance and advice in the course of this study, and the Division of Agricultural Technology, Taiwan Sugar Corporation, for providing the requisite data on sugarcane varieties.

This work was supported in part by the National Science Council funds for research and development in science administration for 1980 and 1981.

LITERATURE CITED

1. Chu, H. T. 1960. The dynamics of sugarcane diseases, research and control. Sugar News 36(11) : 16-22. (In Chinese).
2. Nagarajan, S., L. M. Joshi, K. D. Srivastava and D. V. Singh. 1978. Epidemiology of brown and yellow rusts of wheat in North India III. Impact of varietal change. Pl. Dis. Reptr. 62 : 694-698.
3. Poon, E. S., L. S. Leu and C. Liu. 1982. Pathogeographic studies of sugarcane downy mildew in Taiwan II. A preliminary characterization of host factors in four pathogeographic regions. Ann. Phytopathol. Soc. Japan. 48 : 162-168.
4. Titaturn, S. and O. R. Exconde. 1974. Comparative virulence and gross morphology of isolates of *Sclerospora philippinensis* Weston on corn. Philipp. Agr. 58 : 90-104.