RESEARCH ADVANCES IN SUGARCANE DOWNY MILDEW OF CORN IN TAIWAN

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Introduction

Sugarcane downy mildew (DM) of corn *(Zea mays* L.*)*, caused by *Sclerospora sacchari* Miyake, is one of the major DM diseases that pose great threats to corn production in the various parts of Southeast Asia. The disease is of particular importance in Taiwan because it attacks both corn and sugarcane which are widely grown in the same areas in southern Taiwan. Intensive research on sugarcane DM of corn and its control in Taiwan was begun in 1962, following the epiphytotics in 1960 and 1961. Primary emphasis was placed on the development of resistant varieties and on the ecological study of the disease and its pathogen. Most of the research activities were conducted at the Putze Corn Research Center of the Tainan District Agricultural Improvement Station (DAIS). Results of the research have been mostly published in the Report of the Corn Research Center by the Tainan DAIS at 1-2 year intervals and in the Inter-Asian Corn Improvement Workshop proceedings. All the literature pertinent to the disease has also been reviewed by Chang in 1970 and by Sun in 1970 and 1972 (2, 7, 8).

Current Situation of the Disease

The history of sugarcane DM epiphytotics in sugarcane and corn in Taiwan was briefly reviewed in 1972 (8). The outbreaks of the disease in the past have always been associated with the commercial cultivation of susceptible sugarcane varieties. Sugarcane provides the suitable suscept for *S. sacchari* to survive all year and serves as the source of inocula for primary infection of corn which is extensively grown in the diseased areas only during the fall and winter months. Alternately, corn provides the suitable suscept for the pathogen to propagate abundantly, as corn is more readily infected by the pathogen. The conidia produced on corn in turn reinfect the sugarcane seedlings grown around the diseased corn fields.

The latest epiphytotic of sugarcane DM of corn occurred in 1960 following the release of the first high yielding double-cross corn hybrid, Tainan No. 5, [(Oh 43 × Oh 45) × (D × C)], which is extremely susceptible to *S. sacchari.* It reached a disastrous peak in 1964 when 70% of Tainan No. 5 grown in the Chiayi-Tainan area was severely affected. An eradication campaign was launched in 1965 to rogue the infected sugarcane plants and to prohibit the growing of corn in the epiphytotic areas until a resistant variety of corn was developed. Since then, the disease has been rapidly decreasing year after year, primarily as a result of the subsequent release of resistant sugarcane varieties such as F 176 and F 177, as well as resistant corn hybrids Tainan Nos. 8 and 11. Today, the disease has been reduced to such an insignificant low level that it is considered practically controlled. Furthermore, the resistance of sugarcane and corn varieties to the disease has reached such a level that both crops are now even allowed to be intercropped in the same fields.

The release of Tainan No. 8 [(Ph9 DMR × DMR 3a) × (Ph7 × Ph9)] in 1968 first proved that sugarcane DM of corn could be effectively controlled by the use of resistant varieties. This hybrid performed much better than Tainan No. 5 under diseased conditions but yielded 10 to 15% less in disease free areas. Therefore, the variety

did not become popular following its release. On the other hand, another resistant hybrid Tainan No. 11 [(2027-3-5 × Ly 22-4) × (Ph9 DMR × Ame III)], released by the Putze Corn Research Center in 1972, has been most favorably accepted by the farmers in the past 5 years because the variety is not only highly resistant to *S. sacchari*, but yields 10% more than Tainan No. 5 under disease-free conditions (3). This hybrid has essentially replaced Tainan No. 5 as the leading commercial variety, occupying around 80% of the total area of corn in Taiwan (Table 1).

Table 1. Extension of downy mildew resistant hybrid Tainan No. 11 in Taiwan in 1972-76.

Year	Hectares of corn in Taiwan	Hectares planted to Tainan No. 11	%
1972	25,700	1,600	6.2
1973	30,000	16,000	53.3
1974	38,000	25,000	65.8
1975	48,000	39,200	81.7
1976 (Estimated)	50,000	40,000	80.0

The major defect of using resistant varieties in plant disease control is the possible breakdown of resistance due to a change of virulence in the pathogen. This has happened to many plant diseases, particularly the diseases that are caused by obligate and near-obligate parasites such as cereal rusts and late blight of potato. As *S. sacchari* is an obligate parasite, new virulent races may be expected to occur after the resistant variety Tainan No. 11 is widely grown. However, no breakdown of resistance has been evidenced so far, suggesting either that the resistance is controlled by strong genes or a relatively large number of genes, or that conditions for the establishment of physiologic races are lacking since the disease has a duo host (sugarcane and corn) - pathogen relationship in which any new virulent race produced on one crop may not overcome the resistance on the other. If this is the case, Tainan No. 11 may remain resistant for a longer period than expected.

Parasitism of *Sclerospora sacchari* on Grain Sorghum

The host range of *S. sacchari* in Taiwan has been investigated by several workers. As early as 1911, three gramineous plants — sugarcane *(Saccharum officinarum* L.), corn *(Zea mays* L.) and teosinte *(Euchlaena mexicana* Schrad.) — were reported by Miyake (6) to be infected by *S. sacchari*. The infection of teosinte was verified by Chang and his associates in 1965 (4). In 1966, Chang added gamagrass *(Tripsacum dactyloides* L.) and broomcorn [*Sorghum vulgare* var. *technicum* (Koern.) Jav.] as new hosts of *S. sacchari* (1). Although carefully studied by all of the above workers, grain sorghum *(Sorghum vulgare* Pers.) has never been found to be infected by *S. sacchari* in Taiwan. However, Leece in 1941 (5) reported that sorghum was definitely attacked by *S. sacchari* in Queensland, although only a few plants were found to be infected and conidial production on the diseased leaves was sparse even under extremely favorable climatic conditions. To further investigate the possibility of sorghum as a host of *S. sacchari* in Taiwan, two experiments were conducted at the Putze Corn Research Center in 1975.

In the first experiment, seeds of Taichung No. 3, a sorghum hybrid most widely grown in Taiwan at present, were germinated in large petri dishes (21 cm in diameter) at 25°C in darkness. Two-day-old germlings were artificially inoculated at 25°C in darkness for 48 hours by placing the conidia-bearing sugarcane leaf pieces above the germlings. After inoculation, the germlings were transplanted to box soil and kept in the open (20-30°C) for observation of symptom developments. Diseased plants were recorded and removed daily for 2 weeks. The experiment was repeated three times with four replicates each time. In the second experiment, three varieties of sorghum and eight other gramineous plants, including such host plants as corn, teosinte and broomcorn, were inoculated by the same method and in the same design as described for the first experiment. Results of both experiments are presented in Tables 2 and 3, respectively.

The plumule inoculations revealed that the two-day-old germlings of sorghum were readily infected by *S. sacchari* and the susceptibility differed significantly among different varieties of sorghum (Table 2). The hybrid Taichung No. 1 was highly resistant, Taichung No. 3 moderately susceptible, and the local variety highly susceptible to *S. sacchari* (Table 3). Conidial production was observed on the leaves of all the infected plants. However, conidial production was more abundant on susceptible than on resistant varieties. Similar results were also obtained from broomcorn (Table 3). As expected, corn (Tainan No. 5) and teosinte were highly susceptible. On the other hand, rice, barley, wheat, oat and pearl millet were not infected by *S. sacchari*.

The discovery that sorghum can be infected by *S. sacchari* in Taiwan only through plumule inoculation is interesting. Field infection has never been found in Taiwan although sorghum of both local and hybrid varieties has been extensively grown in the diseased areas of sugarcane DM for years. Moreover, seedling inoculation in the field was also unsuccessful (4, 6). Recently, the writers found that, when sorghum germlings were exposed to light before inoculation, infection was drastically reduced (unpublished). It is, therefore, speculated that the susceptibility of sorghum to *S. sacchari* may be closely related to the photosynthetic activities and the age of the plants.

Pathological Aspects of the Disease

Most research work done on sugarcane DM of corn in Taiwan in the past 15 years has been centered on the development of resistant varieties and on the ecology of the disease and its pathogen, *S. sacchari*, especially those that are related to resistance breeding. Research efforts on resistance breeding have resulted in the release of two highly resistant hybrids, Tainan No. 8 in 1968 and Tainan No. 11 in 1972, for practical field control of the disease. On the other hand, the general features of conidial formation, conidial germination, penetration and infection, and factors affecting their processes, have been extensively studied and, therefore, fairly well understood. Nevertheless, many other pathological aspects of the disease including the mechanism, nature and genetics of resistance, as well as the physiological specialization of *S. sacchari* have not been intensively studied and need further investigation. The following is a list of research subjects on sugar-

Table 2. Susceptibility of sorghum variety Taichung No. 3 to *Sclerospora sacchari* by plumule inoculation.

Test number	treatment[1]	No. of plants tested				Infection%				
		1	2	3	4	1	2	3	4	Av.
I	Inoculated	35	40	51	52	40	43	39	31	38
	Non-inoculated	55				0				0
II	Inoculated	57	44	59	58	26	25	31	33	29
	Non-inoculated	62				0				0
III	Inoculated	61	56	54	65	33	30	33	32	32
	Non-inoculated	70				0				0

[1] The three inoculation tests were conducted on August 16, 23 and 30, 1975, respectively.

Table 3. Susceptibility of some gramineous plants to *Sclerospora sacchari* by plumule inoculaton.

Plant	Variety or origin	No. of plants inoculated[1]			Infection %			
		1	2	3	1	2	3	Av.
Corn	Tainan No.5[2]	80	60	80	0	0	0	0
	Tainan No.5	87	97	93	93	97	95	95
Sorghum	Taichung No.1	180	158	164	5	6	6	6
	Taichung No. 3	213	201	160	24	24	31	26
	Taiwan local	166	158	185	87	88	60	78
Broomcorn	European DW	186	175	190	87	87	81	85
	EXP. 7231	182	172	208	14	14	12	13
	EXP. 7776	76	53	79	38	32	32	34
	Taiwan local	204	146	189	79	84	74	79
Teosinte	U.S.	108	155	101	89	90	85	88
Rice	Tainan No.5	200	150	160	0	0	0	0
Barley	Obidlk	200	150	160	0	0	0	0
Wheat	U.S.	200	150	160	0	0	0	0
Oat	Japan	120	90	100	0	0	0	0
Pearl millet	Taiwan local	240	180	200	0	0	0	0

[1] The three inoculation tests were conducted on October 6, 8 and 11, 1975, respectively.

[2] Non-inoculated control.

cane DM that are either currently undertaken or planned for the near future in Taiwan:

1) Parasitism of *S. sacchari* on grain sorghum (in progress);

2) Culture of *S. sacchari* in tissue culture or on synthetic media (in progress);

3) Nature of resistance to *S. sacchari* in corn and sorghum by means of histochemical techniques (in progress);

4) Physiologic races of *S. sacchari;*

5) Inheritance of DM resistance in corn; and,

6) Establishment of criteria for grading DM resistance.

All the research work listed above is being, or will be, conducted at the Putze Corn Research Center and the Department of Plant Pathology and Entomology of the National Taiwan University.

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