21. A REVIEW ON BREEDING WORK FOR DOWNY MILDEW RESISTANCE IN THAILAND

Sujin JINAHYON*

Sorghum downy mildew of maize incited by *Sclerospora sorghi* Weston and Uppal was found in Thailand in 1968. Introduction of resistant germ plasms from Taiwan, Indonesia and the Philippines through the activity of the Inter-Asian Corn Program was followed in 1969. Extensive testing program suggested that Rogor Syn. 2 and Tainan #10 should be used as "stop-gap" resistant varieties while resistant varieties from the the Philippines would serve as sourses for resistant genes to be transferred into elite local varieties. Aggressive screening and breeding program was not initiated until the rainy season of 1970. In the same year plant pathologists were able to develope a technique to create a uniform artificial epiphytotic condition in the screening nursery.

Genetic studies in the Asian region suggested a polygenic system for resistance to downy mildew. Intensive screening tests were started in Los Baños since 1962. The frequency distribution of the S_1 lines indicated that resistance to *S. philippinensis* is quantitative in nature. The same conclusion was made in the case of resistance to *Sclerophthora rayssiae* in India. Asnani, Handoo and others (1970) indicated a prominent additive type of gene action for the resistance. In the case of *S. maydis* in Indonesia, Hakim and Dahlan (1972) suggested a polygenic inheritance and the gene action for resistance is additive in nature. In Thailand, the data also suggested a polygenic system for resistance to *S. sorghi* (Jinahyon, 1973). Estimation of gene effects indicated statistically significant additive gene effect. However, the existence of dominance and additive $\times$ additive interaction could not be ruled out.

Throughout the Asian region with the exception of Taiwan the majority of farmers still grow open-pollinated varieties. Breeding programs are directed toward the construction of superior composites or synthetics. At present situation such composites and synthetics should also be resistant to downy mildew disease. However, polygenic resistance would not necessarily yield complete resistance to the pathogen but it would act as a deterrent for an epidemic. This situation would allow the pathogen to maintain itself but the level of survival would be low enough not to cause serious economic losses.

Recurrent selection in the form of mass selection, selection based upon S_1 progenies and full sib progenies are presently employed in our breeding program to develope a high level of resistance to the pathogen in many maize populations. We emphasize selection for polygenic resistance and choose the population approach. Table 1 gives the list of downy mildew resistant composites formed in Thailand. Thai DMR #1, 2, 3, 4 and 5 represent intrapopulation improvement for downy mildew resistance. Other populations involve a cross to resistant sources. The best resistant sources in our condition are composites from the Philippines. In 1973, six Suwan DMR Sources were formed. Each source would represent different genetic background and screening location. These sources will later serve to generate new breeding materials and use as reserved resistant gene pools in the program. In 1972–1973, Thailand released Bogor Syn. 2 and Tainan #10

* Assistant Professor and Maize Breeder, Department of Plant Science, Faculty of Agriculture, Kasetsart University, Bangkok, Thailand.

Table 1. Downy mildew resistant composites formed in Thailand

Population	Composition
Thai DMR #1	Synthetic of 60 S_5 lines from Guatemala PB 3, Veratigua, Cuprico, Caribbean Composite, Caribbean Flint Composite and Caribbean Dent Composite.
Thai DMR #2	Synthetic of 34 S_4 lines from the same source populations as Thai DMR #1
Thai DMR #3	Intrapopulation selection from Guatemala E 6
Thai DMR #4	Intrapopulation selection from Cupurico×Flint Comp. E 4
Thai DMR #5	A similar selection to Thai DMR #3
Thai DMR #6	A composite from intercrosses of eight downy mildew resistant sources: Tainan DMR Comp. #1, Tainan DMR Comp. #2, Tainan DMR Comp. #3, Tainan DMR Comp. #4, Tainan DMR Comp. #10, Phil. DMR 1, Phil. DMR 3, Bogor Syn. 2
Thai DMR #7	A cross between Thai DMR #6, Cuba Gr. 1 and Ph 9
Thai Composite #1 DMR	Phil. DMR 1 and 5 crossed to Thai Composite #1. Three backcrosses were made with Thai Composite #1 as recurrent parent. Two cycles of recurrent selection based upon S_1 progenies for D. M. resistance and grain yield will be completed in 1974.
Thai Composite #3 DMR	A composite made from 17 germ plasm sources
	Phil. DMR 5×Thai Comp. #1 (S) C_1–F_3
	Phil. DMR 5×Cup. Flint Comp.–BC^1F_2
	Phil. DMR 5×Guatemala PB 5
	Phil. DMR 5×Caripeno–F_3
	Phil. DMR 5×Caribbean Comp.–F_3
	Phil. DMR 5×Puerto Rico Gr. 1–F_3
	Phil. DMR 5×Cuba 40–Cuba Gr. 1–F_3
	Caribbean Comp. DMR (Phil. local DMR sources)
	Taiwan–CIMMYT Composite 6 (Puerto Rico Gr. 2)
	Taiwan–CIMMYT Composite 7 (Dom. Rep. Comp.)
	Taiwan–CIMMYT Composite 8 (Usatigua)
	Taiwan–CIMMYT Composite 9 (Cuba 16×CBC)
	Taiwan–CIMMYT Composite 13 (Complex)
	Taiwan–CIMMYT Composite 17 (from 92 collections)
	Bogor Syn. 2
	Bogor Comp. 2 (S) C_1
	Tainan DMR 3 (India source materials)
Thai Composite #4 DMR	Bogor Syn. 2
	Thai DMR #6
	Thai Composite #3
	Phil. DMR 1 and 5×Thai Comp. #1–BC^2F_4
	Phil. DMR 1 and 5×Cup. Flint Comp.–BC^2F_4
	Phil. DMR 1 and 5×PB 5–F_5
	Phil. DMR 1 and 5×Caribbean Comp.–F_5
	Phil. DMR 1 and 5×Caripeno–F_5
	Phil. DMR 3 (S) C_1
	Phil. DMR 1 and 5×Comp. LC_3–F_2
Suwan DMR Source 1	Bulk pollination among resistant plants from

Table 1. (Cont'd)

Population	Composition
Suwan DMR Source 1	Mezcla DMR×Mix 1×Colima Gpo. 1×Eto P. B.-F_1
	Mezcla DMR×Ant. Gpo. 2×Lineas Illinois-F_1
	Mezcla DMR×Cogollero-F_1
	Mezcla DMR×Tuxpeno Crema I P. B.×Eto P. B.-F_1
	Mezcla DMR×Tuxpeno Crema I P. B.-F_1
	Mezcla DMR×Mezcla Amarillo P. B.-F_1
	Mezcla DMR×Cholitalpa Chaparro-F_1
	Mezcla DMR×Eto P. B.-F_1
	Mezcla DMR×Cogollero-F_2
	DMR 5×Cogollero-F_2
	(DMR 5×Cogollero)×Cogollero
	DMR 5×(DMR 5×Cogollero)
	(Mezcla DMR×Cogollero)×Mezcla DMR
Suwan DMR Source 2	A composite made from diallel crosses among MIT, Monte Rock, Ph 9, A206 DMR, Aroman, Bogor Syn. 2, Taiwan-Indonesia DMR Comp. #2, Taiwan-Indonesia DMR Com. #4, Tainan #10, Chain DMR Syn.
Suwan DMR Source 3	A composite made from bulked pollination among DMR 1 CIMMYT through DMR 17 CYMMYT selected in Taiwan
Suwan DMR Source 4	A composite from bulked pollination among Tainan DMR 1 through Tainan DMR 12
Suwan DMR Source 5	A composite from bulked pollination among
	Phil. DMR 1×Thai Comp. #1
	Phil. DMR 1×Cup. Flint Comp.
	Phil. DMR 1×Puerto Rico Gr. 1
	Phil. DMR 1 Cuba 40-Cuba Gr. 1
	Phil. DMR 1×Guatemala PB 5
	Phil. DMR 1×Caribbean Comp.
	Phil. DMR 1×Caripeno
Suwan DMR Source 6	A composite from bulked pollination among
	Phil. DMR 5×Thai Comp. #1
	Phil. DMR 5×Cup. Flint Comp.
	Phil. DMR 5×Puerto Rico Gr. 1
	Phil. DMR 5×Cuba 40-Cuba Gr. 1
	Phil. DMR 5×Guatemala PB5
	Phil. DMR 5×Caribbean Comp.
	Phil. DMR×Caripeno
	Phil. DMR 5×Comp. LC_3
Dupurico Flint Composite DMR	From a cross between Phil. DMR 1 and 5 to Cuprico Flint Composite (F)C_1. Three backcrosses and screening were made respectively to Cup. F1 Comp. (F)C_3, C_4 and C_5
Thai Opaque-2 Composite #3	From a cross between Phil. DMR 1 and 5 to Thai Composite #1 (S)C_1 and to Thai Opaque-2 Composite #1
Thai Super Sweet Composite #1	From a cross between Hawaiian Super Sweet and Phil. DMR 3.

for farmers to produce commercial seeds. In the mean time breeding efforts are concentrated on Thai DMR #6, Thai Composite #1 DMR, Thai Composite #3 DMR and Cupurico Flint Composite DMR. Improvement of Thai Opaque-2 Composite #3, Thai Super Sweet Composite #1 and early maturing germ plasms are included in the program.

We can grow three crops of corn a year at the National Corn and Sorghum Research Center at Farm Suwan. Full sib and S_1 progenies are generated in December planting. Evaluation of downy mildew reaction for progenies are made in April planting in artificial epiphytotic field condition. Selected progenies are yield tested in May at one location and August at another location. Compositing of finally selected progenies are made at late August planting in artificial epiphytotic field condition. Therefore one cycle of recurrent selection can be completed within one year.

Table 2. Summary data for uniform station yield trial grown in 1974E at Farm Suwan

Entry	Artificial infection		Diseased free condition	
	% D. M.	Grain yield*	% D. M.	Grain yield*
Thai DMR #6	62	2,314	0	4,661
Bogor Syn. 2 DMR (M) IV	62	2,024	0.4	2,926
Tainan #10 DMR (M) II	83	932	0.4	4,300
Phil. DMR 1, 5×Thai Comp. #1 BC^3 (S) C_1	78	2,231	0.4	5,844
Phil. DMR 1, 5×Cup. Fl. Comp. BC^3 (F) C_1	83	1,096	0	5,100
Thai Composite #3	68	2,391	0.4	4,961
Thai Comp. #1 Early×Phil. DMR 1-F_2	82	1,497	0	5,325
Phil. DMR 5 (S) C_1	34	3,058	0	4,049
Phil. DMR 3 (S) C_1	41	3,104	0	5,572
Guatemala PB 11	93	265	2.8	2,985

* kg/ha

Summary of data from various yield trials are shown in Tables 2, 3 and 4 under artificial infection and diseased free condition. The entries in the Uniform Station Yield Trial (Table 2) are released or potentially released varieties. The infection under artificial epiphytotic condition was considered heavy where the susceptible variety, Guatemala PB 11, showed more than 90% infection. Philippine DMR 3 and 5 could be regarded as resistant varieties with 41% and 34% infection, respectively. Thai DMR #6, Bogor Syn. 2 and Thai Composite #3 DMR were satisfactorily resistant. The level of infection in other varieties were considered high. In the absence of disease, Thai Composite #1 DMR ranked first in grain yield including the early maturing counterpart.

Entries included in the Preliminary Yield Trial (Table 3) are broadbased germ plasms and newly formed composites which may have some potential use in the breeding program. On the basis of grain yield and disease reaction, Thai DMR #6, Thai Composite #1 DMR, Thai Composite #3 DMR, Caribbean Composite DMR, Caripeno DMR, and Philippine DMR 3 would be of value for breeding purpose.

Summary data for the DMR Sources Yield Trial (Table 4) indicated a high yield potential for all entries tested with the exception of Bogor Syn. 2 and Guatemala PB 11. The susceptible Guatemala PB 11 had 92% infection. All other entries were good in resistance and the best among all was Suwan DMR Source 2. A yield test for downy mildew resistant varieties conducted under diseased free condition confirmed the superiority of Thai Composite #1 DMR and the high yielding potential of other breeding populations (Table 5).

Table 3. Summary data for preliminary yield trial grown in 1974E at Farm Suwan

Entry	Artificial infection		Diseased free condition	
	% D. M.	Grain yield*	% D. M.	Grain yield*
Thai DMR #1 (M) II	75	1, 493	0	4, 373
Thai DMR #2 (M) II	67	2, 122	0	2, 705
Thai DMR #3 (M) II	76	889	0	3, 174
Thai DMR #4 (M) II	74	1, 128	0. 5	3, 176
Thai DMR #6	64	1, 895	0. 5	5, 046
Thai DMR #7	82	962	0. 25	4, 136
Thai Comp. #1 DMR	74	1, 646	0. 5	4, 970
Thai Comp. #3 DMR	69	2, 004	0	4, 765
Thai Comp. #4 DMR	74	1, 960	0	3, 835
Caribbean Comp. DMR	63	2, 337	0	4, 677
Caripeno DMR	67	2, 080	0	4, 193
Guatemala DMR	70	1, 666	0. 5	4, 116
Comp. LC_3 DMR	79	1, 744	1. 0	4, 657
Hybrid Comp. DMR	79	1, 323	0	4, 667
A6 T. C. DMR	93	533	0. 5	4, 094
Tuxp. Erect Ant. Gr. 2 DMR	92	375	1. 0	4, 129
Phil. DMR 3 (S) C_1	46	3, 137	0	4, 371
Bogor Syn. 2	81	1, 174	0	3, 085
Guatemala PB 11	96	215	3. 25	3, 477

* kg/ha

Table 4. Summary data for DMR sources yield trial in 1974E at Farm Suwan

Entry	Artificial infection		Diseased free condition	
	% D. M.	Grain yield*	% D. M.	Grain yield*
Suwan DMR Source 1	40	2, 964	0	5, 960
Suwan DMR Source 2	9	3, 581	0	5, 343
Suwan DMR Source 3	31	3, 100	0	5, 358
Suwan DMR Source 4	34	2, 752	0	5, 479
Suwan Early DMR Source 5	46	2, 927	0	5, 718
Suwan DMR Source 6	32	3, 120	0	5, 153
Thai Comp. #1 DMR	31	3, 556	0	5, 062
Thai Comp. #3 DMR	31	3, 655	0	5, 920
Thai Comp. #4 DMR	34	3, 477	0	5, 990
Thai DMR 6	22	3, 073	0	5, 553
Bogor Syn. 2	31	2, 455	0	3, 220
Guatemala PB 11	92	252	0	3, 176

* kg/ha

Table 5. Grain yield for entries in a Yield Trial of Downy Mildew Resistant Varieties grown at Farm Suwan in the Dry Season (December-May) 1974

Entry	Grain yield (kg/ha)
Thai Composite #1 DMR BC^3 (S)C_1	7,594
Cupurico×Flint Comp. DMR BC^3 (F)C_1	7,385
Thai DMR #3 (M)II	7,107
Thai Composite #1 DMR BC^2 F_4	7,062
Composite L×Phil. DMR 5	7,022
Caripeno×Phil. DMR 1,5	6,859
Hybrid Comp.×Phil. DMR 5	6,806
Thai DMR #1 (M)II	6,648
Guatemala×Phil. DMR 1,5	6,524
Phil. DMR 5 (S)C_1	6,293
Thai Composite #3	6,280
Caribbean Comp.×Phil. DMR 1,5	6,263
Thai DMR 4 (M)II	6,219
Guatemala PB 11 (Check)	6,169
Phil. DMR 3 (S)C_1	5,956
Bogor Syn. 2 (M)IV	5,890
Bogor Syn. 2 (Commercial lot)	5,877
Thai DMR 6	5,791
Mean	6,547
L.S.D. (0.5)	600
C.V. (%)	6.5

Table 6. Grain yield and other data for varieties grown in the evaluation of natural mass selection at Farm Suwan in 1973

Entry	Downy mildew infection (%)	Grain yield (kg/ha)
Caribbean Comp. C_0	44	2,385
Caribbean Comp. (M)C_5	32	3,341
Caripeno C_0	57	2,085
Caripeno (M)C_4	40	3,517
L.S.D. (0.05)		548
C.V. (%)		18.92

Two broadbased germ plasms, Caribbean Composite and Caripeno, were subjected to natural mass selection in isolation blocks for 5 and 4 generations, respectively. Table 6 shows the effect from natural selection. Percent infection to downy mildew were significantly reduced in both population and thus reflected in an increase in grain yield.

Recurrent seletcion was conducted to improve the level of infection and grain yield in Thai Composite 1 DMR. In the C_0 cycle, 293 S_1 lines were evaluated for disease reaction and grain yield and 50 progenies were selected to form the first cycle composite (Fig. 1). In the second cycle 1150 S_1 lines were extracted and 200 progenies were selected on the basis of disease reaction for further yield test (Fig. 2). The same

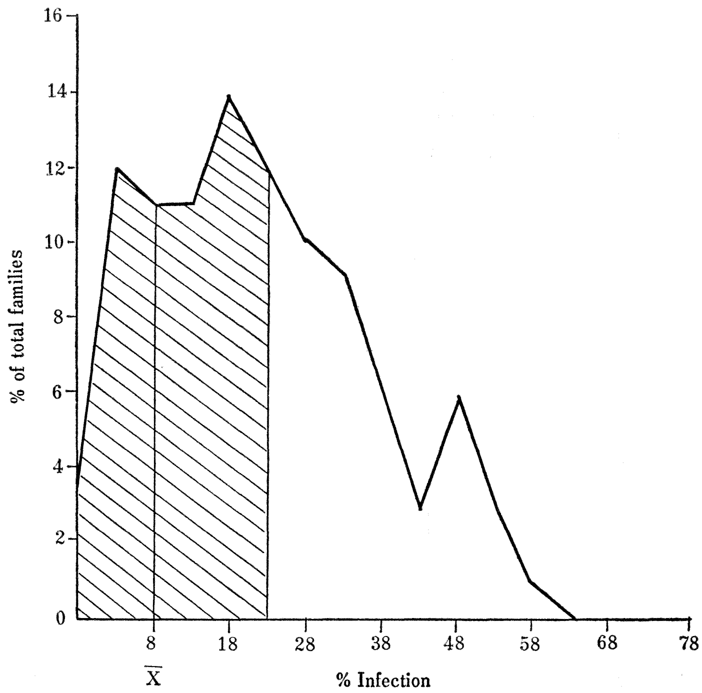

Fig. 1. Distribution of Philippine DMR 1, 5×Thai Composite #1 $BC^3(S)C_0$ lines (293 lines) under artificial downy mildew epiphytotic condition at Farm Suwan in 1973L

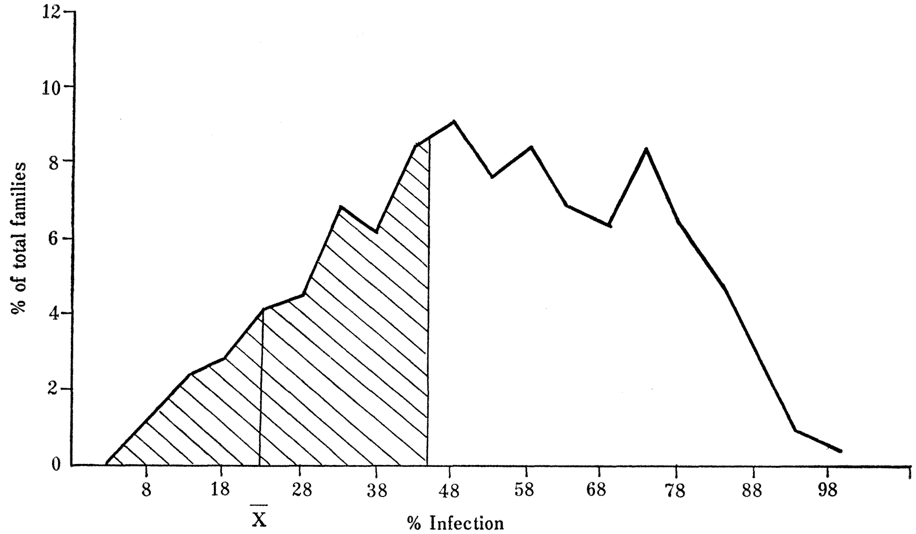

Fig. 2. Distribution of Philippine DMR 1, 5×Thai Composite #1 $BC^3(S)C_1$ lines (1,150 lines) under artificial downy mildew epiphytotic condition at Farm Suwan in 1974E

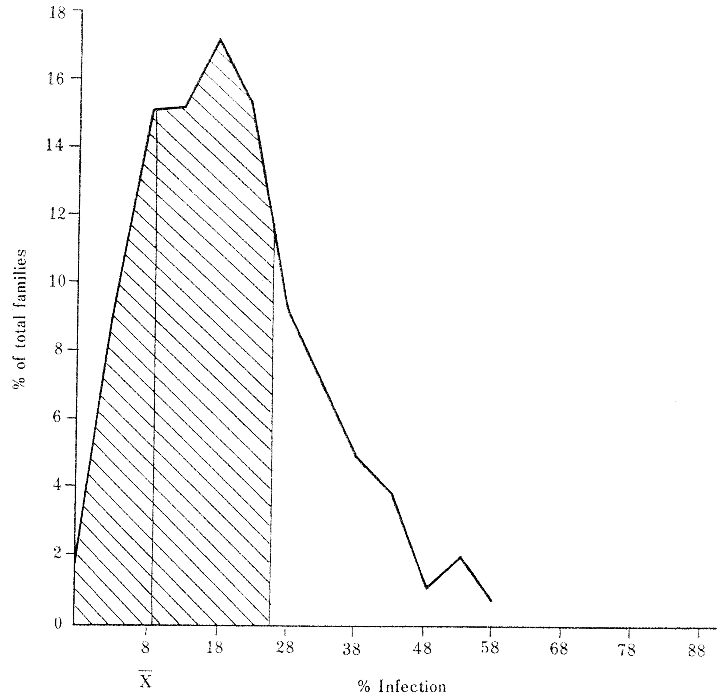

Fig. 3. Distribution of Philippine DMR 1, 5×Cupurico-Flint Compuesto $BC^3(F)C_0$ lines (197 lines) under artificial downy mildew epiphytotic condition at Farm Suwan in 1973L

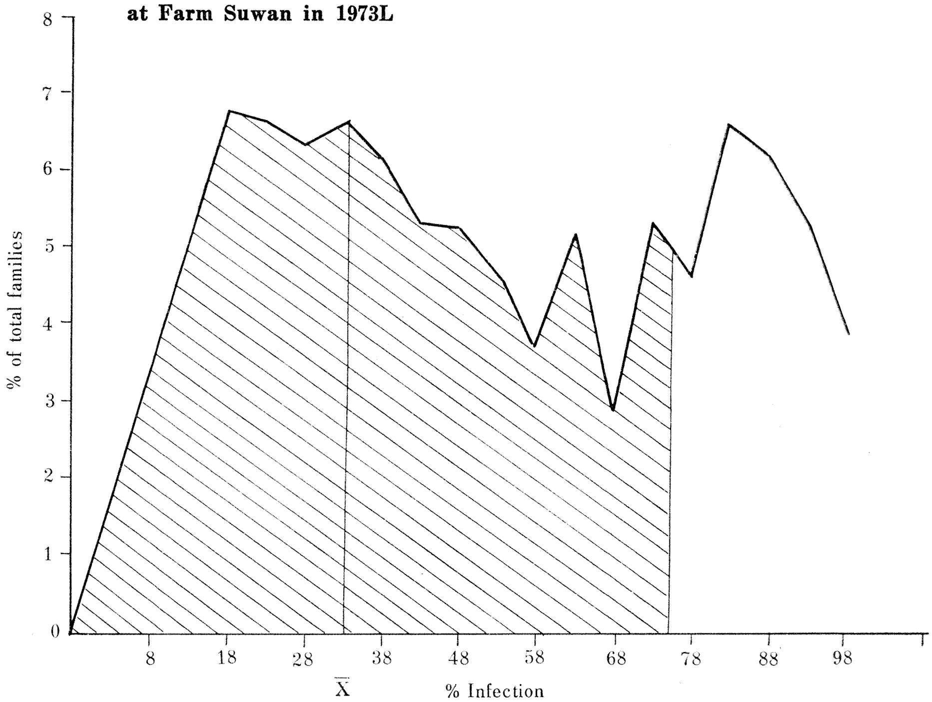

Fig. 4. Distribution of Philippine DMR 1, 5×Cupurico-Flint Compuesto $BC^3(F)C_1$ lines (756 lines) under artificial downy mildew epiphytotic condition at Farm Suwan in 1974E

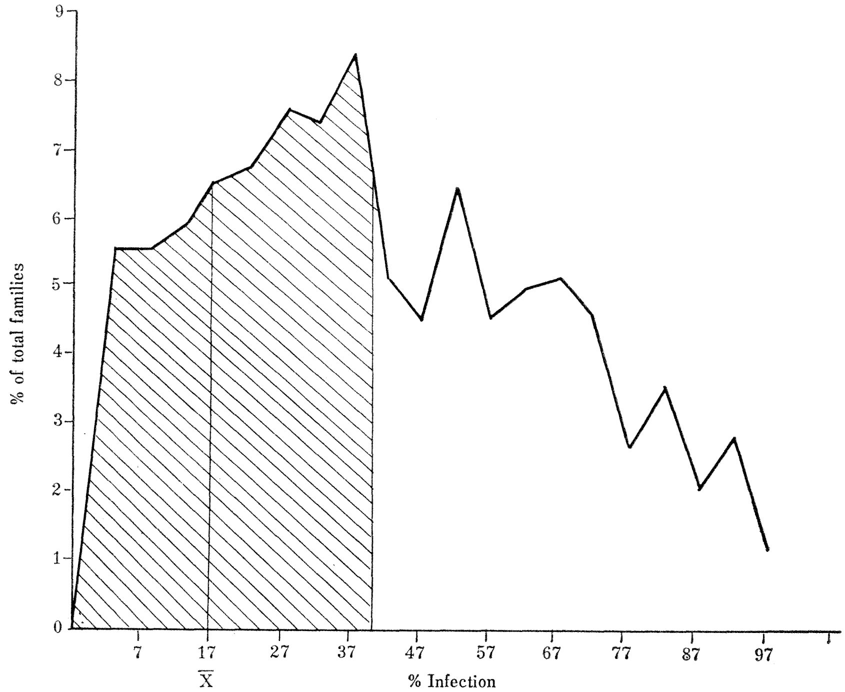

Fig. 5. Distribution of Thai Composite #3 (S)C_0 lines (690 lines) under artificial downy mildew condition at Farm Suwan in 1974E

procedure was used for Cupurico Flint Composite DMR with the exception that full sib progenies were extracted instead of S_1 progenies. Forty four progenies were finally used to form the first cycle composite (Fig. 3) and 210 out of 756 progenies were kept for further yield test in the second cycle of selection (Fig. 4). Selection in Thai Composite #3 was initiated in 1974. Again 200 out of 690 S_1 progenies were kept on the basis of disease reaction for further yield testing (Fig. 5). Improvement of downy mildew resistance in other raw breeding populations were carried by sib-pollination among resistant plants in the screening nursery.

Literature Cited

1. Asnani, V. L. and B. Bhusan. 1970. Inheritance study on the brown stripe downy mildew of maize. Indian Phytopath. **23**: 220–230.
2. Handoo, M. I., B. L. Renfro and M. M. Payak. 1970. On the inheritance of resistance to *Sclerophthora rayssiae* var. *zeae* in maize. Indian Phytopath. **23**: 231–249.
3. Hakim, R. and M. Dahlan. 1972. Segregating behavior of *Sclerospora maydis* of corn. Paper presented at Southeast Asia Regioanl Symposium on plant disease in the tropics, Jogyakarta, Indonesia.
4. Jinahyon, S. 1973. The genetics of resistance and its implications to breeding for resistance in corn. The Ninth Inter-Asian Corn Improvement Workshop Proceedings. 30–39.

Question and Answer

Joginder Singh, India: Your frequency distribution curves for downy mildew of S_1 lines showed a trimodal distribution. Does it mean few genes are involved in the inheritance of resistance or was it purely due to chance resulting from fewer progenies? Will it be desirable to choose a small class interval to redraw the curve and confirm these results?

Answer: I would agree that using the small class interval will help in bringing the distribution back to normal to fit the polygenic assumption. Fluctuation in the form of bimodal or trimodal distribution is probably due to chance and to fluctuation of disease reaction among sets of progenies randomly grouped for field experimentation. However, further statistical testing is needed for determining deviation from the normal distribution.

A. J. Ullstrup, U.S.A.: Have DMR populations been released to farmers? If not, when is release expected?

Answer: Yes, in 1972 we released Bogor Syn 2 and Tainan #10 and this was continued in 1973. In 1974 we released Thai DMR #6, Thai Composite #1 DMR in addition to the aforementioned varieties.

Joginder Singh, India: Following the presentation of Dr. Carangal and yours I think we have a wide array of DMR materials. In fact we have more names than the genetic background of the material. Dr. Carangal suggested the need for a systematic basis for naming these materials. Do you have any suggestions in this regard?

Answer: I agree with you and Dr. Carangal that one day we have to sit together and really work on the system of naming the DMR materials. Otherwise, it will be very confusing in terms of genetic background, to breeders in other regions.