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Introcution

Maize is cultivated mainly in the temperate areas of the world as one of the forage crops, but in tropical Asia, it has been cultivated extensively for a very long time, as the second important staple food crop following rice. Recently, farmers have stepped up the production of this commodity as maize has drawn the attention of traders all over the world owing to its lucrative potential.

In the tropical countries of Asia where maize has been cultivated in large amount for domestic consumption or as a cash crop, maize farmers are compelled to develop appropriate control methods against downy mildew outbreaks which are responsible for a marked decrease of maize yields.

Two genus and 8 species of the pathogenic fungi are known in the world (Dickson (1956)[18], Payak et al. (1967)[46]). Among them 6 species are distributed in the tropical countries of Asia.

In many cases the intensity of the damage varies according to the area and to the year when the epidemics are observed. For example in Taiwan, in the fall of 1964, 48% of the total cultivated area was damaged by *Sclerospora sacchari***. In malang which is located in the eastern part of Java Island (Indonesia), 70 % of the total planted area was infected with *Sclerospora maydis* in 1968, while 52 and 57 % of maize fields covering 50 ha were damaged by the same agent in 1971, in the villages of Sidoluhur and Srigarden, respectively.

As a result, the farmers were forced to abandon the cultivation of maize and had to switch to other crops.*** In Indonesia, depending on the year, 20 to 80 % of the total maize harvests are being lost as a result of the damage (Wendel (1964)[61], Pruakusumah (1965)[49], Subandi (1967)[53]).

In the Philippines, the damage which usually affects 40 to 60% of the total maize yield can reach 80 to 100 % in the case of severe outbreaks (Weston (1920)[62], Rayes (1941)[51], Exconde et al. (1966)[20]).

In India, Gattani (1950)[26] has reported that a 7 acre of maize field was completely destroyed by *Sclerospora philippinensis*.

As mentioned above, downy mildew disease is responsible for a loss of maize amounting to 50 % of the total harvest in the tropical countries of Asia. Therefore, it is important to work out countermeasures aimed at the control of maize downy mildew in these countries. At present, research is being promoted so as to develop chemical control methods together with the breeding of varieties resistant to downy mildew disease and improvement of the methods of cultivation.

Since the fungus was discovered in 1897, many studies have been conducted to determine its taxonomy and the relationship between the formation and germination of conidia and the environmental conditions. According to experimental results, the disease is transmitted through conidia whose production amounts to 10,000 to 50,000/cm^2/day. Unfortunately, however, little information is available concerning the control of the disease. Although some resistant varieties have been developed, the farmers of Indonesia and of the Philippines are not using them because the yield potential is still low.

The author has pursued research relating to methods of prevention of downy

* Rereived on 8 May 1978.

** Chang Shin Chi (Taiwan Corn Research Center) personal letter.

*** Annual Report of East Java DIPERTA.

mildew disease mainly from the angle of maize cultivation techniques at the Corn Research Center in Taiwan, from June 1969 to April 1970 and at the Central Research Institute for Agriculture in Indonesia, from October 1971 to June 1973, and from April 1974 to April 1976.

As the measures aimed at the prevention of the disease, which were developed by the author are now being implemented in Indonesia, they could be introduced to other tropical countries with similar environmental conditions.

The author wishes to express his gratitude to Dr. Noboru Yamada and Dr. Kan-ichi Murakami, former Directors of the Tropical Agriculture Research Center for their invaluable assistance and encouragement.

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I. Description of the Symptoms, Mode of Infection and Lesions and the Infection Cycle of Downy Mildew Disease of Maize in Indonesia and Taiwan.

In this study, the author investigated the time when the symptoms appeared, particularly in relation to the seasons as well as the mode of infection and transmissibility of the disease.

1. Downy mildew disease of maize in Indonesia.

In the tropical countries of Asia, there are 5 species of *Sclerospora* and one species of *Sclerophthora* which have been isolated as pathogenic fungi of maize downy mildew disease, namely *Sclerospora sacchari* in Taiwan, the Philippines, and India, *Sclerospora maydis* in Indonesia and India, *Sclerospora philippinensis* in the Philippines, India, Indonesia and Nepal, *Sclerospora spontanea* in the Philippines, *Sclerospora sorghi* in India and Thailand and *Sclerophthora rayssiae* var. zeae in India and Thailand. References on these fungi are summarized in Table 1. In addition to these species *Sclerospora graminicola* and *Sclerophthora macrospora* have also been recognized as pathogenic agents of maize downy mildew disease.

Table 1. Pathogens of maize downy mildew disease in tropical countries of Asia.

Pathogen	Countries
Sclerospora sacchari Miyake	Taiwan Philippines* India*
Sclerospora maydis (Rae) Butler	Indonesia India*
Sclerospora philippinensis Weston	Philippines India Indonesia (Northern Sulawesi) Nepal (probably)
Sclerospora spontanea Weston	Philippines
Sclerospora sorghi Weston and Uppal	India Thailand
Sclerophthora rayssiae var. zeae Payak and Renfro	India Thailand

* Countries when these pathogens are not important.

Miyake (1912)[43)] reported that the maturation of grains of maize plants inoculated with *Sclerospora sacchari* was not apparently different from that in normal plants. On the other hand, in India, Butler (1913)[5)] reported that maize plants inoculated with *Sclerospora philippinensis* developed severe symptoms at the seedling stage. The lower leaves were usually normal, but the upper part of the plant became chlorotic, owing to the disappearance of the chlorophyll in long streaks. The growth of infected plants was markedly affected and the plants became atrophic and the internodes usually shortened so as to give a shrunken appearance to the head. They displayed a yellow discoloration. Such plants did not usually produce any grains, though sometimes small cobs could be seen. Westen (1920)[62)] (1921)[63)] who investigated plants infected with *Sclerospora philippinensis* and *Sclerospora spontanea* respectively in the

Philippines reported that most of the infected plants usually died one month after the sowing, while plants infected slightly were able to continue to grow. However, these plants seldom produced ears and yields were very low. Melhus et al. (1925)[38] who observed maize plants infected with *Sclerospora graminicola* in the U.S.A., reported that the infected plants showed poor growth and even drawing and some plants died when they were 7 cm high. Melhus et al. (1952)[39] also reported in Indonesia that maize plants infected with *Sclerospora maydis*, showed systemic symptoms when they were 30 to 100 cm high and died shortly after. Leece (1941)[34] reported that plants infected with *Sclerospora sacchari*, showed systemic symptoms at the 5th to 6th leaf stage. Some of them died, whereas others displayed abnormal growth characterized by the presence of multiple ears and of elongated shanks.

As mentioned above, the manifestations of the disease differed: while in some cases the growth of the plants was not impaired, in most cases the yield was markedly reduced.

1) Materials and methods

The experiments were conducted at Cikeumeuh Plant Station, Central Research Institute for Agriculture in Indonesia. Maize plants were artificially inoculated. The susceptible cultivar, Bogor composite 2 (BC-2) was sown on December 16th, 1971. After germination the plants were inoculated with conidia collected from leaves of maize (BC-2) infected with *Sclerospora maydis*. The inoculated plants developed systemic symptoms 18 days after the inoculation and produced conidia in a normal way.

In this field, test plants of a sensitive cultivar (BC-2) and a slightly resistant cultivar (Permadi: BS-2) were sown on January 15th, March 1st and 15th, 1972 respectively.

In a plot, 4 m $\times$ 4.5 m, there were 2 plants per hill. The interval between the plants measured 20 cm and the rows were separated from each other by a distance averaging 75 cm. As fertilizers, 120 kg of N, 60 kg of P_2O_5 and 30 kg of K_2O were applied per hectare. Germination occurred 4 days after sowing and plants grew satisfactorily.

It was only 2 weeks after germination that infected plants displayed symptoms. In plants, sown on January 15th, the author recorded the percentage of infection, the number of dead plants caused by infection, the number of living plants and of those bearing ears 4 and 8 weeks after sowing. In plants, sown on March 1st and 15th, plant height, thickness of the culm, length and width of the leaves, were observed on April 21st and compared with those of normal plants.

2) Results

Table 2 summarizes the results of the observations. The percentage of infection was 40.4 % for BC-2 and 21.4% for Permadi, and the death rate reached 54.2 % for BC-2 and 73.2 % for Permadi. Moreover, the percentage of plants which bore ears was only 2.3 % for BC-2 and 2.1 % for Permadi, and ears were smaller, with about 15 grains in each.

The growth components of infected plants sown on March 1st and March 15th were compared with those of healthy plants, as shown in Table 3. In the plants sown on March 1st, the height of infected maize cultivars BC-2 and Permadi, averaged 55.5 % and 50.9 % of the value recorded in healthy plants respectively, while in plants sown on March 15th the height of infected plants was 78.2 % in BC-2 and 67.9 % in Permadi. This tendency became more evident with the progression of growth.

Table 2. Damage of maize plants due to the infection caused by *Sclerospora maydis* in Indonesia.

Cultivar	Date of sowing	Experimental plot	Total number(1) of tested plant	Number of plant				
				Infected(2)	Dead after(3) infection	Survived(3)	Ears produced(3) after infection	Ears not(3) produced after infection
Bogor composite-2 (BC - 2)	Jan. 15 1972	I	227	71 (31.3)*	39 (54.9)**	32 (45.1)**	4 (5.6)**	28
		II	306	142 (46.5)	59 (41.5)	83 (58.5)	2 (1.2)	81
		III	207	86 (41.5)	64 (74.4)	22 (25.6)	1 (1.2)	21
		Total	740	299 (40.4)	162 (54.2)	137 (45.8)	7 (2.3)	130
Permadi	Jan. 15 1972	I	257	51 (19.8)	43 (84.3)	8 (15.7)	0 (0)	8
		II	243	71 (29.2)	46 (64.8)	25 (35.2)	1 (1.5)	24
		III	165	20 (17.1)	15 (75.0)	5 (25.0)	2 (10.0)	3
		Total	665	142 (21.4)	104 (73.2)	38 (26.8)	3 (2.1)	35

(1) Observed on February 2nd, 1972. (2) Observed 8 weeks after planting. (3) Observd on April 17th, 1972.
Figures in parenthesis indicate the percentage of infection in the total number of tested plants* and percentage in the infected plants**.

Table 3. Comparison of plant height and culm thickness between healty and plants infected with *Sclerospora maydis*.

Culitvar	Date of planting	Experimental plot	Plant height (cm) Healthy (A) plants	Plant height (cm) Infected (B) plants	Plant height (cm) B/A×100 (%)	Culm thickness (cm) Healthy (A) plants	Culm thickness (cm) Infected (B) plants	Culm thickness (cm) B/A×100 (%)
Bogor composite-2 (BC-2)	Mar. 1, 1972	I	164.2	81.8	49.8	1.58	0.68	43.6
		II	164.7	101.4	61.6	1.70	0.94	55.3
		III	150.5	84.3	55.0	1.47	0.85	58.6
		Average	159.9	89.2	55.8	1.58	0.83	52.2
	Mar. 15, 1972	I	102.2	79.4	77.7	1.30	0.88	67.7
		II	83.3	71.1	85.4	1.07	0.77	72.0
		III	93.6	67.8	72.4	1.29	0.75	58.1
		Average	93.0	72.8	78.2	1.22	0.80	65.6
Permadi (S-2)	Mar. 1, 1972	I	182.1	102.5	56.3	1.70	0.92	54.1
		II	165.9	94.3	57.1	1.60	0.77	48.1
		III	182.5	74.2	40.7	1.70	0.72	42.4
		Average	176.8	90.3	50.9	1.67	0.80	48.3
	Mar. 15,	I	119.5	79.7	66.7	1.57	0.92	58.6
		II	101.4	68.2	67.3	1.36	0.77	56.6
		III	101.4	71.4	70.4	1.36	0.75	55.1
		Average	107.4	73.0	67.9	1.43	0.81	56.9

Observed at the Cikeumeuh Plant Station at Central Research Institute for Agriculture, on April 21st, 1972.

The thickness of culms of infected plants sown on March 1st was 52.5 % (BC-2) and 48.3 % (Permadi) of the value recorded in healthy plants, while in those sown on March 15th, the thickness was 65.6 % (BC-2) and 56.9 % (Permadi) of that in healthy plants.

The growth pattern of the leaves is shown in Figure 1. In the plot sown on March 1st, the leaves of infected plants were slightly shorter than those of healthy plants although the difference was not significant. On the other hand, the leaves of infected plants were considerably narrower (43.5 to 53.6 % compared with healthy plants). In the plots sown on March 15th, the leaves of infected plants became also significantly narrower than those of healthy plants. They tended to curl slightly inwards and to become lorate (see Plate 1).

The reason for this discrepancy could be attributed to the difference in the stage of growth, as it is known that there is a gradual decrease in the length of the leaves, with the emergence of the flag leaf.

As for the width of the leaves, the difference between infected and healthy plants increased as the plants grew i.e. 30 % of the value in healthy plant leaves at the middle stage of growth and 45 % at the stage of flag leaf.

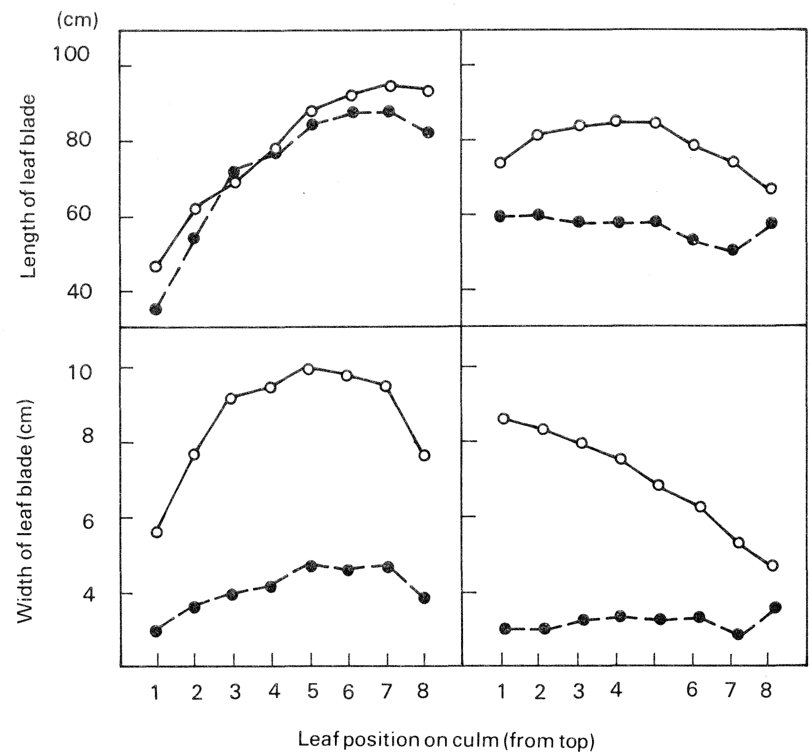


Figure 1. Growth of leaves infected with downy mildew disease of maize.

Left; seeds were sown on March 1, observed on April 21, 1972

Right; seeds were sown on March 15, observed on April 22, 1972

Cultivatar; Bogor composite-2

o——o normal plants ●——● infected plants

3) Discussion

In Indonesia, the lesions and symptoms of plants infected with downy mildew disease of maize caused by *Sclerospora maydis* corresponded to the severity of the epidemic of the disease in the field. This phenomenon was observed over wide areas when the infection became more severe. For instance, half of the plants infected at the seedling stage died while those which continued to grow showed a markedly reduced growth. The leaves were lorate compared with those of healthy plants and some of the plants showed lodging on the soil surface. Moreover the plants with symptoms had small ears and these infected maize plants did not produce any grains. These results are in conformity with the reports by Butler (1913)[5], Weston (1920)[62], Weston (1921)[63], Melhus et al. (1925)[38] (1952)[39], Leece (1941)[34]. In a field located in Malang (East Java) where the infection was not severe, the author also observed infected plants which produced small ears with few grains. These plants showed symptoms only on flag leaves and their sheaths at the maturation stage. Such observations are similar to those reported by Miyake (1912)[43]. However, the symptoms described above were observed only in special cases.

As mentioned above, the infected plants with systemic symptoms did not generally produce ears. Therefore, the degree of yield reduction could be deduced from the percentage of infected plants, as reported by Exconde et al. (1974)[25] in maize plants infected with *Sclerospora philippinensis*.

2. Symptoms of the disease in maize plants in Taiwan and Indonesia

Palm (1918)[44] divided maize plants infected with Java downy mildew into the following three groups. i) Infected plants which remained small with narrow yellow or greenish yellow leaves. Plants of this type often showed lodging as a result of the poorly developed root system (type A). ii) Plants developed normally but the leaves showed yellow streaks and the basal part of the leaf (type B) did not emerge. iii) Upper leaves showed a normal appearance, but only the basal leaves were narrow with sharply defined yellow or brown streaks. The streaks very seldom anastomosed at their basal part (type C).

As mentioned above, various symptoms of the disease were observed, but there was no clear relationship between these symptoms and the mode of infection. The author will discuss the relation between the infection with *Sclerospora sacchari* in Taiwan and that with *Sclerospora maydis* in Indonesia.

1) General symptoms of the disease

Generally the symptoms appeared 2 to 3 weeks after sowing. Newly developed leaves of young diseased seedlings showed light yellow streaks. These streaks, however, became dark yellow after 1 to 2 days (see Plate 2) and the formation of conidiophores and conidia gave a white powdery appearance on both surfaces of the leaves (see Plate 3). Shortly after, these infected plants showed systemic symptoms and severely infected plants died 3 to 4 weeks after sowing. However, some of them continued to grow, showing abnormal growth (see Plate 4) with a markedly atrophic appearance, deformed ears and elongated shanks. Grain did not reach maturity and the yield was markedly reduced. In this case, leaves and sheaths near the flag leaf showed yellow streaks and produced conidia. The streaks could also be observed on tassels and husk cover (see Plate 5). The symptoms mentioned above, could be observed in case of infection with *Sclerospora sacchari* and *S. maydis*.

2) Symptoms at the different growth stages

As mentioned above, the symptoms varied considerably. The author observed additional symptoms which could be divided into 2 groups depending on the stage of growth. These observations were made in plants infected with *Sclerospora sacchari* in Taiwan. However the same symptoms were also observed in the plants infected with *Sclerospora maydis* in Indonesia.

(1) Systemic symptoms at the early growth stages (Type I)

The initial symptoms were observed on the 1st or 2nd leaf. Leaves at the seedling stage showed small yellow-green streaks. In many cases, the lesions of the leaves were punctiform. Especially in Taiwan, the symptoms remained localized when the plants were infected with *Sclerospora sacchari*. In Indonesia, however, initial symptoms involved the veins, particularly in the case of the upper leaves (6th and 7th leaf) (see Plate 6).

As mentioned above, the symptoms appeared initially on the 1st or 2nd leaf with small or short streaks while no symptoms appeared on the 3rd to 4th leaves. With the emergence of the 4th or the 5th leaf, the leaves showed light yellow streaks. Generally, in this case, the symptoms on the 4th or 5th leaf were located only at the base of the leaves. The streaks on the subsequent leaves extended to the upper part of leaf and with the emergence of more leaves the streaks involved the whole surface of the leaf. The systemic symptoms (see Plate 7) appeared only when leaves had been infected prior to their emergence, and these symptoms did not develop further after leaf emergence.

The author investigated the relationship between the appearance of the symptoms and the time of infection. Conidia dispersed from neighboring infected maize germinated in the dew covering the 1st or 2nd leaf developed just after the germination of seeds and invaded immediately into the leaf tissue through stomata of leaf or sheath and plants showed the initial symptoms.

Harjono (1968)[27] confirmed the stomatal infection of *Sclerospora maydis* in maize. As shown by Weston (1920)[62], and Dalmasio et al. (1969)[19], the infection hyphae of *Sclerospora philippinensis*, after reaching the growing point through the tissues of 1st leaf, sheaths and culms, invaded the base of the 4th or 5th leaf which had just begun to elongate. Thereafter, the upper leaves began to show systemic symptoms (see Plate 7). In field observations, the author found few plants showing systemic symptoms at the 5th or 6th leaf stage without initial symptoms at the 1st or 2nd leaf stage. In this case, the author considered that conidia invaded the growing point directly through the coleoptile as reported by Kenneth & Shahor (1973)[32] in Sclerospora sorghi.

As mentioned above, the systemic symptoms at the early stages of growth were caused by the conidia, and it is assumed that the symptoms appeared when the tissues near the growing point were infected before leaf emergence.

(2) Systemic symptoms appearing at the middle or late stages of growth (Type II).

Maize plants with systemic symptoms at the later growth stages were observed (see Plate 8) at Vegetable Seed Farms in the villages of Singosari and Siampardjo, in Malang Prefecture. The percentage of infection of such maize plants was very low compared with that of type I infection. The author considered that in plants infected with downy mildew at the early stages of growth, the development of hyphae in the tissues of maize was slow.

Therefore, the hyphae reached the growing point of maize rather late and the plants showed systemic symptoms at the later stages of growth.

On the other hand in the beginning of the rainy season, since there were no maize plants within the area for at least a few kilometers, conidia could not infect maize plants. Consequently in these fields, it was very difficult to consider that the disease was transmitted by conidia originating from infected maize owing to the relation between the growth stage and the occurrence of the disease. On the other hand, in the preceding year a large number of maize plants had been infected with downy mildew disease in this field. Therefore, the source of infection could be traced to the oospores produced in the infected culms and leaves. Although these considerations remain hypothetical they are very important with respect to the mode of infection, as some aspects of the infection can not be explained only by conidial dissemination.

As a result, the existence of type I and type II in the appearance of the systemic symptoms in maize plants is presumably related to the time of infection. According to the author's classification, all the symptoms reported by Palm (1918)[44] (see page 8) can be included into type I infection and infected plants belonging to the type A of Palm's classification show systemic symptoms but are still alive and have not withered. Type C corresponds to the initial symptoms observed in plants inoculated at the 6th to 7th leaf stages.

3) Relation between the growth progression and the protective effect of fungicides.

Owing to the distinctive characteristics of downy mildew disease, fungicides cannot effectively protect maize plants from being infected, because fungicides cannot reach the growing point. There are many problems which should be solved in order to control the disease.

(1) Materials and methods

At the Corn Research Center located in Potzu, Chiaii in Taiwan, the author conducted some experiments on August 27, 1969 in order to investigate the relation between the growth pattern of maize under standard cultivation methods and the mode of infection.

(2) Results of the observations

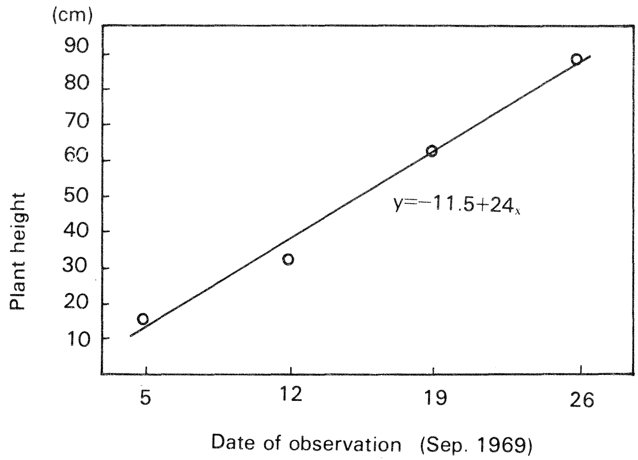
The temperture at the time of seeding averaged 27.5°C. The maize sown on August 30th germinated uniformly. Observations on plant height and on the progression of leaf emergence were made once a week and every day respectively. The results are shown in Figures 2 and 3. Plant growth averaged 24 cm per week, namely 3.5 cm per day. The progression of leaf emergence averaged 0.5 leaf per day.

(3) Relationship between the progression of leaf emergence and the protective effect of pesticides.

Kudo* reported in his letter that the progression of leaf emergence of maize was 0.25 leaf per day at the Tohoku Agricultural Experiment Station located in the north-eastern part of Japan (18.5°C average temperature, in the growing season). Compared with his data, the progression of leaf emergence in tropical areas seems to be about twice as rapid as in Japan.

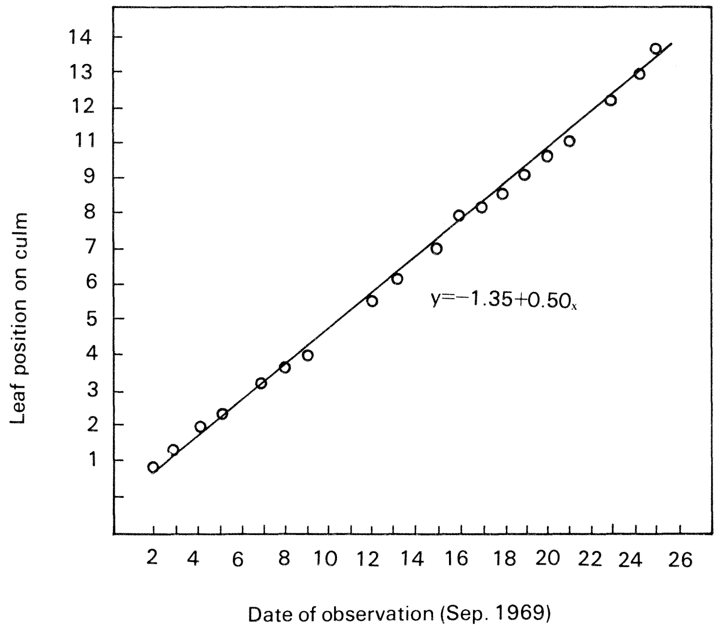
On the other hand, Palm (1918)[44] reported that fungicide spraying against downy mildew disease was seldom effective. However, in Taiwan, Sun et al. (1965)[54] reported that 4 kinds of fungicides were able to check the sporulation and germination of conidia in the laboratory. These are: dichloronaphthoquinone (2 types; Sankinon, Kikinon), Dinitro (1-mythyl heptyl)

* Personal letter of Makoto Kudo (Tohoku Agricultural Experiment Station)



y=−11.5+24x
X; weeks after planting Y; plant height (cm)
Maize was sown on August 27th, 1969
Temperature in August; 27.5°C Maize cultivar; Tainan No.5

Figure 2. Height of maize plants (Taiwan).



Date of planting, average temperature, maize cultivar as in Fig. 2.

Figure 3. Interval of leaf emergance in maize plant (Taiwan).

phenyl crotonate and associated nitro phenols (Kalathan), and manganese ethylene bisdithiocarbamate (Dithane M22).

In the field experiments, daily spraying of manganese ethylene disdithiocarbamate (Dithane M22) was found to protect a high percentage of plants effectively. Although in the loboratory the sporulation and germination were checked, complete control of the disease in the field was difficult to achieve even if daily spraying of fungicides was performed.

On the basis of these observations, author considered that the production of conidia on the infected leaves was checked only in parts of the leaves which were covered with the fungicide. As in tropical areas plants grow comparatively fast, in case of spraying with fungicides during day time, plant leaves were covered with fungicides but in the following night, a new portion of leaf was developed which was not protected by fungicides. Consequently, after one day, the newly developed leaves showed light yellow streaks as a result of the sporulation originating from conidiophores located in the stomata of leaves. The infection of the newly emerged leaves by conidia occurred during the night because no fungicides covered the leaves in spite of the spraying of the plant on the preceding day. The conidia germinated and invaded the tissues through the stomata of the newly developed leaf. Therefore, the second infection caused by the conidia originating from infected leaves could not be controlled unless fungicides were sprayed successively.

Recently, Kajiwara et al. (1975)[30] reported that the disease could be controlled by treating soil with Eclamezol (Pansoil). However, since it is very difficult to use this fungicide economically in maize fields, prevention of the disease by fungicides remains limited.

3. Occurrence and seasonal changes of downy mildew disease caused by *Sclerospora maydis* in Indonesia.

Maize sown mainly in the rainy season (October to March) is the first crop of the season. The damage due to the infection by downy mildew is not extensive in early-sown maize but becomes more severe in late-sown maize.

1) Materials and methods

The following experiment was conducted in one of the fields of the Cikeumeuh Plant Station of the Central Research Institute for Agriculture which was infected by conidia originating from maize contaminated by *Sclerospora maydis*.

Maize plants tested consisted of 2 varieties, Bogor composite-2 (BC-2) and Permadi (Bogor synthetic-2: BS-2) which were sown every 15 days from January 15th in 1972 to January 18th in 1973. The size of a plot was 4.0 × 4.5 m. The width of ridges was 75 cm between the rows, 20 cm between hills and there were 2 plants per hill. Random block method was used. The fertilizer contained 120 kg of nitrogen, 60 kg of phosphorus and 30 kg of potassium per ha. and was applied at the base of the hill.

2) Experiments and results

Climatic conditions at the Muara Plant Station of the Central Research Institute for Agriculture are shown in Table 4. The monthly average temperatures with the maximum temperature were in the range of 28°C in January and 32.7°C in October, and the minimum temperature was about 22°C during the period from January to May and 20.2°C in September and October. Also, there were few fluctuations in the average temperature throughout the year

Table 4. Climatic conditions in Bogor, Indonesia during the period. January, 1972 - June 1973.

Year	Month	Temperature °C monthly average			Monthly precipitation mm	Percentage of sunshine %	Wind velocity m/s	Relative humidity		
		Max.	Min.	Average				1:00 p.m.	12:00 p.m.	Average
1972										
	Jan.	28.0	21.9	24.3	459.0	25	-	-	-	84.7
	Feb.	29.7	22.3	25.3	351.0	47	-	-	-	79.0
	Mar.	29.0	22.1	25.1	554.0	29	-	-	-	82.0
	Apr.	30.5	21.9	25.2	615.0	69	1.35	75.0	94.0	-
	May	30.4	21.9	24.9	335.0	61	1.33	82.0	91.0	-
	Jun.	31.3	20.9	25.7	78.0	81	1.39	66.0	92.0	-
	Jul.	31.4	206.	25.2	68.7	89	1.71	63.0	87.0	-
	Aug.	31.7	21.2	25.6	92.5	79	1.47	67.0	90.0	-
	Sep.	32.5	20.2	26.1	41.9	85	1.75	56.0	91.0	-
	Oct.	32.7	20.5	26.4	291.0	89	1.80	56.0	95.0	-
	Nov.	31.5	21.5	25.7	549.0	70	1.58	66.0	95.0	-
	Dec.	30.0	21.8	25.5	518.1	66	1.54	73.0	95.0	-
Year Average		30.8	21.4			65				75.0
Year Total					3965.0					
1973										
	Jan.	29.2	22.0	25.0	481.0	33	1.48	81.0	96.0	89.0
	Feb.	29.5	22.0	25.0	638.0	47	1.45	81.0	96.0	90.0
	Mar.	29.6	22.1	25.3	365.0	41	1.46	81.0	95.0	89.0
	Apr.	30.7	22.4	26.2	517.0	49	1.24	71.0	95.0	85.0
	May	30.5	21.8	25.5	412.0	52	1.14	69.0	96.0	86.0
	Jun.	30.6	21.5	25.8	318.0	62	1.30	70.0	97.0	87.0

From "Agro-climatology for the years 1972, 1973" compiled by Division of Ecology, Central Research Institute for Agriculture No. 1, 2, 3.
The observatory was located in Muara, Bogor City, elevation: 260 m, longitude: 160°49′E, and latitude: 6°40′S. Climatic conditions in Muara and Cikeumeuh (Experimental field) were similar.

* Monthly average estimated from daily average.

(2.1°C as monthly average temperature).

The precipitation in 1972 averaged 396.5 mm, each month. However, heavy precipitation with more than 400 mm was recorded in January, March, April, November. Generally speaking, there was no definite dry season in Bogor. However, from June to September, the monthly precipitation was less than 100 mm and maize could not grow without irrigation during that season.

In contrast with the amount of precipitation the daylight ratio was less than 50 % from January to March and more than 80 % from June to October. The velocity of the wind registered the lowest values in May 1973 (1.14 m/s) and the highest in October 1972 (1.89 m/s). On the whole the velocity of the wind changed little and there was a breeze continuously throughout the year.

The humidity during daytime was one of the factors associated with seasonal changes. It was less than 70 % from June to November (from the end of the dry season to the beginning of the rainy season), and 56 % on the average in September and October at the end of the dray season. However, during the night the humidity was high throughout the year and was more than 90 % even in the dry season with the lowest record of 87 % in July.

The percentage of downy mildew infection is shown in Figure 4. The percentage of infected plants differed according to the varieties. Although BC-2 showed a higher percentage of infection than Permadi, there was no difference in the seasonal behaviour. As for the disease occurrence, the percentage of infection was low in maize planted early but increased in the late-planted maize.

There was a high percentage of infection at the planting time one month after the beginning of the rainy season. The percentage decreased in the middle of the rainy season but again increased at the end of the rainy season. Thereafter, a high percentage of infection was observed for a whole month during the dry season and after that the growth of the plants became poor. Germination was impaired as a result of the deficiency of water and the infection stopped.

The irrigation of the field from July 15th to September 15th, led to severe infection of the plants.

One the other hand, it is worth mentioning that the percentage of infection had decreased despite the fact that the maize had been sown late in the rainy season on April 15th. In this respect, the author observed in Taiwan that there was no conidial production even when it rained during the night. Therefore, on the basis of the results, the author recorded the amount of precipitation in Indonesia every 6 hours (Figure 5). Rain seldom falls continuously and in the daytime it is not damp. Generally it rains from 2 to 6 P.M. However, in April 1972, the amount of precipitation recorded from 6 to 12 P.M. totalled 175 mm for 10 nights while the total precipitation for the month amounted to 375 mm. The amount of precipitation in the night was about 40 % of the total monthly precipitation for April.

The author suggested that the low percentage of infection of maize planted on April 15 was due to a reduced production of conidia associated with heavy rainfall during the night.

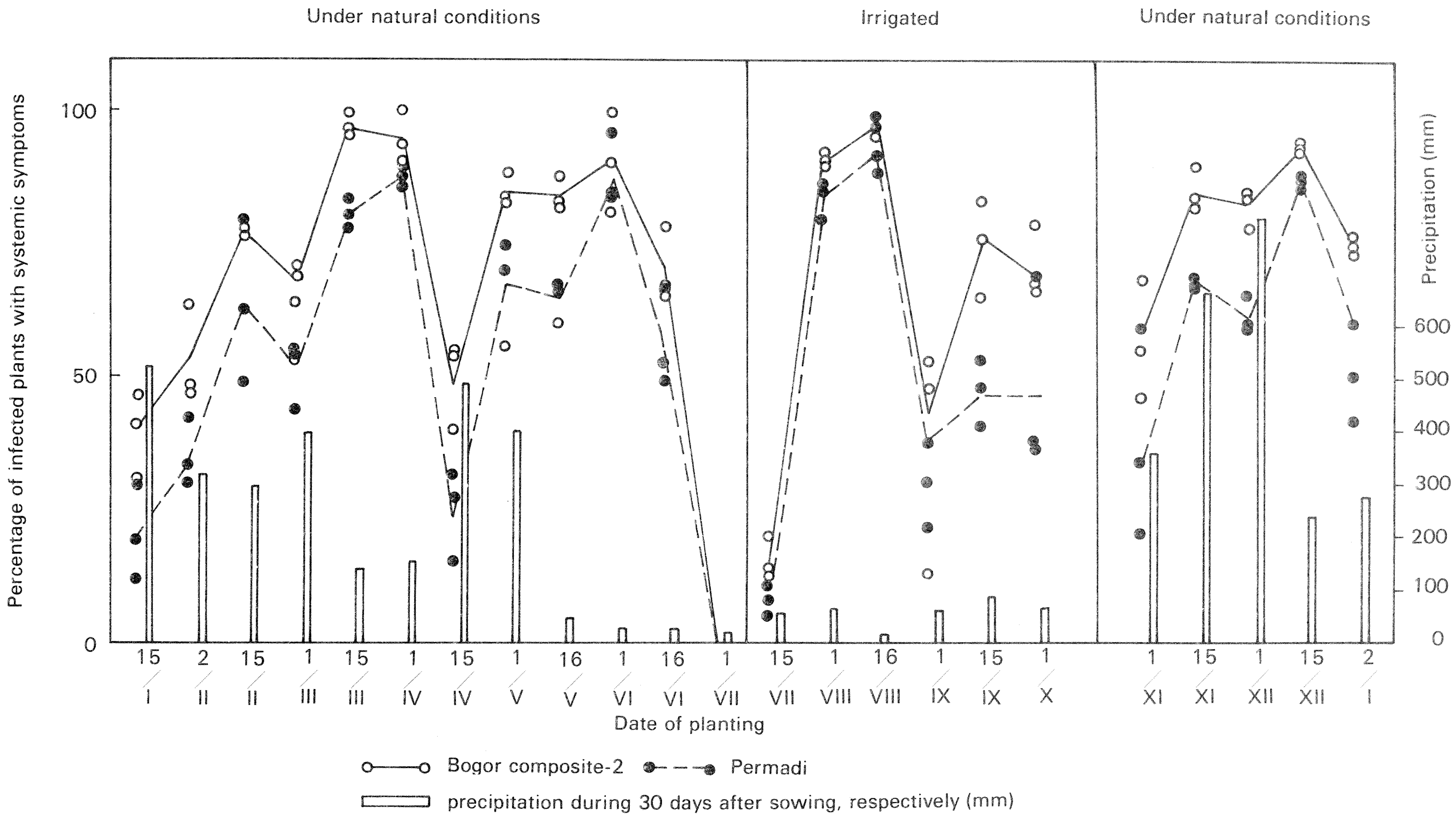
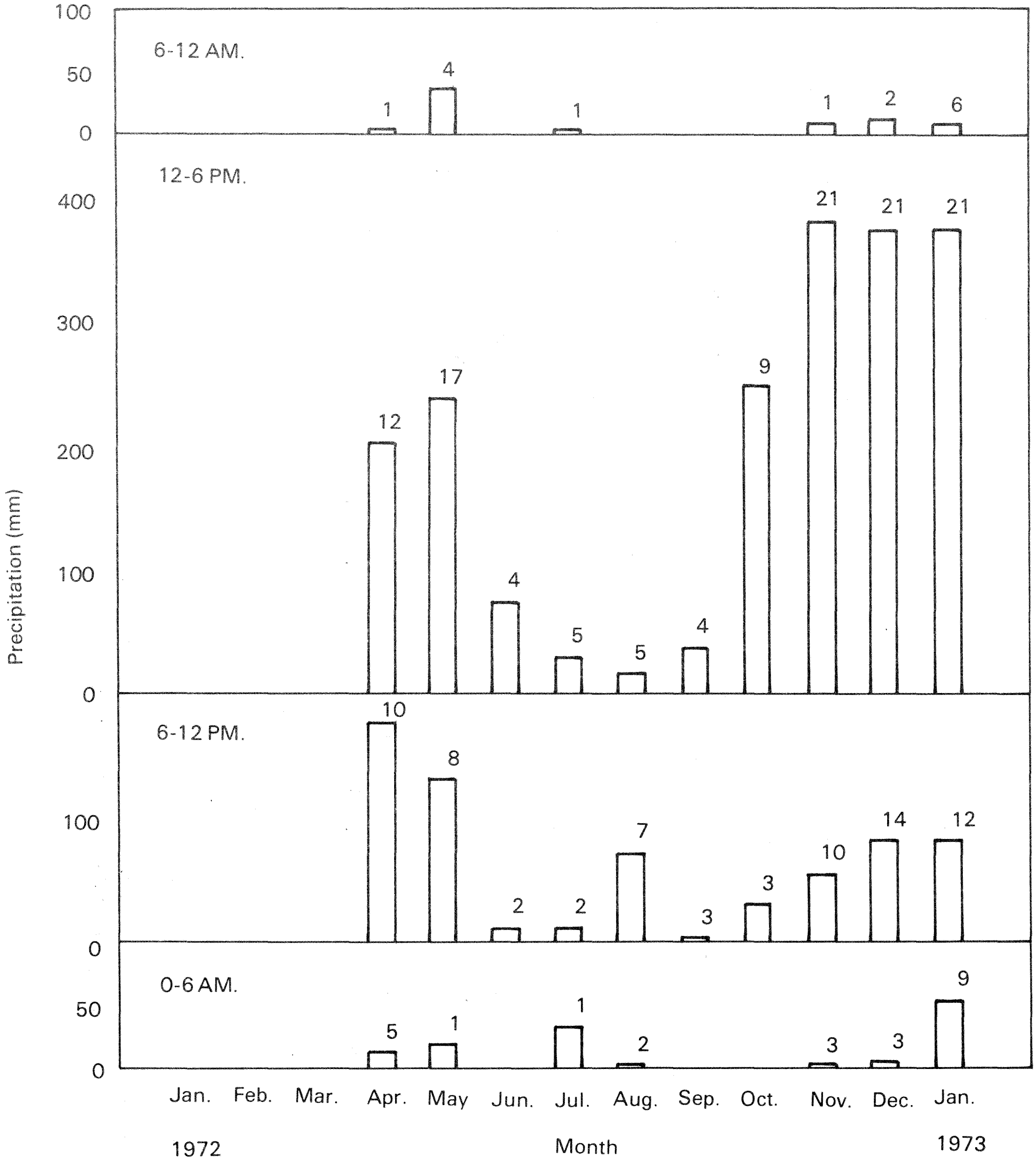


Figure 4. **Seasonal change of the percentage of infection with downy mildew-disease and planting date throughout the year.**



Note: Figures indicate the number of days with rainfall.

Figure 5. Modification of precipitation observed every 6 hours (monthly total).

3) Discussion

Downy mildew disease is mainly transmitted by conidia, Yang et al. (1962)[67], Exconde et al. (1967)[21], Matsumoto et al. (1964)[37] and Chang et al. (1969)[15] reported that the temperature required for conidial production should not be lower than 13°C, and higher than 31°C, the optimal temperature being 19 - 25°C. The opitmal conditions of humidity for conidial production are 95 to 100% and should not be lower than 86 % while those for conidial germination are 100 % (94 % minimum). Weston (1923)[64] reported that under natural conditions, the dew on leaves begins to condense around 7 to 8 p.m. and is present on both surfaces of the leaves around 10 to 11 p.m. At that time, the conidiophore starts to develop in the stomata of the leaves and conidia appear and grow at the top of the conidiophore. The conidia become mature at around 1 to 2 a.m. and conidial production becomes maximum at around 2 to 3 a.m.

Therefore, as the moisture level exceeds 90 % from the sunset on, conidia are produced during the night for 6 to 9 hours. After germination, they invade the leaves through stomata. In Indonesia (Bogor) the temperature seemed to be optimal for the production and germination of conidia throughout the year. During daytime the humidity sometimes decreased to 56 %. However, after sunset it increased rapidly up to 87 % to 97 % at 12 P.M. Generally, when the hygrometer was placed directly on the green leaves, during the night, the level of moisture was 5 to 7 % higher than when it was placed in the box, As a result, it could be assumed that the level of moisture in the filed during the night was more than 95 % in Indonesia. Also, the velocity of the wind was usually 1.3 to 1.8 m/s.

These environmental conditions seemed to be very suitable for the production of conidia and the occurrence of the disease throughout the year.

On the other hand, Miyake (1912)[43] reported that conidial production and disease occurrence were related to the amount of precipitation. However, as mentioned above the author had observed that the conidial production had atendency to slow down when heavy rain occurred during the night. The increase in conidial production during the rainy season was chiefly due to the optimum supply of soil moisture which bears a relation to the growth of maize although the amount of precipitation was not directly related to the acceleration of conidial production or to the occurrence of the disease. Although Miyake reported that the occurrence of the disease depended on the amount of precipitation, one may suggest on the other hand that such findings could be interpreted as a chance phenomenon, for instance conidia might have been transferred to an other field via the irrigation canal. However, these findings could not be applied to Indonesia as in this country, maize fields are seldom being irrigated.

The maize plants were sensitive to dry weather and excessive humidity. Although in this study, the author was unable to observe in detail the modifications of soil moisture, he could nevertheless demonstrate that the moisture level controlled the growth of maize and also conidial production as a source of infection. Then, the author interpreted the relationship between the amount of precipitation and the source of infection as follows: The percentage of infection was low in the beginning of the rainy season and gradually increased with the delay of the sowing time. In the middle of the rainy season, the growth of maize was slow and the percentage of infection fell owing to the decrease of conidial production as a result of the excess of soil moisture. The percentage increased again at the end of the rainy season. The disease seldom occurred when the soil was dry. However, the percentage was high in the fields where infection was induced. Also, the infection decreased when rainfall occurred during the night. To sum up, the occurrence of the disease was closely related to the changes of the environment and the growth of maize was affected by the level of soil moisture depending on rainfall which influenced the production of conidia.

4. Infection cycle of downy mildew of maize.

Effective control methods of this disease are lacking in the tropical countries of Asia. In this chapter the author discusses the infection cycle of downy mildew disease to establish suitable methods of control.

1) Relationship between conidial density and occurrence of the disease.

Since the infection occurred mainly through conidia, the author conducted the following experiments.

(1) Materials and methods

On March 1972 at the Central Research Institute for Agriculture in Indonesia, the maize cultivar, Harapan (susceptible one), was cultivated in unglazed pots measuring 25 cm in diameter and 30 cm in height. From March 7 to 10, 1972, 10 seeds of the test plants were seeded in each pot. The inoculation of downy mildew with varying conidial density took place on the 1st leaf of seedlings immediately after the emergence, i.e. from March 11 to 14, everyday.

Conidia for the inoculation were obtained from the infected leaf, kept above the layer of agar in the petri dish, and under humid conditions, for about 14 hrs at room temperature. The conidia formed on that infected leaf fell down naturally on the agar. The agar with conidia was separated into blocks containing 1, 5, about 10, 50, 100 spores, respectively, under a microscope. Then each block was put on the 1st leaf of maize. The inoculated plants were kept under high moisture conditions for about 24 hrs and then transferred to a net house. Determinations of the percentage of diseased plants showing systemic symptoms was carried out 1 month after inoculation.

(2) Results

Table 5 shows the results of the infection of the plants. The percentage of infection exceeded 90 % when more than about 50 conidia were inoculated. The lower the number of conidia inoculated, the lower the percentage of infection. However, 3 to 11 % infection was obtained even when only one conidium was inoculated.

(3) Discussion.

Miyake (1912)[43)] reported that the disease was transmitted by conidia carried by the irrigation and rain water as well as the wind. On the other hand, Leece (1941)[34)] reported that the wind and the water from rainfall accelerated the occurrence of the disease through transmission of conidia to plants and that conidia germinated immediately under high humidity and then invaded plant tissues via the germtubes.

Harjono (1968)[27)] also reported that the disease occurred following the invasion of conidia through stomata of plants, when conidia in dew dropped on maize seedlings. Rue* noted in Taiwan that the conidial production on the infected leaves amounted to 50.000 cm^2/day.

The author observed in Indonesia a conidial production totalling 30.000/cm^2/day. The author confirmed that the infection of maize could occur even with the inoculation of one conidium and that more than 50 conidia produced more than 90 % infection. Therefore the most important source of infection is represented by the conidia.

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* Rue Lee Shin, Personal Letter (1969, Taiwan Sugar Experiment Station)

Table 5. Relationship between the number of conidia inoculated and the percentage of maize plants infected with *Sclerospora maydis*.

Number of conidia inoculated per maize plant	Experimental plot	Number of plants infected/total I	II	III	IV	Total	Percentage of infection
1	1	1/9	0/9	1/8	2/9	4/35	11.4
	2	0/9	1/9	1/9	1/9	3/36	8.3
	3	1/9	0/9	0/8	0/9	1/35	2.8
	4	0/9	0/9	1/8	0/9	1/35	2.8
5	5	3/8	3/9	3/8	2/9	11/34	32.3
	6	2/9	4/9	3/9	4/9	13/36	36.1
10	7	5/9	7/9	6/8	7/8	25/34	73.0
	8	7/9	6/9	6/7	6/8	25/33	75.8
50	9	8/9	9/9	9/9	7/8	33/35	94.3
	10	9/9	8/9	9/9	8/8	34/35	97.1
100	11	8/8	8/9	8/8	8/8	32/33	97.0
	12	9/9	8/8	7/7	8/9	32/33	97.0

The date of planting, date of germination of maize, date of inoculation of conidia and date of observation were as follows:

Replication	Planting	Germination	Inoculation
I	Mar. 7th	Mar. 11th	Mar. 13th
II	Mar. 8th	Mar. 12th	Mar. 14th
III	Mar. 9th	Mar. 13th	Mar. 15th
IV	Mar. 10th	Mar. 14th	Mar. 16th

This experiment was conducted at the Division of Plant Pathology and Pest Control, Central Research Institute for Agriculture in Indonesia in 1972.
Maize cultivar Harapan, unglazed pots (25 cm in diameter; 30 cm depth).

2) Occurrence of the disease by menas of contaminated seeds from infected plants.

Although Ullstrup (1952)[57] reported seed transmission of the disease he did not elucidate its mechanism.

(1) Materials and methods

In 1973 experiments were conducted at the Cikeumeuh Plant Station of the Central Research Institute for Agriculture in Indonesia. Well ripened seeds obtained from maize (cultivar Harapan) infected with *Sclerospora maydis*, were divided into 2 groups: undried seeds with a moisture content of 34 %) and dried ones (with a moisture content of 18 %). The undried seeds were sown in plastic trays on January 18, 1973 in paddy field soil free from the disease agent. The seeds were also sown on June 22, 1973 in unglazed pots filled with soil. The dried seeds were sown on January 25, 1973 in trays containing identical soil after being dried in open air from January 18 to 24, 1973. Thereafter, observations for the development of the symptoms were made during 20 days.

(2) Results

The number of infected plants and the percentage of infection are shown in Table 6. Plants grown from fresh seeds sown on January 18 showed 100 % infection, whereas those from dried seeds sown on January 25th failed to become infected. In the plots sown on January 18th, fresh seeds germinated on January 22nd, and the 1st leaf stage was observed from January 23th to 24th, the 2nd leaf stage from the 25th to the 26th, and the 3rd leaf stage from the 27th to the 28th. These leaves showed the symptoms from the beginning of emergence, as shown in Plate 9, and the next day after leaves were fully expanded conidia were produced at the site of the lesions; thereafter the plants began to die. However, plants grown from dried seeds planted on January 25, began to germinate on January 29, and the 1st leaf stage occurred between January 31 and February 1. In this case, plants grew normally without any symptoms of downy mildew, but one seed failed to germinate. No infection developed even on February 25.

On the basis of these results, the author concluded that active hyphae existed in fresh seeds. However, in general, all the seeds of infected maize may not have hyphae. Then in 1975 the author conducted new experiments using seeds of 2 ears obtained from the infected maize plants. The results are shown in Table 7. Fifty % of infection occurred in plants grown from seeds obtained from ear No. 1 and 9 % in those from ear No. 2. According to these results, the author confirmed that the transmission of the disease through seeds may occur by using undried seeds obtained from infected maize plants. Secondary infection was induced by conidia formed on the plants.

(3) Ddiscussion

Kulkarni (1913)[33] reported that he failed to detect hyphae in ears of maize plants infected with *Sclerospora graminicola*. On the other hand, however, Ullstrup (1952)[57] reported that there were hyphae in seeds obtained from maize plants infected with *Sclerospora macrospora* and 31 % of the outbreaks of the disease were found to be due to seeds. Chang et al. (1965)[10] (1969)[14] reported, also that when fresh seeds of maize infected with *Sclerospora sacchari* were sown, 12 % of the plants became infected, while dried seeds from the same plants did not give rise to infection. Moreover, they reported that only when seeds with a humidity level ranging from 20.1 % to 55 % were sown, did the infection occur, whereas those with a humidity level of less than 20 % (dry seeds) or more than 55 % (immature seeds) did not give rise to infection.

These results are similar to those of the author's experiments, i.e. when dried seeds were sown, there was no infection, even if seeds were obtained from infected maize while fresh seeds whose percentage of water content varied with the ears gave rise to the infection.

From these results, the author considered that there was no difference between *Sclerospora sacchari* and *Sclerospora maydis* as far as seed infection was concerned. However, the author did not observe hyphae of the fungus in the seeds used in this study. Therefore, since the seeds used in the study conducted in 1973 were obtained from one ear selected at random, it is difficult to consider that hyphae were absent only in seeds which were air-dried, because seeds which were harvested directly from the field showed symptoms at the time of germination. Moreover, as indicated in the experiments conducted in 1975, the percentage of infection of germinated seeds varied with the ears and this phenomenon was undoubtedly related to seeds. As previously mentioned, dissemination of the disease can possibly occur through seeds, if undried seeds gathered from infected maize are sown. Therefore, if one wants to use seeds, seeds should be dried until they contain

Table 6. Difference in the percentage of infected of maize plants between sowing of dried seeds and fresh seeds obtained from plants infected with *Sclerospora maydis.*

Seeds*	Experimental plot	Number of seeds	Date of planting	Date of germination	Number of plants which germinated	Number of plants infected	Number of plants normal	Percentage of Infection
Fresh seeds	I	14	Jan. 18	Jan. 22	14	14 (Jan. 29)	0	100
	II	14	Jan. 18	Jan. 22	14	14 (Jan. 29)	0	100
Dried seeds	I	14	Jan. 25	Jan. 29	14	0 (Feb. 25)	14 (Feb. 25)	0
	II	14	Jan. 25	Jan. 29	13	0 (Feb. 25)	13 (Feb. 25)	0

* Fresh seeds (34% water content), Dried seeds (18% water content).

Table 7. Number of infected plants and percentage of infection, when fresh seeds obtained from plants infected with *Sclorospora maydis,* were sown.

Ear number*	Experimental plot	Number of seeds used	Number of plants germinated	Number of plants infected	Percentage of Infection
1	1	10	9	5	56
	2	10	6	3	50
	3	10	9	4	44
	4	10	9	4	44
	5	10	10	5	50
	6	10	9	5	56
	Total or Average	60	52	26	50
1	1	10	3	0	0
	2	10	6	1	17
	3	10	2	0	0
	Total or Average	30	11	1	9

* 34% water content in seeds of ear number 1, 37% water content in seeds of ear number 2.
Date of observation for infection was 2nd July.

13 to 14 % moisture. In this case, hyphae in seeds are destroyed and one can assume that seed infection does not take place. In some cases when infected maize bears ears of poor quality farmers leave them in the field and do not harvest them. In this case, there is a risk that seeds of maize carrying hyphae will germinate and become a source of infection. Therefore, it is important to avoid leaving ears of infected maize in the field.

3) Infection by oospores

The existnece of oospores as a sexual organ for propagation has been observed in *Sclerospora sacchari*[43] in Taiwan, *Sclerospora philippinensis*[1] in the Philippines and *Sclerospora sorghi*[45] in Thailand. However, with the exception of the North Sulawesi area in Indonesia, up to now the presence of oospores of *Sclerospora maydis* has not been detected. On the other hand, in the eastern part of Java Island in Indonesia, when maize was sown after the dry season which lasted for 3 to 5 months, a small percentage of outbreaks of the disease were sometimes observed. In this case it is unlikely that conidia constituted the primary source of infection and that the disease was propagated through seeds. The author attempted to determine whether there were other plants acting as a carrier of downy mildew disease in the vicinity of fields located in the eastern part of Java.

As result, *Axonopus compressus* (Swartz), an ever green plant has been noted from time to time to develop symptoms similar to those of downy mildew disease. In this plant the formation of conidia has not been observed, and oospore formation also remains doubtful. Although it is not clear whether oospores are formed in *Sclerospora maydis,* as in other spacies of *Sclerospora*, it is considered that if oospores were present they might become a source of primary infection. Since the existence of the oospore stage of *Sclerospora maydis* has not been fully investigated, further studies should be conducted to develop control measures of the disease.

4) Considerations on the process of infection and the infection cycle.

In many cases secondary infection of downy mildew disease of maize occurs via conidia and primary infection occurs seldom observed via seeds originating from plants infected with *Sclerospora maydis*. However, it is also necessary to consider the possibility of oospore infection.

Miyake (1912)[43], Leece (1941)[34] and Leu et al. (1959)[35] carried out research on the primary source of infection of downy mildew disease caused by *Sclerospora sacchari*. According to these authors, conidia and oospores were formed on sugar cane infected with downy mildew disease and also conidia were produced on teosinte. As the pathogenicity of these conidia and oospores to maize has been demonstrated experimentally, these plants can be considered as a source of primary infection. Chang (1966)[6] also demonstrated the formation of conidia on *Sorghum vulgare* which is native to Taiwan and on *Tripsacum dactyloides* infected with *Sclerospora sacchari.* Accordingly it is considered that these cereals once infected may play a role as infection source for maize. However, in Indonesia, there are no exmaples of infection of sugarcane and millet by *Sclerospora maydis*. Besides, *Tripsacum dectyloides* and Teosinte do not grow wild and are not cultivated. Therefore, in the area surveyed by the author there are no examples of infection of other crops or weeds with *Sclerospora maydis*. As a result, in Indonesia, it is doubtful whether these crops and weeds may play a role as the source of infection for maize which is not being cultivated during the long period of dry season. Therefore, further studies on the possibility of infection with oospores should be carried out. In Indonesia, ears of infected maize remaining fields in the case of repeated cultivation of maize, may possibly become a primary source of infection.

As stated above, a large number of conidia is formed on the upper leaves of infected maize. Since even one conidium can induce the disease and a high percentage of plants may be come infected with more than 50 conidia, secondary infection by conidia transmitted by air can easily occur. Moreover, in fields with repeated cultivation, if the preceding sowing of maize has been infected, and if seeds of these infected plants are left in the fields to grow like weeds large damage of maize can be anticipated as the infected seeds become the source of infection for maize.

5. Conclusion

In Indonesia, the disease is responsible to extensive damage and as there are no practical methods of control, in many cases, farmers plant the next crop in contaminated fields. Under such conditions, there is not room for the introduction of new technology. The aughor attempted to develop control methods and to investigate the mode of infection and the distinctive symptoms of the disease along with the damage produced.

From the onset, in the experiments relating to the damage caused by downy mildew disease of maize in Indonesia, more than half of the plants dies showing systemic symptoms while the remainder continued to grow. However, compared with healthy plants the growth was impaired, the leaves were narrow and elongated, the culm was thin and lodging was present at the end of the period of growth. In the plants with systemic symptoms, the percentage of ear production was remarkably low and it was evident that the production of grains was actually impaired.

These results which are similar to those reported by Exconde and Raymundo (1974)[25] indicate the potential damage caused by the disease as well as the similarity of the disease observed in Indonesia to downy mildew disease due to *Sclerospora philippinensis* in the Philippines. Observations of the disease enabled the author to demonstrate that the appearance of the symptoms and their general characteristics could be classified into two types depending on the stage of growth of plants. For instance, systemic symptoms were observed in the beginning (Type I) and in the middle of the period of growth (Type II). Compared with Types A, B and C reported by Palm, Types A and B corresponded to Type I described by the author, while in Type C there were no systemic symptoms but only small streaks developed in the beginning of the infection. The author discussed the relationship between the stage of growth and the symptoms in adding Type II to Palm's classification. The emergence of leaves was advanced by 1 to 2 days in humid tropical areas than in temparate areas. The precocity of plants was the main reason for the difficulty in the prevention of the disease by the use of drugs. The need for systemic fungicides to inhibit the growth of hyphae in plant tissues was discussed.

It was then demonstrated that outbreaks of downy mildew disease in Indonesia were not frequently observed in maize sown in the beinning of the rainy season and that the seasonal changes of the disease outbreaks were related to the amount of water from precipitation, the level of humidity and to the temperture, since seeding takes place all the year round. In other words, as in Indonesia the temperature and the level of humidity are suitable for annual outbreaks of the disease, outbreaks were not observed only when the growth of maize plants was poor even in the rainy season, under unfavorable soil conditions. In the dry season, there were only a few outbreaks of the disease except when irrigation was applied. On the other hand, in the beginning of the rainy season, outbreaks of the disease were seldom observed because the amount of conidia which are the main source of the dissemination of the disease was small owing to the small number of infected plants. Later on, in the rainy season, outbreaks became more frequent since a large number of conidia were produced. Moreover, the decrease in the outbreaks in the middle of the rainy season, was thought to be due to the large amount of rainfall during the night leading to the decrease in the formation of conidia. In short, in Indonesia, it appeared difficult to avoid outbreaks of the disease through modification of the period of cultivation of maize. On the other hand, seed transmission is also recognized, because outbreaks occurred when undried seeds from infected maize were sown whereas outbreaks never occurred when seeds were dried up to a water content of 18 %.

In Indonesia, provided that the seeds do not contain more than 13 % of water, epidemics of downy mildew disease are not usually induced by seeds. In Indonesia farmers usually plow the fields without removing seeds from infected maize. In such cases there is a serious risk that seeds of maize carrying hyphae of the causal fungi may become a source of infection at the time of seed germination, causing the primary infection. Although in Taiwan, the Philippines and in Thailand oospores of downy mildew disease of maize have been observed, in Indonesia, up to now oospores of *Sclerospora maydis* have not been identified. In the eastern part of Jave, the author observed outbreaks of the disease which were not considered to be due to the infection by conidia or seeds. The source of infection was probably represented by drought-resistant organs of the causal fungus including oospores. On the basis of the experiments described above, the author described the sequence of infection shown in Table 6.

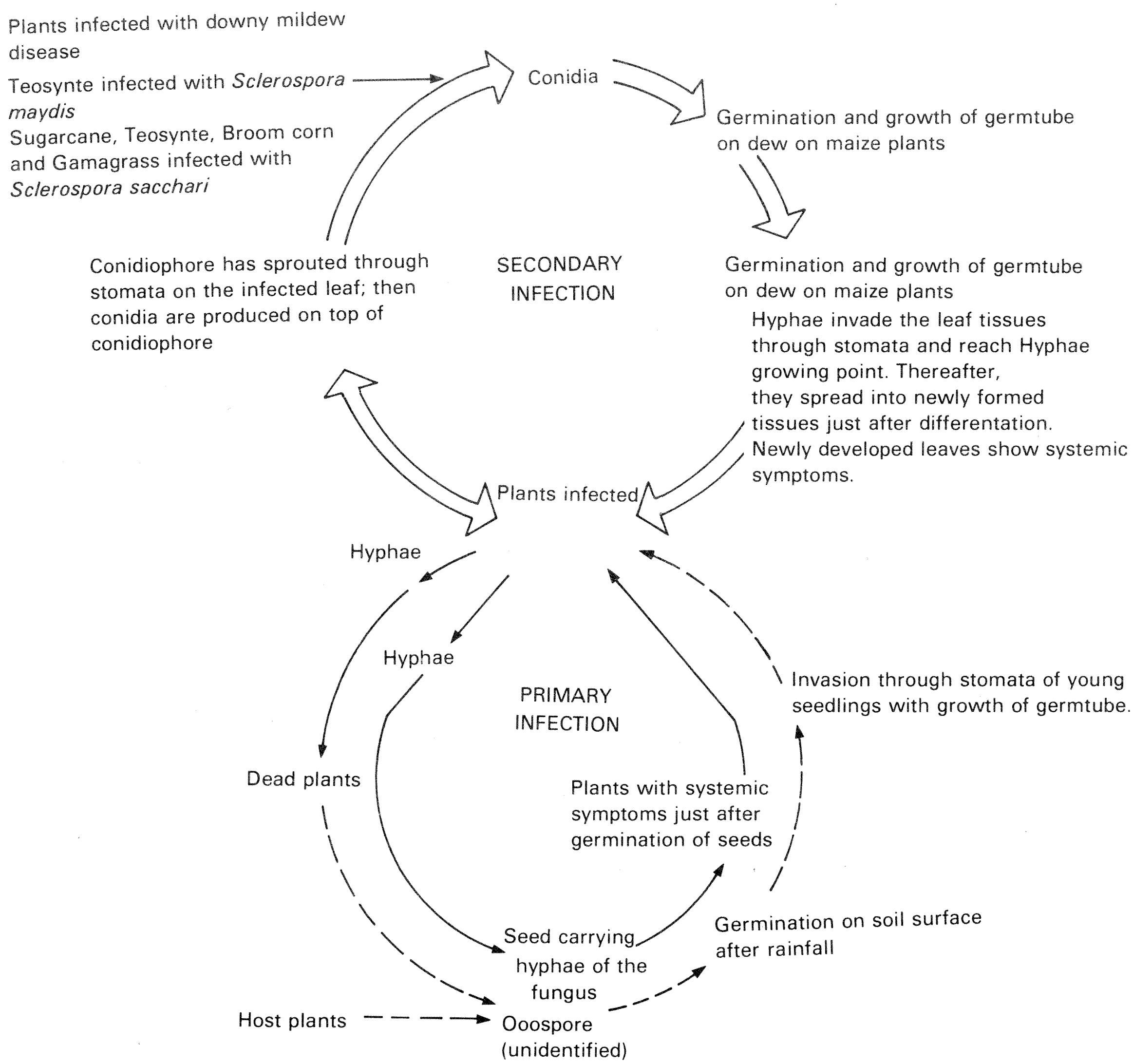


Figure 6. Hypothetical infection cycle of maize downy mildew.

Note; ═ secondary infection cycle
— primary infection cycle
-- hypothetical route

II. Control Methods of Downy Mildew Disease of Maize

As mentioned in Part I, the disease is responsible for considerable damage of maize in the tropical countries of Asia. Recently studies have been promoted in Taiwan, the Philippines, Indonesia and Thailand to establish methods of control for the disease. In Taiwan and the Philippines, chemical control has already been attempted but no effective methods have been devised hitherto.

Chang and Wu (1970)[15] reported that when maize seedlings grew vigorously following irrigation and the application of fertilizers rich in potassium and nitrogen they could be protected from the disease. On the other hand, in 1973, the Division of Agronomy of the Central Research Institute for Agriculture, in Bogor, Indonesia reported that the application of fertilizers containing the usual amount of nitrogen, phosphorus, potassium and micro-elements did not affect the outbreak of the disease.

On the basis of experiments conducted in the framework of the Maize Development Project in East Jave (1972)[28], it was reported that neither the thickness of soil covering seeds nor variations in the height of the ridges at sowing time prevented outbreaks of the disease.

In Taiwan, since suitable methods for controlling the disease are lacking, increase of maize production was recommended. In 1964, there was a widespread outbreak of the disease and in November of this year, the government prohibited the cultivation of maize hence forcing the farmers to cultivate other crops.

As mentioned above, control of the disease is difficult, and the only reliable method is the use of resistant varieties. In the Philippines, Indonesia and other tropical countries of Asia, therefore, breeding of resistant varieties of maize is being promoted.

In view of the present situation the author conducted several experiments aimed to control the disease from the angle of dissemination by conidia.

1. Relationship between the dissemination of conidia and the infection by *Sclerospora maydis* in Indonesia

1) Experiments conducted in Bogor

(1) Materials and methods

Experiment 1.

In October 1972, the following experiment was conducted at the Cikeumeuh Experiment Station of the Central Research Station for Agriculture located in Bogor, Indonesia.

The maize plants present in rows planted on October 10th, 1972 which showed systemic symptoms caused by *Sclerospora maydis* were used as the source of infection. Test plants belonging to the variety Bogor Composite No. 2 were sown on November 2, 1972 in 12 rows parallel with the rows of infected plants with a distance of 3 m, 3.5 m, 4 m, 7 m, 7.5 m, 8 m, 11 m, 11.5 m, 12 m, 15 m, 15.5 m and 16 m respectively. Standard amounts of fertilizer were applied. Each plot consisted of one row measuring 10 m in length. The spacing of the hills was 20 cm between the plants and there were 2 plants per hill. Seven replications were performed.

Experiment 2.

From November 1972 to June 1973, at the Cikeumeuh Experiment Station, test-plots in paddy fields and in cassava fields, which were 300 m apart from the maize fields to avoid the infection with downy mildew disease were selected. Each plot averaged 1.073 ha (plots 1 and 2) and 0.967 ha (plot 3) respectively. In the center of each plot, maize plants (3 plants) infected with *Sclerospora maydis* were transplanted as the source of infection.

The test plants belonging to the susceptible variety Harapan were sown and the number of infected plants observed is indicated in Table 9. The spacing of the plants was 50 cm between the rows and between the hills, with 1 plant per hill. Fertilizer application was similar to that described in Experiment 1.

(2) Results

Experiment 1.

The seeds germinated uniformly on November 6 in the respective plots. By November 8th plants had developed fully into the second leaf stage and systemic symptoms commenced to appear on November 15th. The meteorological data during the period are shown in Table 8. Maximum, minimum and average temperatures during November were 31.5°C, 21.5°C and 25.7°C, respectively.

The monthly precipitation recorded was 549 mm in total and the ratio of daylight hours was 70 %. The humidity recorded during daytime was 66 % and 95 % during the night. The velocity of the wind averaged 1.58 m/sec. These meteorological conditions seemed to be conducive to the growth of maize and the establishment of the infection.

The results of the observations made on November 20th and 21st are shown in Figure 7. The percentage of infected plants within a distance of 3, 3.5, 4 and 7 m from the source of infection was 30.2 %, 27 %, 19.7 %, 17.3 % on the average respectively. The percentage of infection decreased with the distance and was only 7.8 % when plants were 16 m apart from the source of infection. The results suggest that the incidence of the disease transmitted by conidia took place only in a limited area and the presence of a breeze seemed to be necessary, as usually observed in Indonesia. The author, therefore, conducted the following experiment.

Experiment 2.

Plants infected with *Sclerospora maydis* were planted in three plots on February 28, April 26, and April 26, respectively. The test plants were sown on March 1 (plot 1), May 2 (plot 2), April 30 (plot 3). Germination of the test plants was observed on March 6 (plot 1), May 7 (plot 2) and May 5 (plot 3). The first symptoms appeared in test plants on March 19 (plot 1), May 19 (plot 2) and May 18 (plot 3), respectively, and the observation ended on April 28 (plot 1) and June 18 (plot 2 and plot 3). These data are summarized in Table 9. The test plants grew well and the systemic symptoms began to appear 18 days after germination.

As shown in Table 10, the temperature during the peiod averaged 25 to 26°C with a maximum of about 30°C and a minimum of 21 to 22°C. The humidity was 70 to 80 % in the daytime and about 95 % during the night, and the velocity of the wind was in the range of 1.0 to 1.5 m/sec. Daylight ratio was 40 to 60 % as a result of rainfall in the daytime. As mentioned above, these climatic conditions were conducive to the infection of the plants. The relation between the distance separating the plants from the source of infection and test plants which showed systemic symptoms was analyzed. Thereafter, infected plants were removed from the field so as to avoid secondary infection.

As shown in Table 11, in plot 1, the first symptoms were observed on March 19th, and the number of infected plants increased every day until March 29th.

Table 8. Climatic conditions during Exp. 1 at Bogor in November 1972.

	Temperature (°C)			Precipitation	Relative-humidity (%)		Wind velocity	Percentage of day light hours
	Max.	Min.	Average	(mm)	12:00 a.m.	12:00 p.m.	(m/sec)	
1st 10 day-period	32.6	21.2	26.5	233.8	58	94	1.83	86
2nd 10 day-period	31.1	21.9	25.5	129.1	71	95	1.57	66
3rd 10 day-period	30.7	21.4	25.1	186.1	70	95	1.33	55
Average or Total	31.5	21.5	25.7	549.0	66	95	1.58	70

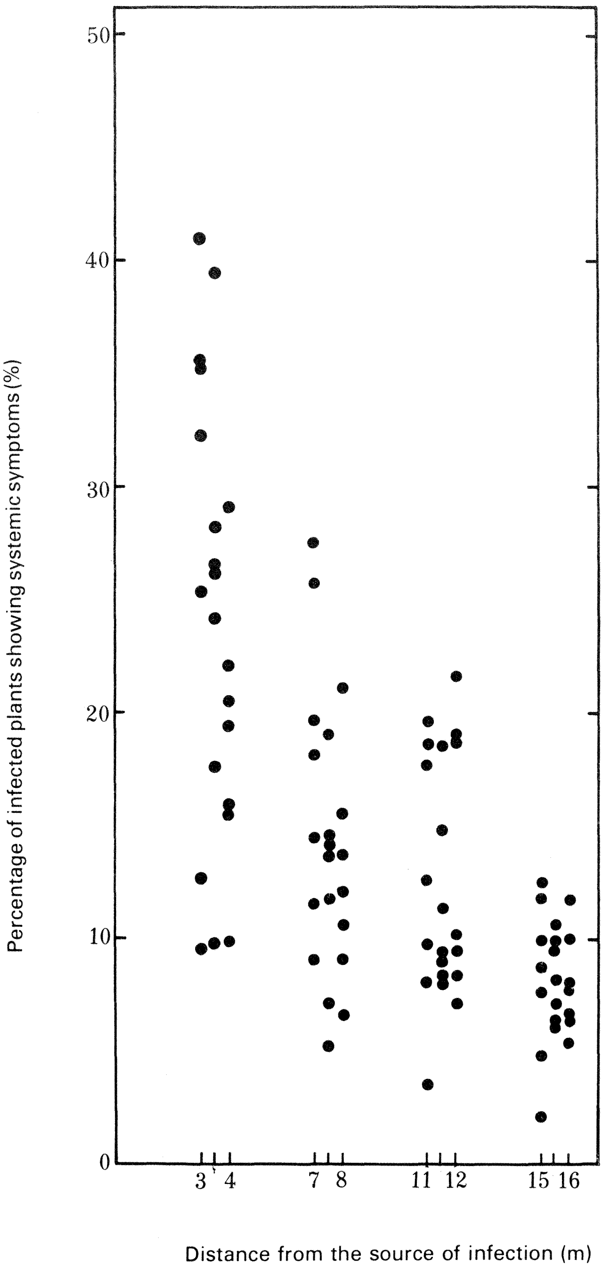
Source: Cited from "Agro-climatology" compiled for the year 1972 by the Division of Ecology, Central Research Institute for Agriculture, 1, Bogor, 1973.
The observation station was located at Muara, Bogor, elevation: 260m, longitude: 160°49'E, latitude 6°40'S.
*: 10-day average calculated from a day average.

*1978

Table 9. Conidial dissemination at Bogor in 1973 (Exp. II).

	1st replication	2nd replication	3rd replication
Date of transplanting*	Feb. 28th	Apr. 26th	Apr. 26th
Date of sowing of test plants	Mar. 1st	May 2nd	Apr. 30th
Date of germination (more than 60% of the plants)	Mar. 6th	May 7th	May 5th
Date of first observation for infection	Mar. 19th	May 19th	May 18th
Date of final observation	Apr. 25th	Jun. 18th	Jun. 18th

* Date of transplanting of inoculated plants as a source of infection.



Maize cultivar; Bogor composite-2
Date of sowing; November 2nd, 1972
Date of observation; November 20th, 21st 1972

Figure 7. **Relationship between the percentage of maize infection caused by *Sclerospora maydis* and the distance from the source of injection in Bogor in 1972.**

Table 10. Climatic conditions during the period from March to June 1973 at Bogor.

		Temperature (°C) (10 days average)			Precipitation 10 days	Relative humidity (%)		Wind velocity*	Percentage of days light hours
		Max.	Min.	Average	(mm)	1:00 p.m.	12:00 p.m.	(m/sec.)	
March	1st 10 day-period	29.7	22.2	25.1	149.0	84	96	1.33	33
	2nd 10 day-period	29.1	22.5	25.5	96.0	80	93	1.52	43
	3rd 10 day-period	29.9	21.6	25.3	120.0	81	95	1.50	46
	Average or total	29.6	22.1	25.3	365.0	81	95	1.46	41
April	1st 10 day-period	30.8	22.5	26.0	110.0	74	96	1.19	47
	2nd 10 day-period	30.9	22.2	26.4	282.0	67	96	0.99	64
	3rd 10 day-period	30.5	22.6	25.8	125.0	72	94	1.36	37
	Average total	30.7	22.4	26.2	517.0	71	95	1.24	49
May	1st 10 day-period	30.7	22.4	26.1	189.0	68	96	-	•58
	2nd 10 day-period	30.6	21.7	25.3	153.0	67	96	1.14	52
	3rd 10 day-period	30.4	21.5	25.2	70.0	73	97	1.14	45
	Average or total	30.5	21.8	25.5	412.0	69	96	1.14	52
June	1st 10 day-period	30.0	21.9	25.6	73.0	72	98	1.17	49
	2nd 10 day-period	31.3	21.6	26.4	26.0	67	95	1.32	77
	3rd 10 day-period	30.5	21.2	25.4	183.0	69	98	1.41	62
	Average or total	30.6	21.5	25.8	318.0	70	97	1.30	62

From "Agro-climatology" compiled by the Division of Ecology, Central Research Institute for Agriculture, Nos. 2 and 3, Bogor, 1973.
The observation station was located in Muara, Bogor, Elevation: 260m, longitude: 160°49′E, latitude: 6°40′S.

Table 11. Relation between the number of infected plants and the distance from the source of infection of the downy mildew of maize caused by *Sclerospora maydis* (plot No. 1, Experiment 2 in Bogor).

Distance from the source of infection (m)	Date of observations																																						Total number of infected plants
	March													April																									
	19	20	21	22	23	42	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
0-1				1											1					1																			3
1-2		1		1	1				1			2				1	1			1																			9
2-3		1		4					1			7	1			1							1	1	1														18
3-4		1		1	1	1						7	3	1	1	1						1					1		1										20
4-5		2	1			1		1				11	3	1	1		2			1		1			2											1			28
5-6		1		2	1			1				5	2	1		2				2				1	1	1	2		1				1						24
6-7	1				1						1	5	2	3	1	3								1			2								1				21
7-8			2			1					1	4	2						1	2				3			2		1		1								20
8-9	1			1							3	2	7	2	3	5		1	1	2									2	1									31
9-10			1			3		2	1		4	3	8	4	3	2		1																					32
10-11		1				1					2	7	7	4	3	1								2		1	1				1	1			1		1		34
11-12		1				1			1			1	1	6	1	2	3	1							2			1	1			1							23
12-13			1	1		1		1			2	1	3	2	3	2					1			1	1		2					1							23
13-14												1	2	6		2		2		1	1			1	1				2							1			20
14-15			1			2					1	1	1	7	1		1	1	1		1			2			1	1	1										23
15-16						4		1			1	1		6	1	1	1			1				1	1		1					1				1			22
16-17									1			1	1	3	2	2	1			2					1	1	1												16
17-18						1		1			2	2		2	2	2		1						1					1	1	1		1			1			19
18-19		1				2					2		2	4	1	2	2			1						1									1				19
19-20								1			1	2	1	2	2	2									1		1	1	1			1		1			1		18
20-21								1						3	1	2	1			1					1			1		1		1					1		14
21-22											1	3	1	1	1	3			1	1												1				1			14
22-23				1							1		1	2	2		2	1		1												1							12
23-24												1	2	3		2		1						1	1	1		1											13
24-25												2			1	2	2		1		1		2	1	1	1													14
25-26						1						1		2	3		2		1	1												1				1			13
26-27												2	1	1	1	1	1								1		2			2									12
27-28		1				1								2		3																			1				8
28-29								1				1	1	2					1								2												8
29-30																																							
30-31													1		2	2															1								6
31-32												1	1			1							1		1							1							6
32-33						1								1	2					1																			5
33-34		1							1			1			1	1																							5
34-35												1				1						1														1			4
35-36												1		1		1																							3
36-37											1			1			1																						3
37-38									1		1			1																									3
38-39												1			1																								2
39-40																	1																						1
40-41																																							0
41-42																																							0
Total number of infected plants	2	11	6	12	4	21	0	10	7	0	24	78	54	76	43	50	22	9	7	19	4	3	4	17	16	6	18	5	12	5	4	10	2	1	4	7	3	0	576

Figure indicates the number of infected plants showing systemic symptoms. This experiment was conducted in 1973.

Table 12. Relation between the number of infected plants and the distance from the source of infection of downy mildew of maize caused by *Sclerospora maydis*. (*plot No. 2 experiments 2 in Bogor*).

Distance from the source of infection (m)	Date of observation																														Total number of infected plant
	May														June																
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
0-1				5																											5
1-2		7		3			3								1																14
2-3		12		10			3		1		1	2					1														30
3-4		3		9	1		11			2	1	1		2			1						1								32
4-5		3		13	1		5			4	1	2			2																31
5-6		6		4	5		8			5		4		4	2		2			2											42
6-7				4	4		6			7	1	3		5	1		1		1	3											36
7-8				6	1		11			8		4		2	1		2			2			1		1			1			40
8-9		3		9	1		5			4		3		3	2		5		1		1		1								38
9-10				8	5		4		2	4		3	1	2	1		7			4	1		1	1			1				45
10-11		1		2	1		11			1		6		3	3		7	1			1		2		1						40
11-12				6	3		9			3	1	1	3	3	3	1	2	1	1	4		1			1						43
12-13		1		4	2		6	1	2	6		6	2	1	2		4				1		1								39
13-14		1		6	1		7			9		2		2	2		3		2	1											36
14-15				2	1		6			1		3	1		2	3	1	1		3		1	1	1		1			1		29
15-16		5		4	1		7	1		2		3	1	2	1		3	1			1		1								33
16-17		2		4			5			3		5		2	4	1	3	1	1		1		1								33
17-18		1		2	2		8		1	4		4		3			1		2	1	1		1				1				32
18-19				4	1		8			5		3	1	3	1		1			2	1	1				1					32
19-20				2	6		7			3		1			3	2	3	1		1			1	1			1				32
20-21				2	4		3			4		1	2	2	1	1	4		1	1	1			1							28
21-22		2			2		7			4	1	1	1	3	3			1	2	1			1								29
22-23				2			4			4		1		3	1	1	2			1	1		1								21
23-24				1	2		2			3	1	3		4			3	2	1	2											24
24-25				4			2			3				1	1	2	1	1	1	1	1		1								19
25-26		1		3	1		4		1	2		2		2				1		2											19
26-27				1			2			1		2	2	3	1	1	1			1	1		1								17
27-28				2	1		1			1	1	2		1		1	1	1	1		1				1						15
28-29				1	1		4		1	1		1	2	1	1		2	1													16
29-30				1			1			2		2		1	2		2		1		1			1							14
30-31				2			4					1			1		1			2			2								13
31-32							3			1	1	3		2			1						1								12
32-33				1	1		1					1	1		1	1	4			1											12
33-34							4			2													1								7
34-35		2		1			1			1		2			1			1													9
35-36										3					1		3						1								8
36-37				1	1		2					1		1																	6
37-38							1		1			1					1														4
37-39							1			1					1																3
39-40					1																		1								2
40-41							1			1																					2
41-42																				1											1
Total number of infected plants	0	50	0	129	50	0	178	2	9	105	9	80	17	61	46	14	73	14	15	36	14	3	22	5	4	2	3	1	1	0	943

Figure indicates the number of infected plants showing systemic symptoms. This experiment was conducted in 1973.

Although several infected plants were observed until April 3rd, their number decreased and the infection persisted until April 24th. Thereafter no infection was observed.

Thirty four plants which showed the maximum degree of infection were observed within a radius of 10 to 11 m around the infection source, and the percentage of infection decreased gradually with the distance. The infection was not observed in an area 40 m apart from the infection source.

As shown in Table 12, in plot 2, the symptoms were observed from May 19th, and on May 24th, the number of infected plants reached the maximum i.e. 178 plants/day. Thereafter, the percentage of infected plants decreased gradually and the infection ceased on June 15th. No infection was observed within a radius of 42 m from the source of infection.

As shown in Table 13, in plot 3, the first symptoms were observed from May 18th to June 8th. Thereafter, no infection was noted. The number on infected plants amounted to 33 within a radius of 10 to 11 m, and decreased gradually with the distance. No infected plants were seen within a radius of maore than 38 m from the source of infection.

The relationship between the percentage of infection and the distance from the source of infection in the 3 plots is shown in Figure 8. The highest percentage of infected plants was observed within a 3 m distance from the infection source in the three plots. Less than 1 % infection occurred in plants located beyond 29 to 30 m radius in the case of plot 1, 35 - 36 m radius in the case of plot 2, and 25 to 26 m radius in the case of plot 3, respectively. No infection was noted, if the distance was 40 m in the case of plot 1, 42 m in the case of plot 2 and 39 m in the case of plot 3, respectively.

2) Experiments conducted at Cibadak

In Indonesia, it was generally considered that the disease did not occur in areas located at an elevation of more than 800 m, and since the elevation at the Cibadak Plant Station is 1050 m, natural incidence of the disease did not take place. To determine the relationship between the climatic conditions and the occurrence of the disease, the author selected an area without infection to determine the range of dissemination of the conidia of the causal fungus.

(1) Materials and methods

The experiment were conducted in the paddy fields of Cibadak Plant Station (longitude 107°01′ East, latitude 7°00′ South) where a drainage system had been built. The surface area of the plots measured 900 m^2. In the center of the plot, 3 plants infected with *Sclerospora maydis* were transplanted as a source of infection. Around them, seeds of the maize cultivar Bogor composite-2, were sown on September 20th 1972 with 2 replications. The distance between the rows was 50 cm and between the hills 30 cm. The observations were performed every day after the germination of seeds to record the first appearance of the systemic symptoms.

(2) Results

Conidial formation was observed on the infected plants transplanted as a source of infection on September 23th. On September 25th, the test plants germinated uniformly and grew normally. According to the data recorded at the Horticulture Experiment Station located near the test field the weather conditions (Table 14) were as follows. The maximum temperature was 26.2°C, and the minimum temperature 16.6°C in October 1972. The average

Table 13. Relation between the number of infected plants and the distance from the source of infection of the downy mildew of maize caused by *Sclerospora maydis* (plot No. 3, Experiment 2 in Bogor).

Distance from the source of infection (m)	Date of observation May 18	19	20	21	22	23	24	25	26	27	28	29	30	31	June 1	2	3	4	5	6	7	8	9	10	Total number of infected plants
0-1																									0
1-2	5	1		4			1		1			2		1			2								17
2-3	2	3		6			3		3		1														18
3-4	2	5		8	1		4		5			3		2		1	1								32
4-5	2	4		3			8		1	1				1		1									21
5-6	2	1		5	2		3		4	2							2								21
6-7	4	5		3	2		5			1		5					2								27
7-8		8		2	2		4					1	1	3			2								23
8-9	1	3		3	4		6			1		1		6			4								29
9-10	3			2	3		6			3		3		3											23
10-11	3			4	2		7			4		4		4			3		1		1				33
11-12		4		6	1		4		1	2		4		3			5								30
12-13	1	3		2	3		9			1				5	1		1								26
13-14	1	3		2			8			2	1	1		2			2								22
14-15	1	1		3			7		1			2	1	3			2				2				23
15-16				3	5					3	1	1					3			3					19
16-17		4		1	1		1	2		1		1		2			3				1				17
17-18		1		3			3		4		1	1		4			1								18
18-19		1		5	1		2		1			2		1			3								16
19-20		1		2	4		2		1			3		1			2								16
20-21		2		1	1		1		1	2	1	1		2			2								14
21-22		2		1	1		3			1				1			2								11
22-23	1	1		1			3			2		1					1								10
23-24					1		1		1								2		1		1				7
24-25		2					1			1		1	1				1								7
25-26				1	1		1					1		2											6
26-27									1					1			1								3
27-28							1										1				1				3
28-29							1					2													3
29-30							1		1								1								3
30-31				1																		1			2
31-32		1		1																					2
32-33														1											1
33-34																	1								1
34-35																									0
35-36														1											1
36-37																									0
37-38												1													1
38-39																									0
39-40																									0
40-41																									0
41-42																									0
Total number of infected plants	28	56	0	73	35	0	96	2	26	27	5	41	3	49	1	2	50	0	2	3	6	1	0	0	506

Figure indicates the number of infected plants showing systemic symptoms. This experiment was conducted in 1973.

Table 14. Climatic conditions at Cibadak during the period extending September - November, 1972.

		Temperature °C 10 days average			10-days Precipitation	Relative humidity %		Wind velocity*	Percentage day light hours
		Maximum	Minimum	Average	mm	1:00 p.m.	12:00 p.m.	(m/sec)	
September	1st 10 days	24.4	14.6	21.0	0	55	85	1.44	68
	2nd 10 days	25.0	15.4	21.4	58.0	52	86	1.67	77
	3rd 10 days	25.2	15.6	21.5	0	66	94	1.60	77
	Average	24.7	15.2	21.4		58	88	1.60	74
	Total				58.0				
October	1st 10 days	26.1	-	22.5	11.0	51	87	1.49	77
	2nd 10 days	26.4	16.2	23.0	0.5	51	86	1.69	90
	3rd 10 days	26.1	16.9	22.8	75.1	59	83	1.55	75
	Average	26.2	16.6	22.8		54	85	1.58	80
	Total				86.6				
November	1st 10 days	26.7	15.5	23.3	78.5	53	83	1.57	82
	2nd 10 days	25.4	16.6	22.1	137.2	66	90	1.36	58
	3rd 10 days	34.7	17.2	21.4	129.0	80	92	1.39	50
	Average	25.6	16.4	22.2		66	88	1.46	64
	Total				344.7				

Source: "Agro-climatology" compiled for the year 1972 by the Division of Ecology, Central Research Institute for Agriculture, No. 1 Bogor, 1973.
The station of observation was located in Cipanas, West Java, elevation: 1100m, longitude: 109°'E, latitude 6°45'S.
* 10 days average calculated from a day average.

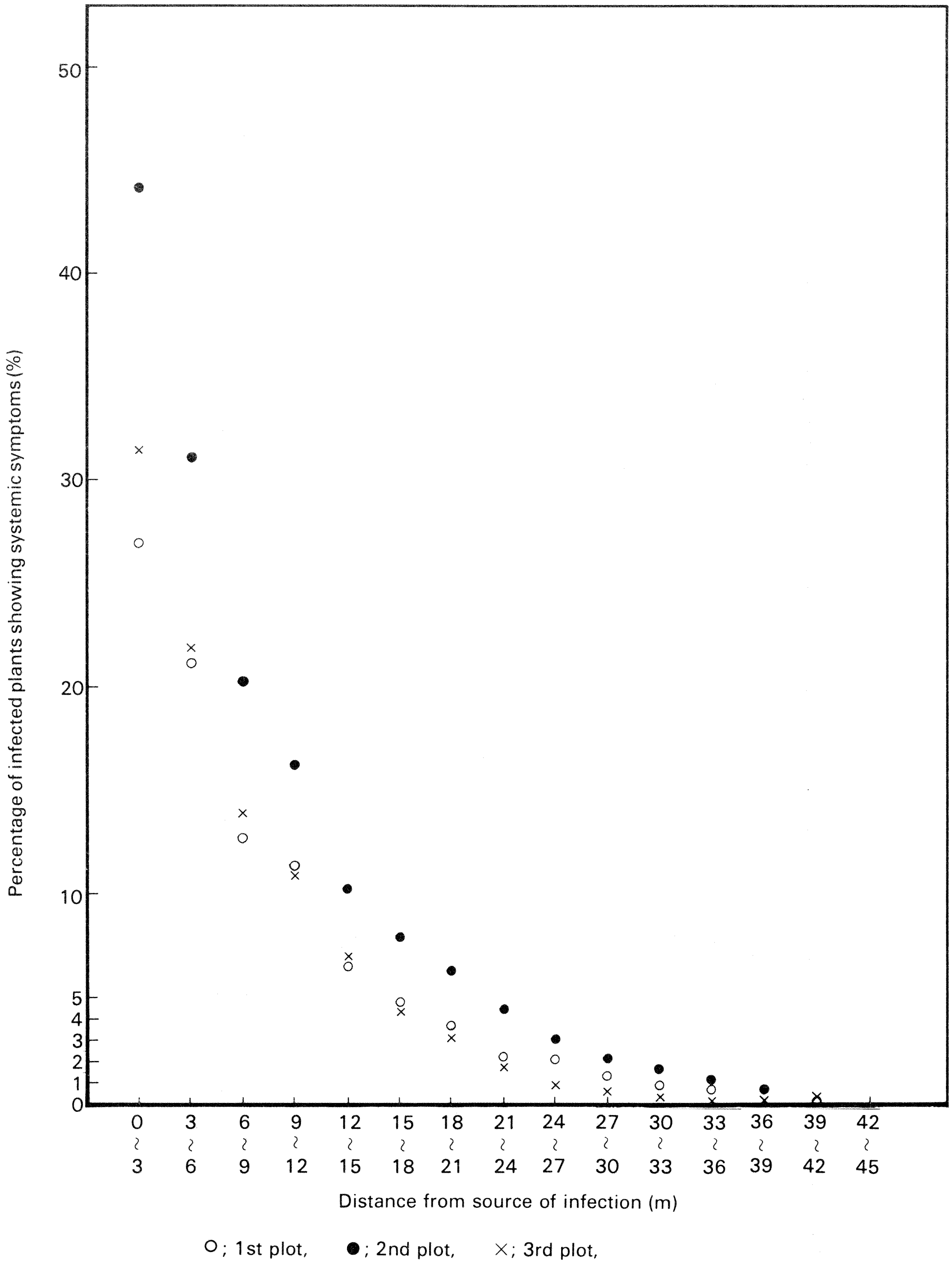


Figure 8. **Relationship between the percentage of maize infected with *Sclerospora maydis* and the distance from the source of infection in Bogor in 1973.**

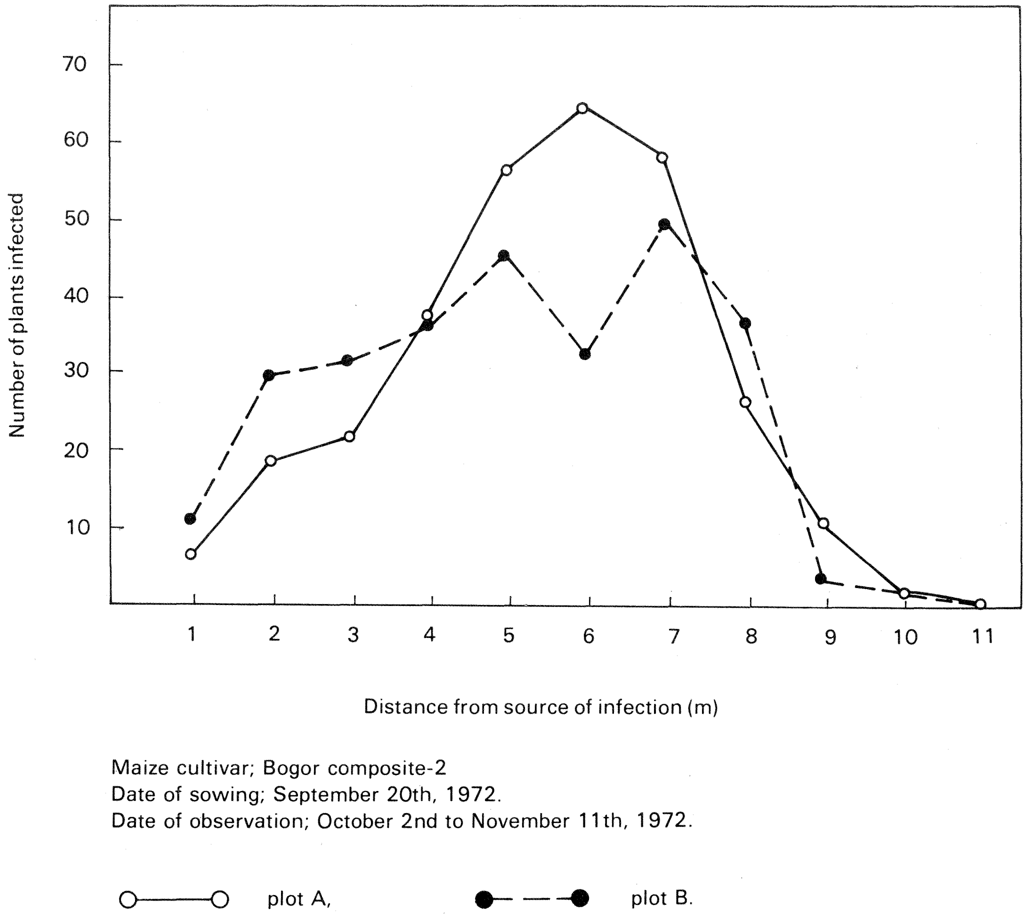


Figure 9. Relationship between number of plants infected with *Sclerospora maydis* and distance from the source of infection at Cibadak in 1972.

temperature was about 5°C lower than at Bogor.

Results of the observations on the relationship between the disease occurrence and the distance from the infection source are shown in Figure 9. Plants tested began to show the symptoms as early as October 2nd and the number of infected plants increased every day, reaching a maximum at the end of October, followed by a gradual decrease. However the infection continued until November 11. Systemic symptoms were observed within a range of 1 - 10 m, with a maximum within 5 to 6 m. At a distance of more than 10 m from the infection source the disease did not occur.

3) Discussion

As far as the dissemination of the disease by conidia is concerned, Palm (1918)[44] reported that dissemination of conidia was possible even if the distance from the source of infection was beyond 2 km. On the other hand, Matsumoto et al. (1964)[37] reported that conidia lost their germination capacity when exposed to a regine of

95 % humidity and 25°C temperature for one hour. In Taiwan and Indonesia, since the temperature rapidly increased while the humidity level rapidly decreased around 6 a.m., the germination capacity of the conidia was lost after sunrise. Moreover, the velocity of wind, only 1.0 to 1.5 m/sec, was not conducive to conidial dissemination. In Taiwan, the author observed that when the wind velocity was high, the humidity level became variable and conidia were seldom produced.

On the basis of the considerations mentioned previously, the author observed that conidial dissemination could occur only within a very short distance from the source of infection and also confirmed that under the climatic conditions prevailing in Indonesia conidial dissemination by air was possible even in plants in plots 42 m apart from the infection source. Although Palm's report stated that conidial dissemination occurred even within a 2 km range such finding could not be verified in Indonesia. Observation that conidial dissemination is limited to a 42 m radius from the infection source is important from the angle of disease control.

2. Symptoms and growth stages of maize

As for the mode of infection of downy mildew disease of maize, the author often observed that among two or three plants per hill, one plant showed severe symptoms, while the others were normal. On the basis of such findings, the existence of a relationship between the infection of downy mildew and the growth stage of maize can be postulated.

1) Materials and methods

Experiment 1.

In October 1969, the following experiment was conducted in one of the fields located at the Corn Research Center in Taiwan. On the night of October 22nd, seedlings of the maize cultivar Tainan No.5, were inoculated at the 1st leaf stage with conidia collected from sugar cane infected with *Sclerospora sacchari*. The seedlings were then transplanted to the field and were observed for the appearance of symptoms.

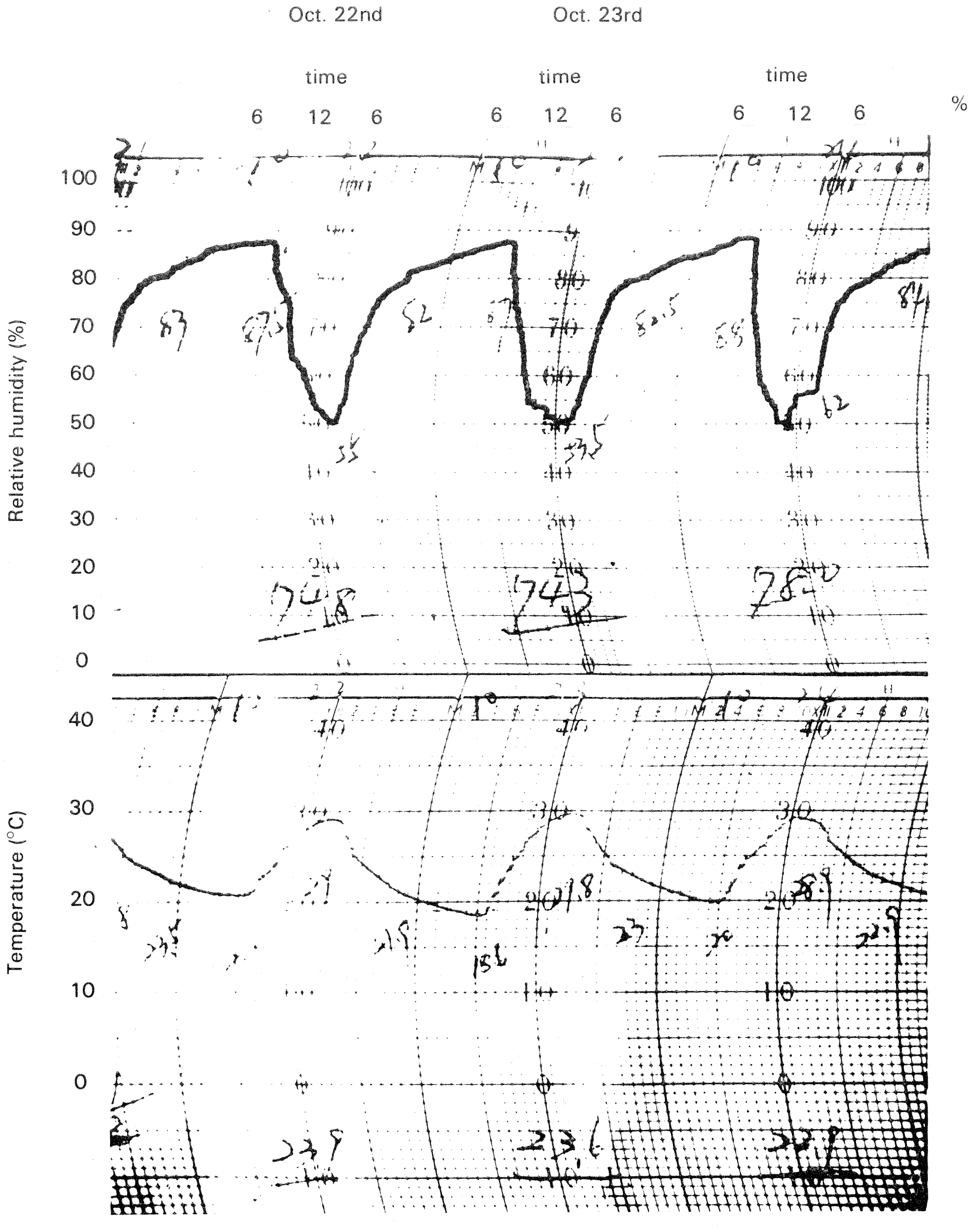
Experiment 2.

In May 1970, a field was selected again in the experiment at the Corn Research Center in Taiwan. Maize cultivar, Tainan No.5 was then sown 6 times at 2 day-intervals from May 25th to June 4th. From the 1st to 6th leaf stage the seedlings were exposed to the infection transmitted by conidia from sugar cane infected with *Sclerospora sacchari*. Then the seedlings were transplanted to isolate them from the infection source.

2) Results

In Experiment 1, the temperature and the relative humidity recorded during the night of October 22nd are shown in Figure 10. On that night, the weather was fair, the wind was not strong and the relative humidity was more than 80 % at 8 p.m. Moreover, the humidity increased until 5:30 a.m. (87.5 %). On the other hand, the temperature decreased gradually and reached 22.5°C at 8 p.m. while the minimum temperature (18.5°C) was observed in the morning. These conditions were suitable for the production of conidia and the seedlings were covered by a large amount of dew.

The number of infected plants and the percentage of infection with systemic symptoms are shown in Table 15. The inoculation was performed on October 22 at the 1.5th, 1.2th, 0.8th, 0.5th and 0.2th leaf stage of the plants.



Location; Potzu, Chiaii.
Date; October 22nd and 23rd, 1969.

Figure 10. Diurnal change in temperature and relative humidity in Taiwan.

Table 15. Percentage of downy mildew infection of maize in seedlings inoculated with *Sclerospora sacchari*.

Leaf stage at inoculation time	Number of plants inoculated	Number of plants infected		Percentage of infection
		Nov. 1st	Nov. 7th	
1.5	10	5	5	100
	10	6	4	100
1.2	17	6	11	100
	16	6	10	100
0.8	19	6	13	100
	19	5	14	100
0.5	16	3	13	100
	15	5	9	93
0.2	17	5	9	82
	18	4	10	78

Planted on October 18th, 1969 inoculated on October 22nd, 1969.

The plants at the 0.8th, 1.2th and 1.5th leaf stage showed 100 % infection with systemic symptoms. Among the plants at the 0.5th leaf stage, some showed 100 % infection and the others 93 % infection. Plants at the 0.2th leaf stage, which corresponds to the time when the first leaf usually begins to appear at the top of the coleoptile, showed 78 to 82 % infection and systemic symptoms were noted.

As mentioned above, it was clear that the maize seedlings exposed for one night to conidia produced on infected sugar cane showed 100 % infection.

In Experiment 2, the test plants were exposed to conidia for 2 nights on June 10th and 11th to induce full infection. The plants tested were grown in an isolated field and were checked twice for the apperance of infection with systemic symptoms on June 22 and 29. The number of infected plants and percentage of infection are shown in Table 16.

At the time of the observation of June 22, test plants of plot No. 6 which had reached the 1st leaf stage at the time of inoculation, showed 100 % infection. Plants in plot No. 5 which had reached the 2nd leaf stage at the time of inoculation showed 94 % of infection. Plants in plots No. 1 to 4, however, which had reached the 6th, 5th, 4th and 3rd leaf stage at the time of inoculation showed 0, 6, 16 and 42 % infection respectively. On the other hand, during the observation on June 29, the test plants in plots No. 4 to 6 which had grown to the 1st to 3rd leaf stage at the time of inoculation showed 100 % infection with systemic symptoms while those which had reached the 4th, 5th and 6th leaf stage at the time of inoculation showed 43 %, 15 % and 0 % infection, respectively. These results demonstrate that the percentage of infection decreased as the plants grew and that at the 6th leaf stage systemic symptoms seldom appeared.

The author observed only the plants which had been damaged and which showed systemic symptoms. Although these results are based on a limited number of experiments, it is interesting to note that recently Kajiwara (1974)[29] reported similar results in plants inoculated with *Sclerospora maydis* in Indonesia. On the basis of these results, the author concluded that the maize plants grow well after the 6th leaf stage without developing systemic symptoms even if infected with conidia.

Table 16. Relation between the leaf stage of maize seedlings at the time of inoculation and the infection with *Sclerospora sacchari*.

Experimental plot	Leaf stage at the time of inoculation	Date of sowing	Date of germination	Number of plants inoculated	June 22nd		June 29th	
					Number of infected plants	Percentage of infection	Number of infected plants	Percentage of infection
1	6	5 25	5 29	54	0	0	0	0
2	5	5 27	5 31	71	4	6	11	15.0
3	4	5 29	6 2	110	18	16	47	42.7
4	3	5 31	6 4	113	47	42	113	100
5	2	6 2	6 7	155	146	94	155	100
6	1	6 4	6 9	179	179	100	179	100

This experiment was conducted in 1969 and the inoculation of pathogenic conidia took place on June 10th and 11th.

3) Discussion

Even if the temperture conditions were optimal, no conidia were produced when the level of humidity fluctuated due to strong wind or rainfall during the night. In general when the weather was fair during the night, there was a relative increase in the level of humidity as a result of the decrease in temperature. Under these conditions, a large number of conidia were produced on infected plants, and these may play a role as infection source for the maize seedlings showing 100 % infection.

Maize seedlings, in the 1st to 3rd leaf stages, were easily infected when exposed to conidia for 2 nights under the above mentioned conditions. However, the percentage of infection decreased when the plants reached a more advanced leaf stage, whereas when the plants were beyond the 6th leaf stage, only initial symptoms appeared without systemic symptoms. These results are in agreement with those obtained by Kajiwara (1974)[29]. Also Chang in Taiwan reported that maize plants at an advanced stage failed to develop the infection. Therefore, the author could confirm that during the early stages of growth, from the time of germination to the 3rd leaf stage maize plants were easily infected with the conidia. However, plants at a more advanced stage, were unfrequently infected. On the other hand, when systemic symptoms affected maize plants, once the plants had reached the 5th leaf stage at the time of inoculation they became a source of infection through the production of conidia. However, the plants which grew beyond the 6th leaf stage at the time of inoculation became seldom infected. On the basis of these results, the author concluded that both normal and infected plants could be found in the same hill, because, in a plot planted with maize, some seedlings were infected with conidia dispersed from a neighbouring plot and infected plants may produce conidia after the plant reached the 6th leaf stage, while other plants in the same plot which had already reached the 6th leaf stage did not show systemic symptoms even when exposed to conidia. Therefore, the infected maize became the source of secondary infection only to maize grown in an adjacent field, while it was very difficult to infect plants at the same stage in the same field.

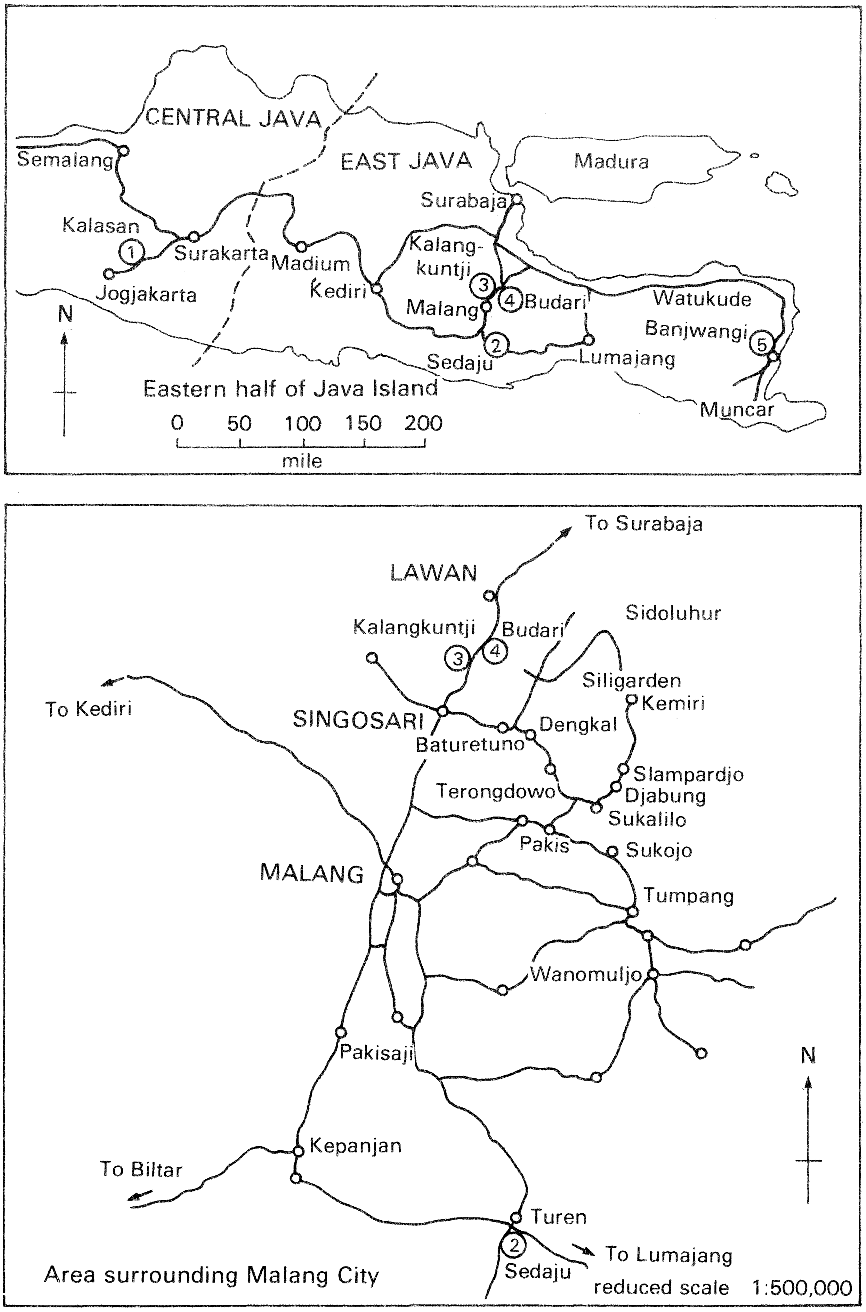
One of the striking characteristics of the cycle of infection in this disease, is that the distribution of infected plants was observed at random in the field.

3. Some aspects of disease incidence in Indonesia.

Previous results showed that downy mildew disease transmitted by conidia seldom occurred in a field when test plants were located at a distance of more than 42 m from the source of infection. The author conducted further experiments in maize production fields in Central and East Java which are known to be an epidemic area of downy mildew disease.

1) Methods

In the uplands of East Java, observations were made on crops growing in the beginning of the rainy season when epidemics usually occur. Observations were made on three occasions from October 10th to 26th 1972, from November 25th to December 12th, 1972 and from December 25th, 1972 to January 11st, 1973 in the area indicated in Figure 11. Observations were also made in Malang and Banjuwangi regions where the disease occurrence in 1971 was severe. In severly damaged fields with a high percentage of infection, the author investigated the planting data and height of plants in fields, and surveyed the infection sources.



— — — — State border line

———— Area surveyed during the trip

1 —— 5 Areas with severe infection of maize

Figure 11. **Map of Eastern half of Java Island (upper) and area surrounding Malang City where occurrence of infection of maize was observed (lower).**

2) Results

In 1971, the rainy season came early and the disease spread widely over large areas in Central and East Java. On the other hand, in 1972, the dry season lasted a long time and rain did not fall until October. For example there was almost no precipitation in Slampardjo and Singosari, Malang Prefecture, through June to October (Tables 17 - 18). As maize was not planted in these districts from 10th to 26th, October no observation was performed. In Malang, precipitation occurre at the end of October, and almost all the farmers planted maize on November 4. In the Rumadjan district, however, maize was sown at the end of October. At the time of the second observation, in most of the tested areas maize was already sown but the disease was not recognized. At the Budari Seed Farm near Singosari, diseased maize plants were found on November 11 (cultivar Harapan). At that

Table 17. Daily precipitation (mm) in Slampardjo in 1972.

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	6	1	6	11	3	-	-	-	-	-	-	-
2	19	3	-	1	4	-	-	-	-	-	-	-
3	8	-	2	-	2	-	-	-	-	-	-	67
4	47	30	-	-	-	-	-	-	-	-	-	6
5	1	-	-	-	1	-	-	-	-	-	3	45
6	3	-	10	-	28	-	-	-	-	-	-	3
7	9	7	45	-	-	-	-	-	-	-	-	65
8	2	2	82	1	12	-	-	-	-	-	-	2
9	-	2	-	5	22	-	-	-	-	-	-	-
10	15	5	-	-	9	-	-	-	-	-	-	20
11	2	6	-	-	17	-	-	-	-	-	-	2
12	-	-	-	-	-	-	-	-	-	-	-	-
13	7	-	-	-	-	-	-	8	-	-	-	9
14	25	-	19	-	21	-	-	-	-	-	-	18
15	11	-	-	-	-	-	-	-	-	-	20	4
16	24	-	17	-	-	-	-	-	-	-	-	-
17	9	-	-	9	-	-	-	-	-	-	5	18
18	7	-	-	-	-	-	-	-	-	-	11	-
19	11	4	3	-	-	-	-	-	-	-	-	7
20	-	-	9	-	-	-	-	-	-	-	-	-
21	40	11	-	-	-	-	-	-	-	-	-	24
22	9	4	16	-	-	5	-	-	-	-	3	1
23	-	35	11	-	-	-	-	-	-	-	2	-
24	-	3	-	8	-	-	-	-	-	-	23	-
25	4	-	1	-	-	-	-	-	-	-	-	-
26	-	2	5	-	44	-	-	-	-	-	20	39
27	5	-	-	-	-	-	-	-	-	-	40	2
28	26	3	1	-	-	-	-	-	-	-	23	20
29	1	-	19	3	-	-	-	-	-	26	7	7
30	-	-	2	-	-	-	-	-	-	-	26	7
31	1	-	-	-	-	-	-	-	-	11	-	8
Total	292	120	248	38	163	5	-	8	-	37	183	375
Number of days/month with rainfall	24	16	16	7	11	1	-	1	-	2	12	21

Annual precipitation: 1469mm
Number of days with rainfall: 111/year
Slampardjo, Disrict Djabung, East Java (elevation: 575m), 1972.

Table 18. Daily precipitation (mm) in Singosari District, in 1972.

Day	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1	-	0	8	6	1	-	-	-	-	-	-	-
2	7	26	-	-	3	-	-	-	-	-	-	-
3	20	-	-	-	-	-	-	-	-	-	-	32
4	50	-	-	-	-	-	-	-	-	-	7	3
5	-	6	-	-	-	-	-	-	-	-	5	6
6	5	-	14	-	-	-	-	-	-	-	-	-
7	9	0	6	-	-	-	-	-	-	-	-	-
8	19	3	31	3	18	-	-	-	-	-	-	14
9	43	-	-	-	31	-	-	-	-	-	-	-
10	5	-	-	-	1	-	-	-	-	-	-	4
11	8	4	-	-	3	-	-	-	-	-	5	5
12	0	-	-	-	2	-	-	-	-	-	-	28
13	2	-	-	-	-	-	-	-	-	-	-	1
14	15	-	25	-	-	-	-	-	-	-	3	12
15	6	2	2	-	-	-	-	-	-	-	-	1
16	0	-	18	29	-	-	-	-	-	-	-	3
17	40	-	44	-	-	-	-	-	-	-	-	-
18	103	-	12	13	-	-	-	-	-	-	-	-
19	-	5	5	-	-	-	-	-	-	-	6	-
20	-	6	22	-	-	-	-	-	-	-	-	8
21	3	-	19	-	-	-	-	-	-	-	7	9
22	-	2	20	-	-	-	-	-	-	-	-	-
23	-	-	39	16	-	-	-	-	-	-	-	-
24	-	2	2	3	-	-	-	-	-	-	-	-
25	1	-	0	-	-	-	-	-	-	-	-	-
26	0	0	4	-	-	-	-	-	-	-	-	21
27	9	1	2	-	-	-	-	-	-	-	15	-
28	15	-	2	-	-	-	-	-	-	-	17	17
29	0	-	6	5	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-	-	5	74	-
31	3	-	-	-	-	-	-	-	-	-	-	-
Total	345	67	281	75	59	-	-	-	-	5	141	164
Number of days/month with rainfall	19	10	19	7	7	-	-	-	-	1	9	15

Annual precipitation: 1137mm
Number of days with rainfall: 62/year
Singosari district, East Java (elevation 478 m), 1972.

time, the disease began to appear gradually in several fields in Malang Prefecture and the results of observations in this area are shown in Table 19.

In most of the fields, the percentage of infection was very low, but in the following 5 fields Budari-2 (E:), Kalasan (0:), Sedaju (P:), Kalang Kuntji (Q:) and Banjuwangi (R:) severe outbreak of the disease was observed. In fields where a low percentage of infection occurred, symptoms tended to involve the upper leaves of plants (Plate 8). According to the author's classification, the disease belonged to type (II) in which systemic symptoms appeared in the middle or later growth stages.

The author considred that the disease was not transmitted by conidia or seeds but perhaps by other agents which would remain pathogenic even under low humidity conditions, for example by oospores, though these have not yet been

Table 19. Areas and rate of infection of maize fields with *Sclerospora maydis* in Central and Eastern areas of Java (Oct. 1972 - Jan. 1973).

Locations	Date of planting	Date of observation	Number of plants observed	or acreage of fileds observed	Number of infected plants showing systemic symptoms	Percentage of infection	Position of the lowest leaf showing systemic symptoms
A: Tunpang	5 Oct.	29 Nov.	619		46	7.4	7 or 8
B: Wonomuljo	8 Nov.	30 Nov.		25ha.	0	0	-
	23 Nov.	30 Nov.		100ha.	0	0	-
	8-23 Nov.	16 Dec.		125ha.	0	0	-
C: Sidoluhur	17-25 Nov.	30 Nov.		240ha.	0	0	-
		9 Dec.			0	0	-
		13 Dec.			0	0	-
		16 Dec.			0	0	-
	20 Nov.	3 Jan.		0.5ha.	5	-	13 - 15
D: Baturetino	(1) 3 Nov.	13 Dec.	209		31	14.8	8
		30 Dec.	576		57	9.9	8
	(2) 3 Nov.	6 Dec.		0.2ha.	1	-	6
		13 Dec.	681		8	1.2	6
		15 Dec.	202		13	6.4	6
	(3) 4 Nov.	6 Dec.		0.9ha.	1	-	7
		13 Dec.		0.9ha.	3	-	7
		16 Dec.	121		8	6.6	7
	(4) 4 Nov.	6 Dec.		0.3ha.	1	-	7
		13 Dec.	673		12	1.9	7
		16 Dec.	119		3	2.5	7
	(5) 5 Nov.	6 Dec.		0.6ha.	0	0	-
		13 Dec.		0.6ha.	4	-	-
		16 Dec.	118		12	10.2	-
E: Budari Center	(1) 11 Nov.	11 Dec.	1811		24	1.3	8
	(2) 7 Nov.	8 Jan.	578		537	92.9	5
F: Dangkal	(1) 3 Nov.	6 Dec.		0.1ha.	0	0	-
		16 Dec.			1	-	9
	(2) 3 Nov.	16 Dec.		0.8ha.	1	-	9
	(3) 3 Nov.	20 Dec.	312		34	11.0	7 - 8
G: Singosari	(1) 11 Nov.	6 Dec.	367		4	1.1	8
	(2) 11 Nov.	6 Dec.	385		25	6.5	9 - 10
H: Siligardeng	(1) 13-14 Nov.	9 Dec.		0.3ha.	1	-	7
	(p. Savali)	16 Dec.			3	-	7
	(2) 13-14 Nov.	9 Dec.		0.2ha.	1	-	7
	(P. Rai)	16 Dec.			2	-	7

Locations	Date of planting	Date of observation	Number of plants observed	or acreage of fileds observed	Number of infected plants showing systemic symptoms	Percentage of infection	Position of the lowest leaf showing systemic symptoms
	(3) 13-14 Nov.	16 Dec.		0.1ha.	3	-	7
	(4) 13-14 Nov.	20 Dec.		0.3ha.	0	0	-
	(5) 13-14 Nov.	16 Dec.		0.9ha.	1	-	8
I: Slamparjo	(1) 4 Nov.	9 Dec.		0.4ha.	3	-	11
	(2) 4 Nov.	9 Dec.		0.2ha.	1	-	8
	(3) 4 Nov.	23 Dec.		0.3ha.	0	0	-
	(4) 4 Nov.	23 Dec.		0.3ha.	2	-	9
	(5) 4 Nov.	23 Dec.		0.4ha.	3	-	9
J: Terongdowo	20 Nov.	20 Dec.		1ha.	0	0	-
K: Sukojo	20 Nov.	20 Dec.		1ha.	1	-	8
L: Sukalilo	(1) 3 Nov.	23 Dec.		0.3ha.	2	-	9
	(2) 3 Nov.	23 Dec.		0.4ha.	3	-	8
M: Muncar (Banjuwangi)	10 Sep.*	29 Dec.	332		13	3.9	9
N: Watukude (Banjuwangi)	29 Nov.	29 Dec.		0.7ha.	3	-	8
O: Kalasan	(1) 2 Dec.**	26 Dec.	426		400	93.9	4
(near Jogja)	(2) 2 Dec.**	26 Dec.	238		216	90.8	4
	(3) 16 Dec.**	26 Dec.	163		12	7.4	10
P: Sedaju	(1) 11 Dec.	5 Jan.	173		151	87.3	4 - 5
(Turen)	(2) 11 Dec.	5 Jan.	266		254	95.5	4 - 5
	(3) 5 Oct.	5 Jan.	-		-	16 - 20	10 - 12
Q: Karangkuntji	(1) 18 Dec.	3 Jan.	217		190	97.6	5
	(2) 18 Dec.	3 Jan.	275		244	88.7	5
	(3) 10 Nov.	28 Dec.	846		166	19.6	9
R: Banjuwngi	(1) 14 Dec.	29 Dec.	114		30	26.3	4
	(2) 20 Nov.	29 Dec.	250		5	2.0	9 - 10
S: Jabung	(1) 4 Nov.	5 Jan.		2.0ha.	0	0	-
	(2) 20 Nov.	5 Jan.		2.0ha.	0	0	-
	(3) 2 Dec.	5 Jan.		2.0ha.	0	0	-
	(4) 4 Nov.	5 Jan.		0.3ha.	13	-	9
T: Kediri	(1) 4 Nov.***	8 Jan.		0.3ha.	0	0	-
	(2) 13-14 Nov.***	8 Jan.		0.5ha.	0	0	-

Maize cultivar: Harapan. Observation was conducted during the rainy season of 1972.
* Cultivar: Genja Tongkol ** Unkonwn cultivar *** Kretek.

identified in *Sclerospora maydis*.

Fields where maize plants showed a low percentage of infection could be seen in several other areas in Indonesia. Moreover, there were fields which had experienced severe infection in 1971 and where other crops were planted after plowing the diseased maize.

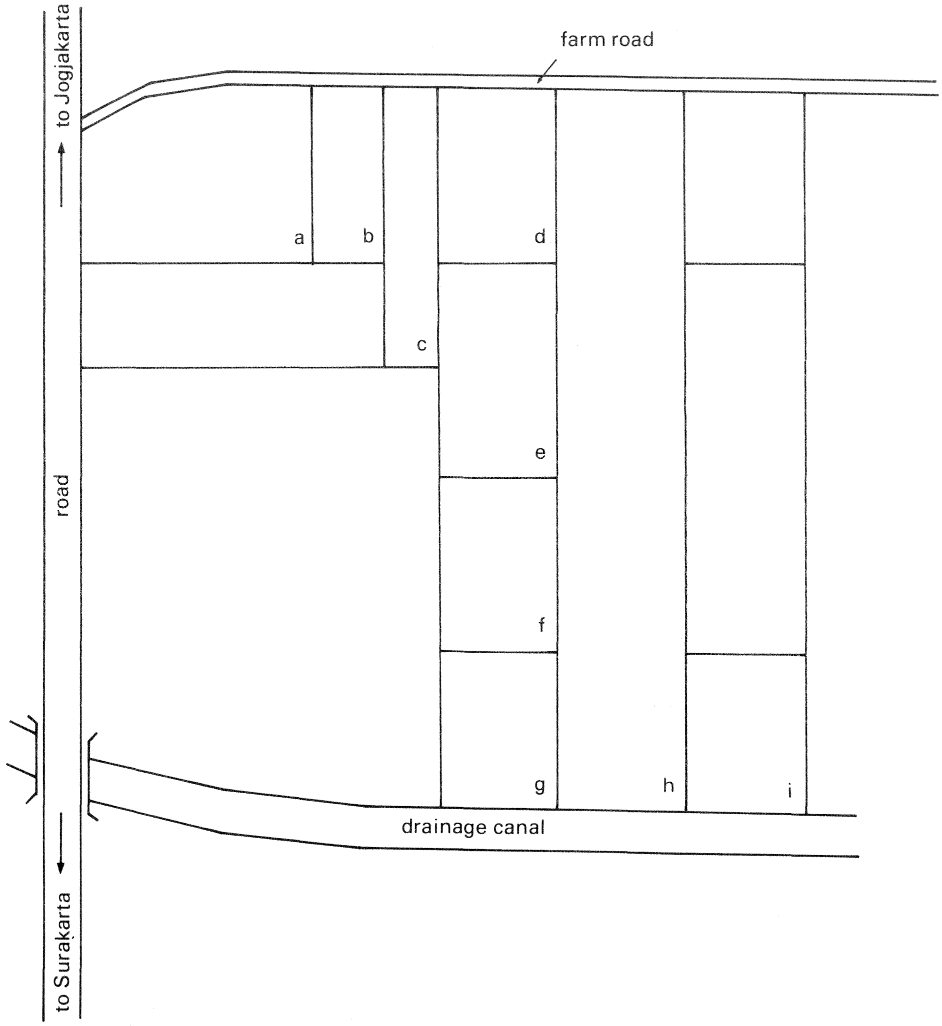
However, maize sown in 1972 did not develop downy mildew disease. The author surveyed the Baturetuno (D:), Siligardeng (H:), Slamporjio (I:) fields etc. and found a low percentage of infection. These findings suggested that there was a relationship between the outbreak of the preceding year and the occurrence of the disease in the following year. In contrast, in Djabung, Malang (see Plate 11-1) and Kederi (see Plate 11-2) there was a difference in the growing stage of the maize planted in adjacent fields. Under such conditions, if there were infected plants in the field sown early one would expect the disease to be transmitted to the maize sown subsequently. However, in these areas, no plants became infected. These findings suggest that even in the epidemic areas, such as Malang, if no pathogenic agents are present near the field, infection will not take place. The only fields where maize plants were severely affected by the disease were the 5 fields previously mentioned. To analyze the cause of these phenomena, the author observed in detail the propagation of the disease in the fields and surrounding areas. In the case of Kalasan which is located in the eastern part of Yogyakarta, field conditions and disease occurrence are indicated in Figure 12. The figure shows that more than 90 % infection was observed in plants located in plots "d" to "g". Plot "h" which is adjacent to plots "d" to "g" had already been plowed. This field had been previously planted with maize but had been plowed due to heavy infection and new crops were planted. In the plots "a", "c" and "i", where maize was grown, the relationship between the percentage of infection and the plant height was as follows: 7.4 % · 75 cm, 9.4 % · 150 cm and 7.4 % · 130 cm, respectively.

The author could not determine the mode of propagation of infection in plots "a", "c" and "i". On the other hand, however, there was a clear difference between maize grown in plots "d" to "g" and in the other plots since the plants grown in plots "d" to "g" were sown after the disease of maize was observed in the other plots. The author concluded that the source of infection was represented by the infected plants in plots "c" and "i". Moreover, the field where plants were most infected, as shown in Plate 12-1, was field (d) located in Kalasan.

In Sedaju in the southern part of Malang the mode of propagation of the disease is indicated in Table 19 - P: and in Figure 13. As Figure 13 shows, the plants grown in plots "b" to "k" displayed 87.3 to 95.5 % infection and measured 64 to 77 cm. Systemic symptoms were present in plants which had reached the 9.7 to 10th leaf stage, from the 6.3th, 6.7th leaves upwards. In plot "l" which was adjacent to plots "b" and "k" the maize plants which had reached the 2nd to 3rd leaf stage at the time, showed lesions on the 1st leaf but did not show any systemic symptoms. Moreover, the maize present in field "l" had been infected (100 %) and as a result, the field had been plowed and subsequently seeds were replanted in the same field.

The maize grown in field "a" showed 16 % infection 70 days after sowing. Maize grown in field "m" showed 20 % infection when it reached the ripening stage. Those fields are shown in Plate 12-2.

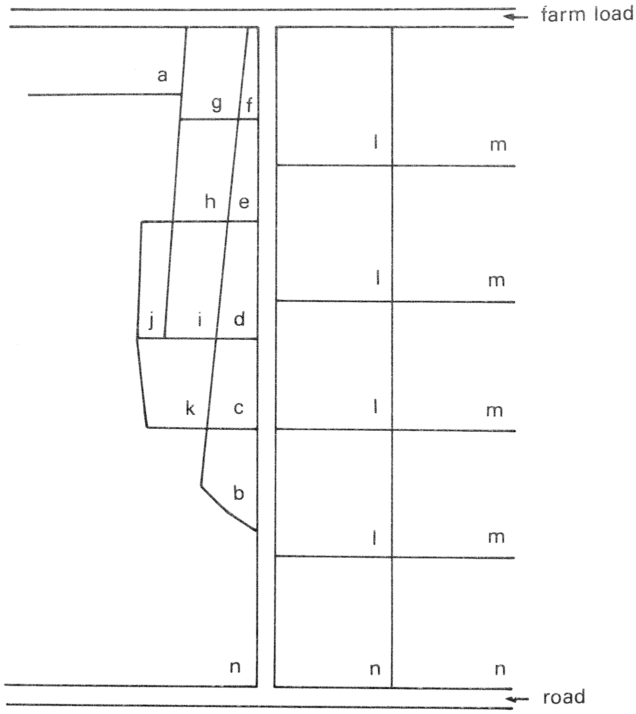
On the basis of the results mentioned above, the author considered that the



Field	a	c	d-f	g	i
Crop	maize	maize	maize	maize	maize
Percentage of plants infected with downy mildew disease (%)	7.4	9.4	93.9	90.8	7.4
Plant height at the period of observation (cm)	75	150	33.4	33.4	130

Date of observation: December 26th, 1972. b: sweet potato. h: no crop, just after plowing, in this field maize had been planted earlier than in fields d~g, the field was plowed up owing to severe infection of maize.

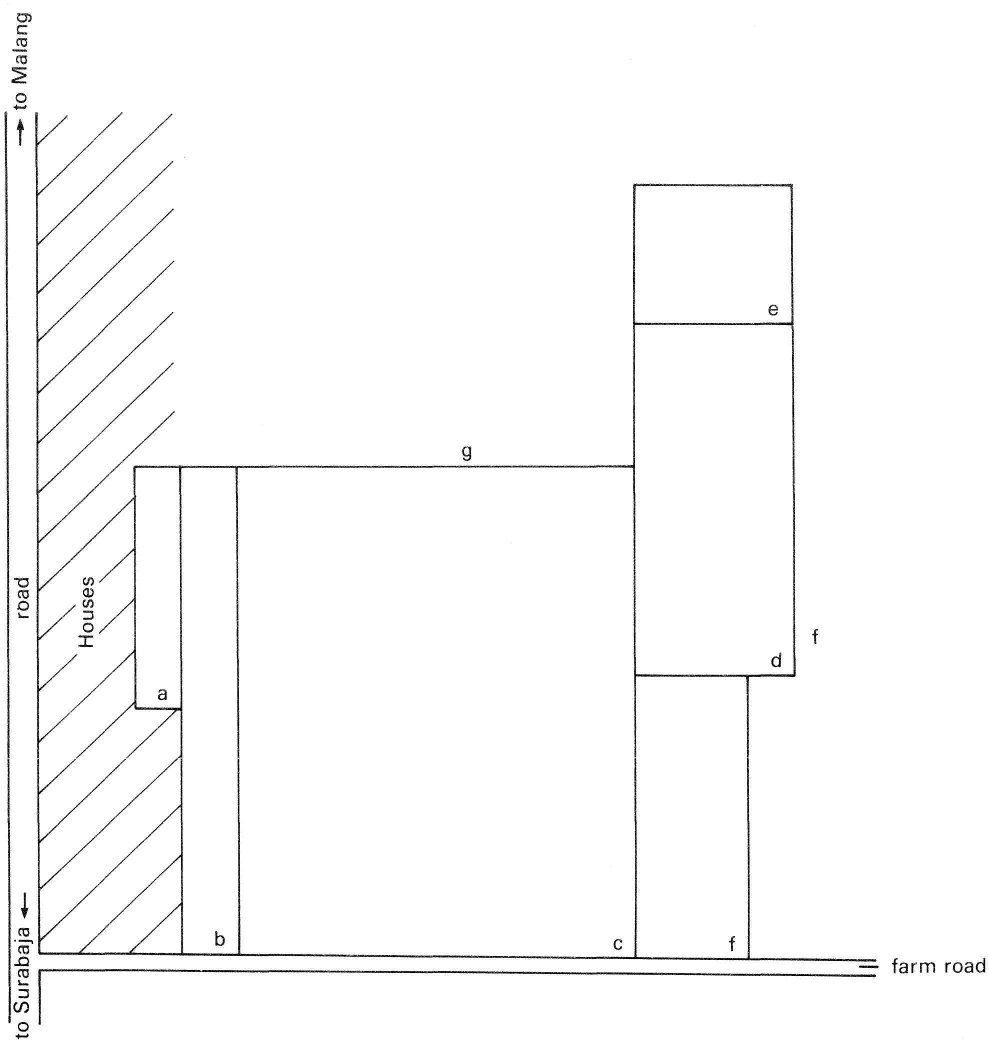
Figure 12. Topography of maize fields with heavy infection and surrounding areas (kalasan near Jogjakarta). Maize cultivar: Harapan.



Field	a	b	c	d	e-k	l	m
Crop	maize	maize	maize	maize	maize	maize	maize
Percentage of plants infected with downy mildew discose (%)	15.0	87.3	95.5	93.1	do	0.0	20
Plant height (cm)	—	64	69	77	do	—	—
Position of lowest leaf on culm showing systemic symptoms	—	6.7	6.3	6.3	do	—	—
Leaf stage at the period of observation	—	9.7	10.7	11.0	do	—	—
Growth stage at the period of observation	period of ear emergence	early growth stage	do	do	do	5 days after germination	matuation stage

Date of observation: January 5th, 1973.

Figure 13. Topography of maize fields with heavy infection and surrondings areas (Sudaju, Turen, Malang prefecture). Maize cultivar: Harapan.



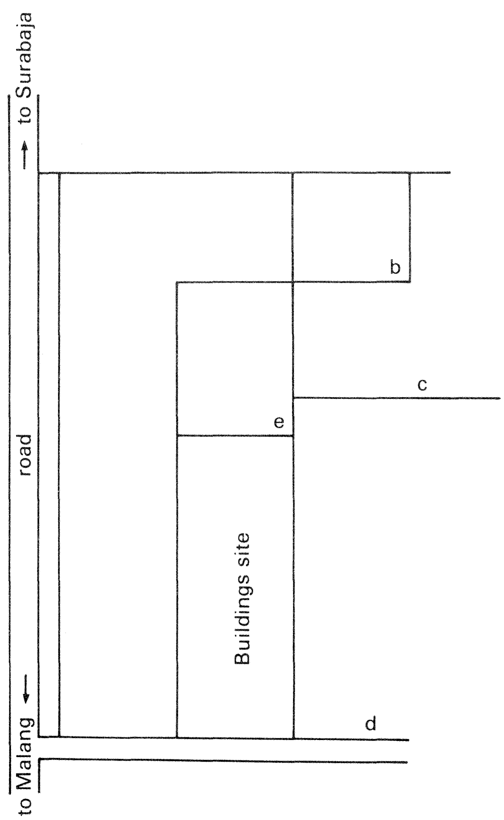
Field	a	b	c	d	e	f	g
Crop	maize	maize	maize	maize	maize	rice	upland rice
Percentage of infected plants (%)	89	98	20	74	42	—	—
Plant height (cm)	50	50	103	107	130	—	—
Position of lowest leaf on culm showing systemic symptoms	6.2	6.6	9.9	7.2	9.1	—	—
Days after sowing	20	20	45	30	30	—	—

Figure 14. Topography of maize fields with heavy infection and surrounding areas (Karang Kuntji near Budari, Malang Prefecture) (January 3rd, 1973). Maize cultivar: Harapan.

source of infection of fileds "b - k" was represented by the maize grown in fields "l" and "a", before plowing took place.

The distribution of the infected maize in the field of Karang Kuntji is shown in Table 19 - A: and Figure 14. Also maize grown in fields "a" and "b" which were adjacent to a field where maize had experienced a low rate of infection showed a high percentage of infection. Field conditions are shown in Plate 12-3.

The mode of propagation of the disease in the maize fields of the Seed Center of the State Government of East Jave located in the Budari District, Malang Prefecture, is shown in Table 19 and in Figure 15. In this Center, maize was sown



Field	a	b	c	d	e
Crop	maize	maize	maize	maize	ground-nut
Percentage of infected plants (%)	3	93	0	0	—
Days after sowing	58	32	12	11	—

Date of observation: Janauary 8th, 1973.

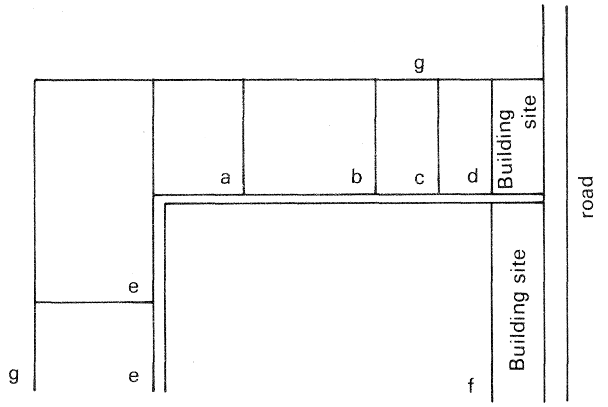
Figure 15. **Topography of maize fields with heavy infection and surrounding areas (Budari Seed Farm located in Budari, Malang Prefecture).**
Maize cultivar: Harapan.

on November 11 following the first rain consecutive to the dry season. Maize cultivar Harapan was sown in field "a" on December 2 and among a total of 1811 plants observed 9 plnts showed systemic symptoms. Then the number of infected plants increased up to 1.3 %.

The Center sown maize (Harapan) in field "b" on December 7 so as to increase the production of seeds of Harapan cultivar. The maize plants showed heavy infection with *Sclerospora maydis* at the end of December. More then 90 % of the plants became infected on January 11 in 1973 and field "b" was plowed up. As a result the author concluded that the source of infection of the maize grown in field "b" originated from infected plants present in field "a".

In the maize field located in Banjuwangi, East Jave, the mode of propagation of the disease is shown in Table 19-R: and in Figure 16. As indicated in Figure 16, fields "b" and "c" were sown at the same time. The percentage of infection at the early growth stage was 26.3 % for field "b" and 9.8 % for field "c" respectively. On January 25, 90 % of the plants became infected in field "b" against 54 % in field "c". Moreover, the field was adjacent to a road and a palm forest.

On the basis of these findings, the author considred that the source of infection in fields "b" and "c" could be traced to conidia produced in field "a" which was



Field	a	b	c	d	e	f	g
Crop	maize	maize	maize	maize	maize	soybean	coconut palm
Percentage of infected plants (%)	2.0	26.3	9.8	—	1.0	—	—
Plant height (cm)	114	36.1	38.8	—	—	—	—
Position of lowest leaf on culm showing systemic symptoms	9	4	5	—	—	—	—

Date of observation: December 19th, 1972.
In this field, more than 90% of maize plants showed systemic symptoms in later observation.

Figure 16. Topography of maize fields with heavy infection and surrounding areas (Banjuwangi City). Maize cultivar: Harapan.

adjacent to field "b" and where maize had been sown earlier. The above mentioned findings can be summarized as follows.

i) No infection was noted in maize sown far from the source of infection.

ii) Even in the fields where no infection was reported by the farmers, yet invariably a small percentage of infected plants was observed in those fields which had experienced severe infection the year before.

iii) Except for 5 plots, most of the fields showed a low rate of infection.

iv) In fields which were heavily infected the source of infection could be traced to an adjacent filed where maize sown earlier showed only mild symptoms.

3) Discussion

In this study, the disease of maize was mainly transmitted by conidia when the distance between plants and the source of infection did not exceed 42 cm. The author conducted the observations in order to investigate the mode of transmission of downy mildew disease of maize in fields located in East Java. The author observed that 5 plots having a high percentage of infection were adjacent to a filed showing a low percentage of infection. As there was no other source of infection within a range of 42 m, the author concluded that the adjacenet field was the source of infection. Such findings are further corroborated by the fact that there was no infection in plots when the source of infection could not be found within a short distance from fields sown with maize at different stages of growth. These results emphasize the importance of the distance from the infection source.

In 1972, in East Java, comparatively little damage was inflicted to maize sown in the beginning of the rainy season. This was due to the fact that in that particular year the dry season lasted a long time and maize seeds were sown uniformly as soon as it started raining.

Therefore, when conidia were produced on infected maize in the field, the other plants were fully grown and thus not prone to infection. On the other hand the five plots mentioned above which were in the vicinity of the source of infection suffered serious damage. Thus, such results show that maize plants at advanced stages of growth are seldom infected. To determine the reason why these fields experienced little infection, in 1972, the author observed fields where maize plants had been heavily infected in the preceding year.

In 1972 in East Java no rain was recorded for four months and fields became dry and no crops could grow. Thereafter maize was sown after the first rainfall. Consequently, there was no possible source of infection in that area. Therefore, it is very difficult to consider that the source of the primary infection was due to conidia of *Sclerospora maydis*. Moreover, since the seeds sown were fairly dry, they did not become a source of infection. Therefore, in this case, the source of primary infection could be represented by oospores or some other organs which resisted drought and remained in plants which had died in the preceding year. Such hypothesis, however requires further investigations. As mentioned above, although such observations did not enable to determine the source of primary infection in maize sown in fields after the long dry spell, they could provide information about the transmission of the disease by conidia present in plants located within a short distance of a contaminated field.

4. Considerations on the control measures against downy mildew disease.

On the basis of the results of the present studies control methods of downy mildew disease of maize were considered from the standpoint of maize cultivation. Measures are aimed to prevent conidial dissemination, which is the main factor for contributing to the disease epidemic. The conidia may not disperse beyond a distance of 42 m from the source of infection.

Therefore, if the infected maize and other plants susceptible to this disease within a range of 42 m from the source of infection were removed control could be effective. Moreover, since maize is particularly susceptible to the disease before reaching the 6th leaf stage, special care should be taken during this period of growth.

Seed-borne infection could be easily controlled by using dried seeds. Ears of maize remaining in the fields should be removed, as ears are unlikely to be dry. Dead leaves and culms of infected plants should be removed completely, because the presence of leaves and culms of maize plants infected in the previous crop season may be a possible source of primary infection. Therefore, it is necessary to remove every single infected plant present in a field.

Since cross-infection among plants is seldom observed, when maize is sown at the same time, protection against the disease should be possible in adjusting the planting time.

At present in Indonesia, such procedure is applied and in the Dengkol District located in Malang, East Jave, appreciable results have been obtained. In the Baturetuno District adjacent to Dengkol where such measures have not been implemented, heavy infection of maize has been observed. Therefore, such methods for preventing the disease should be applied to areas of tropical Asia where there are similar climatic conditions and maize plants are affected by downy mildew disease.

5. Conclusions

In order to establish preventive measures against downy mildew disease of maize, the author investigated the relationship between the dissemination of conidia of *Sclerospora maydis* and the infection of maize. He also observed that the severity of the symptoms of infected plants depended on the growth stage of maize. Finally, the mode of disease incidence in Indonesia was studied. On the basis of these results, the author established effective control measures. Although Palm (1918)[44] reported that conidial dissemination took place within a range of 2 km, the author clearly demonstrated that the infection could not be observed beyond a range of 42 m. This may be important in devising measures to control the disease. The author could establish that the infection caused by conidia originating from maize infected with *Sclerospora maydis* occurred only in plants at the early stages of growth and not beyond the sixth leaf stage.

Recently Kajiwara (1974)[29] obtained similar results. On the basis of these findings, since the systemic symptoms were only observed in plants beyond the 6th leaf stage the author concluded that secondary infection in the same field seldom occurred due to the fact that when infected plants produced conidia other plants in the same field had already reached the 6th leaf stage. In this observation on the mode of propagation of the disease in production fields of East Java, the author demonstrated that maize fields with a high percentage of infection could represent a source of infection for an adjacent field. A high percentage of infection was not observed unless there was a source of infection in an adjacent field. Also, when a field had experienced severe infection during the previous crop season, few infected plants were observed in the adjacent field. In that case, the author suggested that oospores or other organs resistant to dry conditions could be considered as a primary source of infection and should be taken into account when devising preventive measures.

III. General conclusions

Maize crop comes next to rice in the tropical countries of Asia as staple food. The damage caused by downy mildew disease of maize is an important problem which should be solved. Although a large number of investigations have been conducted from the angle of plant pathology there are only a few reports dealing with effective control measures, and no fungicides have been found to be effective hitherto. Moreover, the breeding of maize varieties resistant to the disease has just begun in these countries and varieties combining high yielding properties and resistance to downy mildew disease have not yet been released.

Downy mildew disease is chiefly disseminated by conidia originating from infected plants and in Indonesia, sometimes more than 90 % of maize plants were found to be infected. As generally there is a lock of effective control methods, infected maize in a farm is plowed up and replanted with other crops.

The author performed several experiments so as to establish control measures of the disease. More than half of the infected plants which developed systemic symptoms caused by *Sclerospora maydis*, died in the early period of growth while others continued to grow but failed to produce ears. In the case of low grade infection, damage is avoidable only by thinning infected plants. However, in case of heavy infection, damage is irreversible.

In the beginning of the disease occurrence, conidia germinate in the dew covering newly formed leaves of maize seedlings and invade plants through stomata. Lesions at the invasion point are small but hyphae spread into tissues of newly formed leaves and sheath. After the invasion by the hyphae, newly formed leaves show systemic symptoms. In tropical countries, maize grows twice as fast as in Japan.

Although in laboratory experiment, conidial germination can be controlled by the use of fungicides, in the natural environment, even if maize plants are sprayed with fungicides, the protection by fungicides is difficult, because new leaves sprout during the night, and in the next morning conidia reach these newly formed leaves and germinate on the leaves without being covered with fungicides. This is the reason why it is difficult to control the disease by fungicides.

The average temperature in Indonesia is about 25°C during the day throughout the year, with a maximum temperture of 32 - 33°C and minimum temperature 21 - 22°C. The humidity which avarages 50 - 60 % during the day increases to more than 90 % during the night. Such conditions are conducive to the production and germination of conidia except when it rains and the wind is strong during the night. Therefore, when maize is sown during the rainy season or in the dry season with water supplied by irrigation a large number of conidia can be produced every morning, making it difficult to apply prevention methods.

It was possible to demonstrate that conidia or infected seeds were responsible for the infection of the plants.

In East Java, Indonesia, farmers had noticed that the percentage of infection was low when maize was sown early in the rainy season. The author also confirmed these findings. However, as the author failed to identify conidia or other pathogenic agents, he suggested that the source of primary infection should be traced in the plants which died by infection with downy mildew disease in the previous crop season. Contamination of seeds with oospores or other agents which tolerate the conditions prevalent during the dry season has not yet been confirmed. On the other hand, the disease became more severe in case of late sowing during the rainy season. But even in the late sowings, the only field with a high percentage of infection was the one adjacent to a field where maize had been sown about 3 weeks in advance and as a result, the infection had already produced conidia.

Dry seeds (less than 20 % moisture) were seldom responsible for the infection of plants. As hyphae present in the infected plants do not tolerate dry conditions, they do not act as a source of primary infection for maize except in the case of repeated cultivation.

Conidia can represent a source of infection only within a distance of 42 m. Also, cross-infection among plants is difficult to consider since within the same field plants are at the same growth stage.

On the basis of the results of the studies and observations mentioned above, the author devised methods of prevention against the disease from the standpoint of crop production, in taking into account the environmental conditions prevalent in Indonesia. These measures can be summarized as follows:

1. Since it is very important to eliminate the source of primary infection for the prevention of the disease, infected plants including ears from previous crop seasons and maize plants growing like weeds as a result of spontaneous germination should be removed from the fields including adjacent fields.
2. Before sowing new plants the infected maize plants present within a range of 42 m from the fields should be removed, so as to prevent the dissemination by conidia.
3. Whenever possible, maize sowing should be synchronized, as plants at different stages of growth are likely to be infected by conidia present within a range of 42 m.
4. Seeds should be dried 13 - 14 % moisture) to reduce the possibility to act as a source of contamination.

More investigations should be conduceted to define precisely the relationship between the presence of maize plants which died due to infection with downy mildew disease and the source of primary infection.

As mentioned above, the origin and process of conidial infection was clarified by the present investigation as regards their role in secondary infection. Accordingly, if the source of infection in an adjacent field is removed, conidial infection is not observed and maize production is satisfactory even if some infection takes place by oospores or other agents which tolerate dry conditions. Such measures should enable to control the disease effectively, as observed in some parts of Indonesia.

The results of this investigation are thus encouraging and the application of the above mentioned preventive measures could involve larger areas of the tropics.

Summary

In tropical and sub-tropical countries, downy mildew disease of maize seriously hampers maize production. The present study was carried out to investigate the extent of the damage produced, the characteristics of the appearance of the systemic symptoms, the mode of occurrence of the disease. On the basis of the results obtained, the author suggested effective control measures from the angle of maize cultivation under the present situation. The results can be summarized as follows:

1. More than 50 % among the infected plants with systemic symptoms caused by *Sclerospora maydis* died, while the growth of the other half was severely impaired with only 2 - 3 % ear production. Grain production was practically inexistant.
2. Small localized lesions were observed at the time of conidia penetration. The hyphae became elongated and reached the growing point. Subsequently they invaded the newly formed tissues. Newly formed leaves showed yellow streaks. As for the systemic symptoms they manifested themselves under 2 forms.
   a) At first, local lesions were present on leaves at the point of invasion of the germtube of conidia (see Plate 6) and systemic symptoms were not observed before the 5th or 6th leaf stage (type I).
   b) The systemic symptoms appeared in the middle or late growing stages (type II).
3. In tropical countries of Asia, control by fungicides is difficult to achieve since the growth rate of leaves is twice as fast as in Japan.
4. In Indonesia, the temperature and humidity level are conducive to the production and dissemination of conidia throughout the years. As a result, the damage is severe.
5. Transmission of the disease takes place by conidia and contaminated seeds originating from infected plants. However there are cases where the source of primary infection remains unclear.
6. In Indonesia, the author demonstrated that conidial dissemination of the disease occurred within a range of 42 m.
7. The sensitiveity of maize plant to the disease was found to vary depending on the stage of growth. Sensitivity was maximum at the first leaf stge and decreased with advancing growth. It became difficult to infect plants after the plants reached the 6th leaf stage. As conidial production in infected plants chiefly developed from the 6th leaf stage, onward it became evident that the infection of plants located in the same plot and sown at the same time could not occur.
8. Results from field experiments showed that heavily infected maize plants produced abundant conidia enabling the infection of adjacent plots to take place. Conidial infection could occur within a short distance. Also, there were some instances where conidial production as a source of secondary infection could not be detected in the plot where maize plants showed mild infection.

   In the case of maize cultivation in a field which had been heavily infected during the previous crop season, infected plants could be observed although conidia could not be recognized as a source of primary infection in adjacent fields. Therefore the author suggested that oospores or other pathogenic agents which tolerate dry conditions be considered as the source of the infection, although such structures have not been demonstrated hitherto. In that respect further stdies should be conducted.
9. On the basis of these investigations, control measures aimed at the prevention of

the disease were proposed from the angle of crop production.

a) At the time of sowing, infected maize and sensitive plants should be removed in the adjacent plots within a range of 42 m so as to prevent conidial dissemination. Since maize is sensitive to the disease before reaching the 6th leaf stage, infected plants in adjacent fields should be removed to avoid the infection.
b) Within an area, sowing should take place at the same time to prevent cross-infection among plants at different stages of growth.
c) When maize plants become infected, they should be removed and burned, so as to prevent infection in the next sowing season via seeds or unknown agents acting as a source of primary infection.
d) Seeds should be used only after being dried (13 to 14 % moisture).

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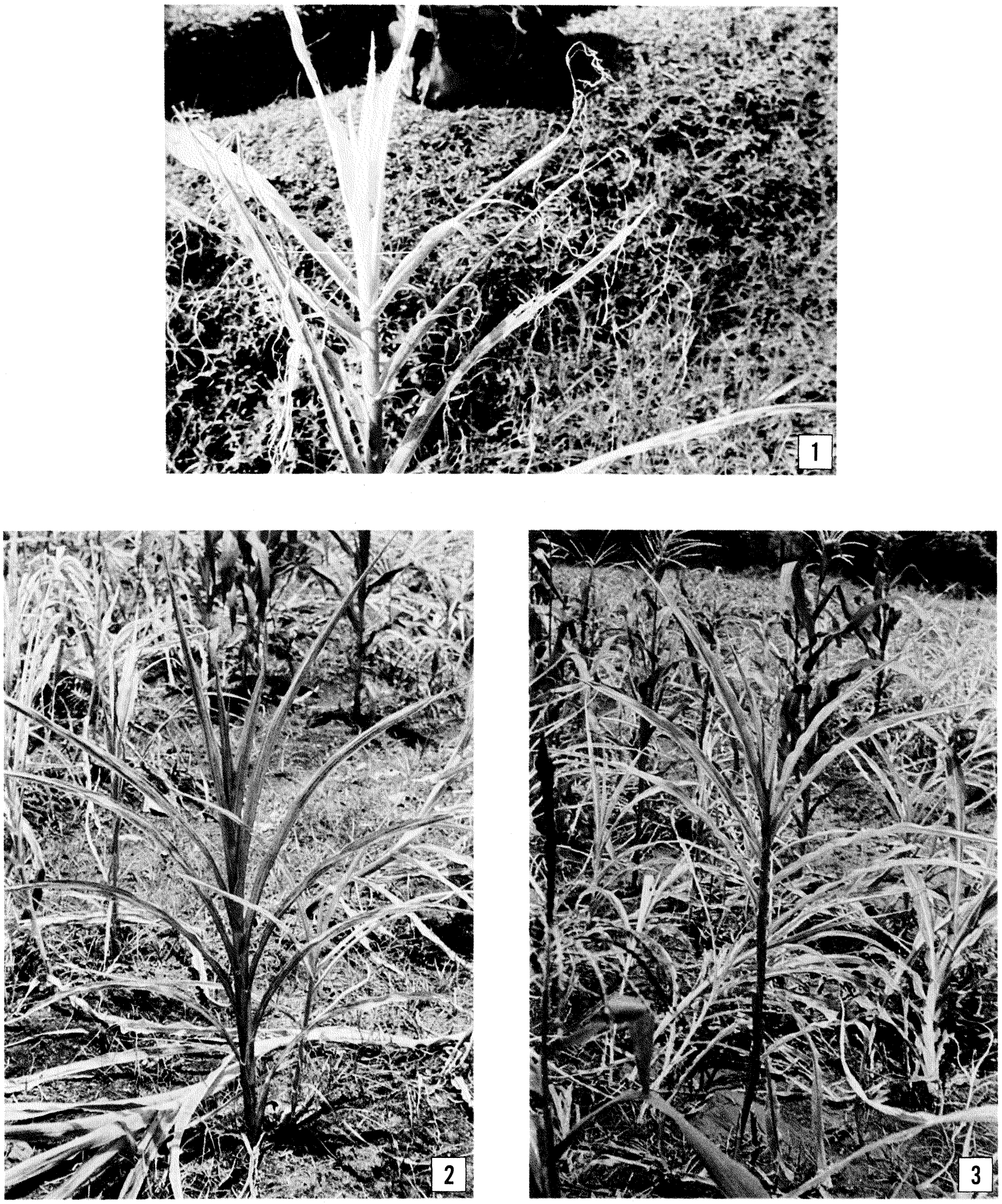


1) Maize continues to grow but the leaves show heavy yellowing due to infection.
2) The leaves show yellow streaks and become narrow with a tendency to lodging.
3) Leaves show yellow streaks of various width (see also Plate 2).

Plate 1 Systemic symptoms of downy mildew disease of maize caused by *Sclerospora maydis.*

1) Wide yellow streaks, maize cultivar "Harapan"
2) Narrow yellow streaks, maize cultivar "Harapan"

Plate 2 Systemic symptoms of downy mildew disease of maize caused by *Sclerospora maydis.*

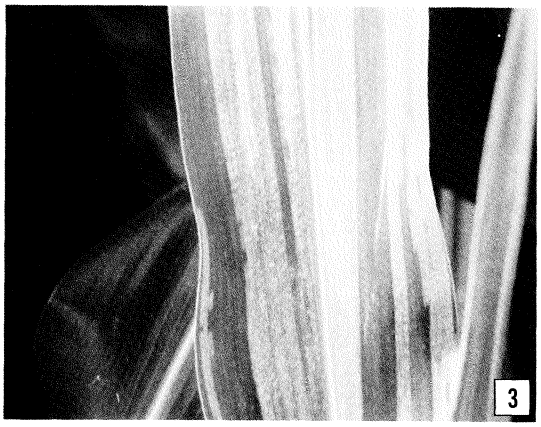
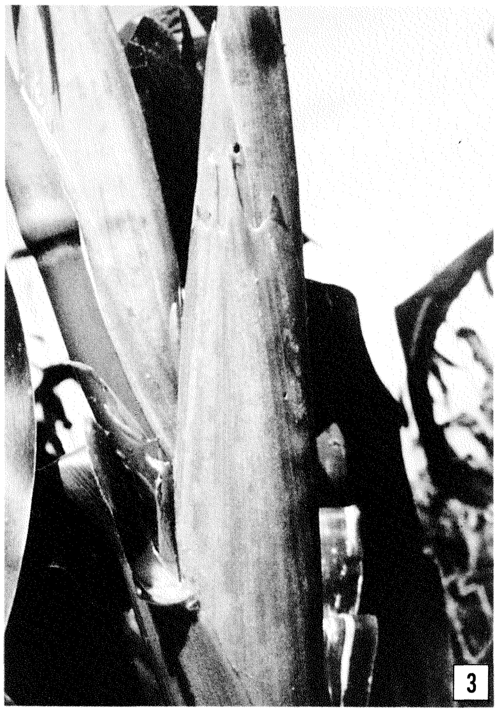


Plate 3 Conidia of *Sclerospora maydis* on leaves of maize cultivar "Harapan".

Plate 4 **Abnormal plant with multiple ears infected with *Sclerospora sacchari,* maize cultivar "Tainan No. 5".**



1) Flag leaf 2) Leaf sheath 3) Ear (husk cover)

Plate 5 **Systemic symptoms caused by *Sclerospora sacchari* at the maturation stage of maize cultivar "Tainan No. 5".**

Plate 6 Symptoms observed immediately after the infection of maize cultivar "Tainan No. 5" with *Sclerospora sacchari* (1) and of maize cultivar "Harapan" with *Sclerospora maydis* (2).

1) Natural infection caused by *Sclerospora maydis,* maize cultivar "Harapan"
2) Artificial inoculation with *Sclerospora sacchari,* at the 1st leaf stage of maize cultivar "Tainan No. 5"

Plate 7 Emergence of leaves and appearance of systemic symptoms of downy mildew disease of maize.

Plant at the 12th leaf stage showing symptoms in the village of Singosari on November 1972. There was no secondary infection in the field.

Plate 8 Systemic symptoms of downy mildew disease caused by *Sclerospora maydis* in maize at the middle period of growth.

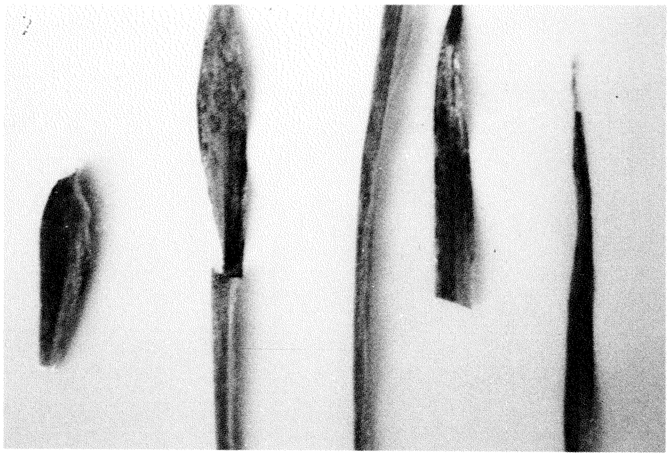
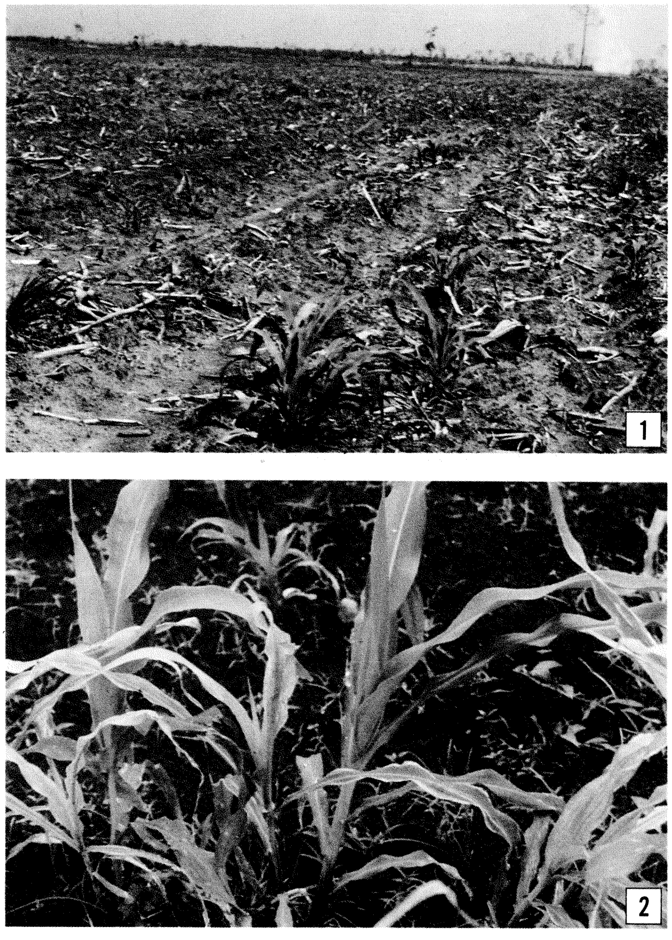


Plate 9 Symptoms appearing in a plant 8 days after germination. The plant had been infected with *Sclerospora maydis* through seeds. (from left, 1st, 2nd, 3rd, and 4th leaf).

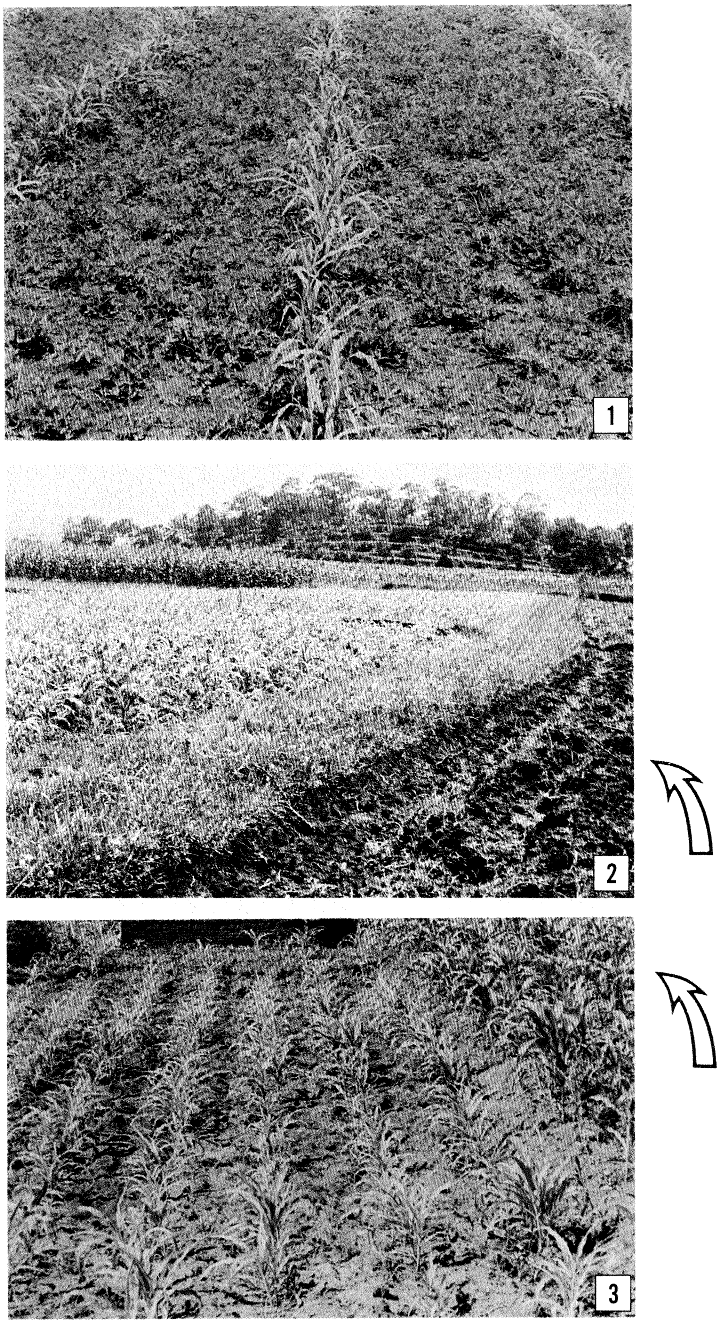


1) Maize cultivar "Metro" grew as weed after germination of seeds from ears that remained in the field.
2) Downy mildew disease of maize in the field mentioned above.

Plate 10 Downy mildew disease of maize caused by *Sclerospora maydis* in a field after harvesting of maize (at Lampung).

1) Djabung, Malang Prefecture. Example of maize field without any infection downy mildew disease. No source of infection could be found in adjacent fields. (Maize cultivar: Harapan.)
2) Kediri District, Kediri Prefecture. Area of farmer epidemics. However this area presently was spared of infection owing to enforcement of control measures.

Plate 11 Maize field without infection with downy mildew disese.



1) Karasan (see Figure 12 d)
2) Sedaju (see Figure 13 c) the arrow indicats field "1"
3) Karang Kuntji (see Figure 14 b) the arrow indicates field "c"

Plate 12 Fields with infection with *Sclerospora maydis* of maize.