16. CHEMICAL CONTROL OF MAIZE DOWNY MILDEW

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Downy mildew is a factor limiting maize production in several areas of Asia and is considered serious in some other regions of the world. It is the major disease of corn in the Philippines, Taiwan, Indonesia and Thailand. Despite extensive corn production in Malaysia, Vietnam, Korea and Khmer Republic, downy mildew has not been reported from these countries.

Yield losses attributed to this disease have been reported. In the Philippines, *Sclerospora philippinensis* Weston caused yield losses of 15–40%, and in some instances as high as 80–100% (Exconde et al. 1966). In India, the same pathogen was once reported to cause 100% infection in a seven-acre block of maize (Gattani, 1950). In Taiwan and India, *S. sacchari* Miyake has caused infection as high as 70% and reduced corn yield by 6 to 51.4% (Chang and Ling, 1968; Singh and Chaube, 1968). *Sclerospora maydis* (Rac.) Butler is reported to have caused infection ranging from 20–90% in Indonesia (Wendel, 1964; Purakusumah, 1965; and Subandi, 1967) and 10% in India (McRae, 1928). Recently (Tantera, 1974) a new outbreak of *S. maydis* occurred in 100,000 hectares field at Lampung (So. Sumatera), Indonesia which was a new settlement and was free from the disease for about a year (personal communication). In Thailand, (Pupipat, 1974) *S. sorghi* Weston and Uppal have been reported to cause 15–20% loss in yield (personal communication).

This paper presents some studies on the chemical control of downy mildew of corn in the Philippines and some other countries.

Philippines

Among the several methods of chemical application to control downy mildew, foliar sprays, soil treatments and seed treatments either with protectants or eradicants had been looked into. Orillo (1956) found that Phygon (50% 2, 3-dichloro-1, 4-naphthoquinone) at 1 lb/100 gal of water sprayed at an interval of 1 to 2 weeks gave 45% control.

From 1962–1965, extensive seedbed and field tests of 63 fungicides and 8 antibiotics showed that under severe epiphytotic outbreaks no fungicides could give adequate protection against the pathogen (Orillo et al. 1964; Exconde et al. 1965; and Exconde et al. 1966). The study made by Dalmacio and Exconde (1969) showed that the invasion of the shoot apex is a pre-requisite for systemic infection or complete chlorosis of all the leaves of infected plants. Also, they proved that the vulnerability of corn to infection by *S. philippinensis* decreases with plant age. With these findings the use of protectant and systemic fungicides has been re-studied to supplement the meager information on the use of chemicals for the control of this malady.

Extensive studies conducted by Dalmacio and Exconde (1971) and Exconde and Dalmacio (1971) on the use of protectant fungicides showed that 3 spray applications of Duter (20% triphynyl tin hydroxide) at 0.83 lb/100 gal at 2, 6 and 10 days after emergence and alternate 5 sprayings with Dithane M-45 (85% zinc manganese ethylene bisdithiocarbamate) at 2 lb/100 gal at 4, 8, 12, 14 and 16 days after emergence effectively

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controlled downy mildew. However, later study by Exconde, Raymundo and Soriano (1972) showed that on UPCA Var. 3 and Ph 801 no significant difference in infection was obtained between 8 and 4 sprayings of Duter-Dithane M-45 combination. Following the spray schedule of Duter-Dithane M-45, Daconil 2787 (5.8% tetrachloroisophtalonitrate) in combination with Duter gave the same degree of control of downy mildew (Exconde and Raymundo, 1972). Schultz Manimtim (1970) and Minimtim (1971) evaluated some systemic fungicides by seed treatment, foliar application and combination of the two. They found that neither dip nor dust applications of Benlate (50% butylcarbamoyl 2 benzimidazole carbamate), Thiobendazole (40% 2–4 Thiazalyl benzimedazole) and Polyoxin (10% polyoxin B) controlled downy mildew. Furthermore, combination of seed treatment plus foliar application of concentrated suspension of Uniroyal F 427 (75% 2, 3-dihydro-5 orthophenyl carboxynilido-6-methyl, 1, 4-oxathiin), Thiobendazole and Benlate to newly emerged seedlings did not control the disease.

Schultz (1971) found that corn seeds treated with Demosan (60% chloroneb) by both slurry and dip applications reduced disease incidence up to 2½ week after planting even when exposed to high inoculum density. Thereafter, he noted that the fungistatic properties of the compound were either inadequate or its systemic movement was too limited to effect control. Later, Schultz and Dalmacio (1971) obtained successful sustained control of downy mildew with combination treatments involving seed treatment (methyl cellulose 60 mg 10% Demosang/g seed) plus covering plants until 3 days after emergence plus foliar applications (5.0 g 65% wettabe Demosan 0.6 ml deep penetrant/1), at 3, 6, 10 and 15 days after emergence.

Because of the need for new effective chemicals to control downy mildew, Exconde and Raymundo (1972) evaluated in seedflats and in seedbeds 9 experimental systemic fungicides. Results in seedflats showed that CP 11-647-1 and El 273 sprayed 4 times at 3-day interval gave 20.1% and 37.4% infection, respectively, compared to the untreated check which had 100% infection. Although CP 11-647-1 was promising at 5 ml/liter, it was phytotoxic. In seedbed, 12 daily spray applications gave CP 11-647-1, Cercobin, and El-273 infection percentage of 3.6, 9.1 and 15.2, respectively, while the untreated check gave 82.3%. When 4 sprayings were made at 3-day interval, infection percentage was 89.4 for CP 11-647-1, 83.0 for Cercobin, and 92.0 for El-273. This observation corroborates the earlier findings that the fungistatic properties of the chemicals at the dosage used were insufficient to effect sustained control of the disease.

Further study on foliar spray with 5 systemic fungicides starting 2 days after emergence at various frequencies and different intervals of spray application showed that at daily spray for 14 days, Cela (experimental) and Dexon (70% dimethylaminophenyl-diazonatrium sulfonate) gave 89 and 92% control, respectively. At every 3 days spray also for 14 days, Dexon gave 80% control while Cela had 58%. When the spray interval was widened by one day for each subsequent spray to effect less number of spray application only Dexon performed effectively. Other chemicals evaluated, Cp 25-385, Cercobin, El-273 failed to sustain prolonged control (Exconde and Raymundo, 1973).

It could be noted from the above that the most promising chemical method of controlling downy mildew is by spraying with Duter-Dithane M-45 combination or Daconil 2787 and seed-treatment plus foliar application of Demosan. Study of this nature was conducted at 4 places in the Philippines during the 1971–1972 season (Exconde et al. 1972). Results of this study showed that 8 sprayings with Duter1Dithane M-45 combination gave the most effective control. Demosan seed treatment plus foliar spray was less effective.

The economic feasibility of using Duter-Dithane M-45 and Demosan seed treatment plus foliar spray to control downy mildew was studied by Raymundo, Exconde and Soriano (1973). We found that returns above added costs with 8 sprayings of Duter-Dithane

M-45, 4 sprayings with Duter-Dithane M-45, Demosan high and Demosan low rate was ₱697.45, ₱566.40, ₱-2,120.96, and ₱-1,840.01/ha, respectively. On UPCA VAR. 3 and Ph 801, added returns amounted to ₱1,238.03, ₱1,202.02, ₱1,913.19, and ₱1,482.40, respectively. In the case of Demosan treatment, we found negative added incomes for low and high rate applications in both UPCA Var. 3 and Ph 801 because of the lesser degree of control against downy mildew and the high cost of the chemical.

Raymundo and Exconde (1974) evaluated the economic feasibility of resistant varieties, fungicide application and roguing for the control of corn downy mildew. We found significant increases in yield in all treatments, except on 4 and 8 sprays of Duter/Dithane M-45 during the dry season of 1973 and on roguing. We found further that the use of resistant varieties gave the highest additional income and sprays of Duter/Dithane M-45 gave generally lower income than with the use of resistant varieties. Eight sprays resulted in higher increased income compared with 4 sprays during the dry season but not during the wet season.

The use of mineral oil, alone or in combination with protectant fungicide have been also explored. Estrada and Exconde (1974) sprayed 7 mineral oils each at 0.4 ml/pot of 5 corn seedlings. After spraying inoculation was done by atomizing until run-off spore suspension of 45,000 conidia/ml. We found that banana spray oil and F-1243 gave 1.6% infection; F-1865 and F-3200, no infection, Orchex 696, 1.7% infection and the control, 62.5% infection. We found further, that except for a slight toxic effect on plants that were sprayed for 7–8 times with F-1805, Orchex 696, and F-1243, the other oils tested did not inflict any intolerable phytotoxic effect.

Other Countries

India, extensive studies have been conducted on the effectiveness of chemicals for the control of downy mildew. Singh, J. P. et al. (1970) have shown the control of brown stripe downy mildew of maize with fungicide. Of 16 chemicals tried, bleaching powder, rhizoctol, captan, plantvax and fennite inhibited sporangial germination in the laboratory test and had some effect when they were sprayed or used as a soil drench. Based on the result of laboratory screening and field trials, captan and plantvax spraying proved to be the most promising chemical for practical application. He found that maize plants systematically infected with *Sclerospora philippinensis* could not recover by application of Bordeaux mixture. In soil drenching trial, vitavax gave good protection against brown stripe of maize. Bleaching powder in various concentration was effective in controlling the disease in pot experiment.

Study conducted by Singh et al. (1970) showed that downy mildews of maize caused by *Sclerospora sacchari* and *Sclerophthora rayssiae* var. *zeae* were influenced by the nutrition of the host. Zinc deficiency predisposed the plants to attack of downy mildews. Wet soil application of NPK fertilizer mixture plus foliar application of zinc, iron, boron, copper and molybdenum reduced disease incidence significantly. Seed treatment with paratoluene sulfonamide and soiltreatment with bleaching powder (33% chlorine) followed by spraying of crop with zinc lime mixture resulted in a high degree of protection against these diseases in preliminary trial.

Nene and Saxena (1970) showed the possibility of controlling downy mildew through foliar sprays of fungicides. Among the fungicides tested, Captan, Dithane M-45, Ziram and Miltox gave good control of the disease. Miltox though effective, caused phytotoxicity because of the presence of copper.

To control the downy mildew of maize, Govindu (1974) recommended the spraying of the 15 days old maize with 40 g zineb in 18 liters of water and this is repeated 30 and 45 days after sowing (personnal communication).

Research in Taiwan showed again the possibility of using fungicide for control of

sugar downy mildew in maize. Laboratory test showed that maneb (manganese ethylene bisdithiocarbamate) and a few other fungicide inhibited the conidial formation and germination of *Sclerospora sacchari*. Greenhouse and field test further proved that maneb was an effective protectant against downy mildew when sprayed 4 to 6 times on healthy maize seedlings at 4 to 7 day interval under moderate disease conditions. However, under severe conditions, they found that maneb was neither effective nor feasible because complete coverage of the healthy leaf tissues with chemicals was difficult and chances of infection through these uprotected tissues became so great that protection was no longer possible, unless heavier sprays were made at shorter interval. The use of systemic fungicide has not been attempted but remains a promising means of downy mildew control. A single early application of an effective systemic might well protect the seedling during its period of susceptibility (Sun, 1970).

Sun and Lai (1966) applied several foliar sprays at 5-day interval and found Dithane M-22 very promising. Degree of control was very low and they attributed this to the rapid growth of corn seedlings such that new leaf tissues were developed during the interval of spray. These unprotected newly-developed tissue eventually would be exposed to infection. However, Chang and Ling (1968) later found that Dithane M-22 gave zero and 3.5% infection when sprayed daily and once every other day, respectively, while the control had 87.8%. They obtained yiel ddifference of 50% between treated and untreated plots.

Chang (1970), suggested the impracticality of the use of chemical for the control of downy mildew in commercial maize production. However, he suggested that it may be useful in experimental field trials for breeding or for other purposes when a downy-miledw-free condition is required. Dithane M-22 proved effective when diluted 400 times and mixed with a sticker-spreader and sprayed on 3 succeeding days on young seedlings followed by 4 sprays at 7-day intervals. Some systemic fungicides for controlling the downy mildew are presently under test.

In-furrow application of several fungicides conducted in the United States in 1965 showed that none of the treatments at either 1 or 5 pound rates gave the slightest indication that they would reduce downy mildew. In general, fungicide application appeared to enhance downy mildew infection. The fungicides tested were Dexon, Polyram, Lanstan, Actidione and Dexon plus Polyram. In 1966, no difference in either systemically diseased seedlings or foliar infection were detected, however, the incidence of infestation was not influenced by soil incorporation of several common fungicides. Foliar spread of downy mildew were not successfully controlled in 3 separated attempts, primarily because during these studies foliar spread failed to occur (Frederiksen et al., 1970).

Research done on *Sclerospora maydis* in Indonesia has included evaluation of fungicide as seed and foliar protectant but details of the experiment have not been reported (Exconde, 1970).

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Question and Answer

R. A. Frederiksen, U.S.A.: Have you attempted to reduce the inoculum by spraying adjacent plants?

Answer: Yes, it tremendously reduced the inoculum potential in the area.

Sangam Lal, India: Have you ever tried a combination of seed treatment+roguing of infected plants+foliar spray of fungicide, if required?

Answer: No. We have tried, though, seed treatment plus foliar spraying. Roguing was done separately.

Yamaguchi, Japan (Comment): In Japan, many chemicals were tested experimentally against rice downy mildew *Sclerophathora macrospora*. As a result of these experiments, seed coating or seed dippling of Actidione and the drenching of seedling beds before infection with Pansoil (5-ethoxy-3-trichloromethyl-1, 2, 4-thiadiazole) were found to be moderately effective. However, after infection these chemicals did not show practicable effects, and these chemicals are not yet utilized by farmers.

M. M. Payak, India: Have you evolved and standardized any *in vitro* method of evaluating chemicals for determining their effectiveness on Downy Mildews?

Answer: Yes; the method utilizes the spore—slide germination test, wherein uniform inoculum density, age of the inoculum, length of the incubation period, etc., are used.

R. Kenneth, Israel: 1) As J. P. Singh controlled brown stripe downy mildew

with plantvax, we may ask how this systemic fungicide, which is toxic almost only to Basidiomycetes (particularly rusts) could have succeeded. We found that a similar fungicide, VITAVAX, causes changes in barley and pea plants, among which is the excess transpiration due to the stomata remaining open to some degree. Plants wilt faster in dry soil. Perhaps foliage surface is dryer, preventing zoospore germination on the leaf, and preventing the local lesions typical of this disease.

2) Are any antisporulants known which could possibly act against downy mildews? For some of them—no conidia, no disease.

Answer: 1) It is enlightening to know that J. P. Singh obtained control of brown stripe downy mildew with plantvax considering that experiences of other donwy mildew workers showed otherwise.

2) Mineral oils seem to act as antisporulants.

Sangam Lal, India: Duter has been found to be more effective than Dithane M-45, which is a combination product of zinc and manganese. But in the case of Dithane M-45 spray, we always have greater grain yield. Probably it is because of the indirect availability of zinc to the plants. Have you ever tried Duter+zinc sulfate or Dithane M-45+$ZnSO_4$ combinations?

Answer: No. However, I wish to point out that other workers have reported the toxic effect of zinc on conidia of some *Sclerosporas*. I still believe that the main effect of Dithane M-45 on plants is to protect, rather than to provide nutrients to the plants thereby enhancing their resistance.

S. Y. Mah, Malaysia: In your experiments using foliar spraying, did you use any surfactant or sticker-spreader?

Answer: Yes; Tenac and Tween 80.

N. Yamada, Japan: I am very much impressed with the economic analysis you have made on the use of chemicals. I have a question in relation to the cost of inputs shown in your slide. Does the cost include cost for labor of application, cost of instrument to be used for application or the cost of chemicals alone?

Answer: The added cost includes the cost of the chemicals, labor in applying the chemicals, and the cost of harvesting the added produce.

D. M. Tantera, Indonesia: 1) We have to protect the plant against infection for only about 3 weeks. Do you think that in the near future a good systemic fungicide other than those which you have been testing will come out?

2) Do you feel a lack in the system fungicides presently available so that they could not give sufficient protection from downy mildew infection?

Answer: 1) Yes, we should expect to obtain other systemic fungicides which have not been included in our experiments.

2) This may be because the current systemic fungicides provided by chemical companies have not been developed or screened against the *Sclerosporas*.

K. M. Safeeulla, India (Comment): One of the methods we have followed to study the effect of chemicals on Sporangial germination in order to control *S. graminicola* is to float the diseased leaf bits in Petri dishes containing the chemicals to be tried and to see the effect on Sporulation and spore germination.

We have tried different chemicals and found variations in sporulation and also spore germination.

M. Riccelli, Venezuela: Would spray applications of fungicides be still effective when corn is grown under heavy rains?

How many additional applications would you need?

Answer: 1) No, the rain will wash out the chemical. A sticker added to the material will help prevent the washing of the fungicides applied.

2) It would depend upon the age of the plant and the availability of the inoculum.