THE QUEST FOR THE CONTROL OF PHILIPPINE CORN DOWNY MILDEW

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Abstract

Until about 1980, the annual Philippine loss in yield due to Philippine corn downy mildew caused by *Peronosclerospora philippinensis* (Weston) Shaw was estimated at 205,470 metric tons of corn valued currently at ₱267,111,000. After 16 years of research on the etiology of the disease and field testing of foliar spraying, seed-dressing and soil treating of nearly 800 chemical toxicants, Apron 35 SD (formerly Ridomil) has finally been found effective as seed-dressing. This fungicide can absolutely control corn downy mildew from seedling emergence until harvest.

Introduction

The causes of low yields in farmers field have been identified and discussed in several symposia/congresses sponsored by various government agencies and professional societies. The low yields are mainly due to a number of interrelated causes, viz. a) minimal usage of fertilizers, b) damage by diseases, particularly downy mildew, c) high losses due to weeds, d) damage by insect pests like corn borer, armyworm and corn maggots, e) insufficient control/ lack of water, f) low usage of high yielding corn varieties, g) use of marginal and very unproductive land for corn production, h) lack of locally adaptable machineries and equipment for land preparation, planting and cultivation for small scale farming, and i) low adoption of recommended agronomic cultural practices (Mercado, 1976).

Of these interrelated causes of low yields of corn in farmer's field, I shall discuss only the role of downy mildew caused by *Peronosclerospora philippinensis* (Weston) Shaw. In the 1974-1975 crop year, our estimated national yield loss due to this disease was 8% with corresponding yield reduction of 205,470 metric tons valued at ₱178,759,000.

One of the adjuncts in the control of corn downy mildew is the use of downy-mildew resistant (DMR) varieties which have been developed from 1970 to date. Among the DMR's which have gained a fairly wide acceptance among farmers are Phil. DMR-2, Phil. DMR Composite 1, Phil. DMR Composite 2 and lately Ginintuan, an improved version of Thailand's Suwan 1. These varieties have an appreciable degree of resistance to downy mildew compared to UPCA Var. 1 and 3.

It can be noted from the above discussion that even though DMR varieties have been developed, some of these do not possess high level of resistance particularly under severe epiphytotic conditions. In view of this problem on some DMR varieties, a complementary control strategy, possibly the use of seed-dressing, should be considered in the overall management of corn downy mildew.

History of chemical control. Among the several methods of chemical application to control Philippine corn downy mildew, foliar sprays, soil treatments, and seed treatments either with protectant or eradicants had been looked into. Weston (1923) suggested the soaking of the seeds in 70% alcohol from 30 sec to 1 min; afterwards the seeds have to be washed in running water for 1 hr. and finally dried. Orillo and Gibe (1956) reported that out of the 8 fungicides sprayed in the field for the control of downy mildew, Phygon XL (50% 2, 3-dichloro-1, 4-napthoquinone) and Fermate (76% ferric dimethyldithiocarbamate) were effective.

From 1962-1965, extensive seedbed and field tests of fungicides and 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 *P. philippinensis* decreases with plant age. With these findings, the use of protectant and systemic fungicides has been re-studied to gain more 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 for Duter (10% 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 controlled downy mildew. Schultz and Manimtim (1970) and Manimtim (1971) evaluated some systemic fungicides for seed treatment, foliar application and combination of the two. They found that neither dip nor dust applications of Bonlate (50% butylcarbamoyl 2 benzimidazole carbamate), Thiabendazole (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), Thiabendazole, and Benlate to newly emerged seedlings did not control the disease.

Schultz (1971) found that corn seeds treated with Demosan (60%chlonoreb) by both slurry and dip applications reduced disease incidence up to 2-1/2 weeks after planting even when exposed to high inoculum density. Thereafter, he noted that the fungistatic proportion of the compound were either inadequate or its systemic movement was too limited to effect control.

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 seedflat experiments 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 was promising at 5 m/l, it was phytotoxic.

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-diazonatium sulfonate) gave 89 and 92% control, respectively. At every 3-day spray application also for 14 days, Dexon gave 80% control while Cela gave 58%.

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. The economic feasibility of using Duter-Dithane M-45 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, on UPCA Var. 3 and Ph 801, amounted to ₱1,238.03, ₱1,202.02, ₱1,913.19 and ₱1,482.40, respectively.

Raymundo and Exconde (1976) evaluated the economic feasibility of resistant varieties, and fungicide application for the control of corn downy mildew. We found significant increases in yield in all treatments, except on 4 and 8 spray applications of Duter/Dithane M-45 during the dry season of 1973. We found further that the use of resistant varieties gave the highest additional income and spray application of Duter-Dithane M-45 gave generally lower income than with the use of resistant varieties. Eight applications resulted in highest increased income compared with 4 spray applications during the dry season but not during the wet season.

Field test of the oil's protective value either alone or in combination with Dithane M-45 on UPCA Var. 3 for 2 seasons was conducted by Estrada and Exconde (1976). Significantly, we found low level of infections in both seasons from the oil- and oil-fungicide-treated plants compared with the control. F-1243 was slightly more effective than F-1805 when applied singly or in combination with Dithane M-45. Yield loss was consistently reduced among plants sprayed with F-1243+Dithane M-45 compared to other treatments. Furthermore, we found that the low incidence of downy mildew as a consequence of spraying with F-1243+Dithane M-45 resulted in an increased yield and consequently in economic returns. In all cases, F-1243 + Dithane M-45 gave the highest added returns.

Ridomil: — A newly discovered fungicide for corn downy mildew control. — It will be seen from the foregoing discussions that none of nearly 800 fungicides tested from 1962 to late 1977 has offered substantial solution to the downy mildew problem. Perhaps, it is worth looking back on the few random thoughts on the future outlook of the downy mildew problem in East Asia and Southeast Asia which I have stated in a special lecture I delivered in the first International Downy Mildew Conference held in Nanintal, India in 1969 and in other meetings and symposia (Exconde, 1970; 1973; 1974). In all of these meetings/symposia I sounded off a call to the chemical companies around the world to include the Oomycetes in the group of pathogens being used to evaluate the biological spectrum of their candidate chemicals. In all of these occasions I also conceptualized the kind of chemical that could be adapted by farmers in combating the downy mildew problem in the region. I opined that a seed dressing fungicide that can be taken into the system of the corn plants and protect the corn plant from the downy mildew pathogens for at least 6 weeks is wanting. It seems that Ridomil has provided the answer to some of the thoughts that I have conceptualized regarding corn downy mildew control by chemicals.

The experiments on Ridomil. — In July 1977 Ridomil WP 10 and WP 25 were made available to us by Mr. Wolf R. Dinnendahl, Agro-chemical Division, Ciba-Geigy, Philippines, for evaluation as foliar spray for downy mildew control. As what I have contended before that the most realistic method of controlling corn downy mildew is by means of seed dressing, it has always occurred to me that new fungicides should be evaluated first by seed dressing, then foliar spraying and if necessary by soil application.

On 8 August 1977, preliminary study on seed dressing of Ridomil WP 10 was made with rates of 2, 4, 6 and 8 g a.i./kg seed plus untreated seeds. Treated and untreated seeds were planted in plastic trays and then the seeded trays were exposed underneath the mildewed corn plants in the field for 30 days. Our results showed that at all rates tested, no infections of downy mildew were observed compared to 45% infection in the untreated seeds which occurred as early as 3 weeks after planting.

In November 1977, field experiments on foliar spraying as recommended by the company were undertaken. Two frequencies of spraying, 4 and 8, both on protectant and eradicant tests were made. Results showed that in both frequencies of spraying, Ridomil used either as protectant or eradicant did not effectively control corn downy mildew.

In view of the failure of Ridomil to control Philippine corn downy mildew by foliar spray applications as originally conceived by Ciba-Geigy and because of the very encouraging results on seed dressing we have obtained in our preliminary experiments, 4 field trials on seed dressing in replicated plots were made from November 1977 to February 1978. Two trials were conducted under moderate low inoculum density. In all trials seed dressing was by "slurry". Infection percentage was taken at 16, 23, 30, 42 and 63 days after seedling emergence by taking the ratio of the total infected plants and the total population multiplied by 100. In 2 trials, the crop was harvested as green corn, 63 days after emergence, while the other 2 trials, the crop was harvested at 110-120 days after planting as unshelled corn.

Results of all trials conducted under moderately low and high inoculum densities showed that all rates tested, (2, 4, 6 and 8g a.i./kg seed) no infection of downy mildew was observed from seedling emergence until harvest, either as green corn or unshelled corn (Exconde and Molina, 1978). The lowest rate of 0.5 g a.i./kg seed on moderately resistant variety performed as good as 1 ga.i./kg seed on a susceptible variety. We believe that the present finding is considered as a significant "breakthrough" in the long (16 years) elusive search for the chemical control of corn downy mildew, the most destructive disease of corn in the Philippines. Furthermore, the ease by which the chemical can be applied to the seed and the small amount of chemical needed to sustain 100% control of corn mildew from seedling emergence until harvest makes Ridomil a "wonder" chemical for corn downy mildew control.

Regional trials of Apron 35 SD on varieties and hybrids. — In 1978-79 wet and dry seasons, trials were made at Tumauini, Isabela; Musuan, Bukidnon; Kabacan, North Cotabato and UPLB. Results showed that on untreated seeds of UPCA Var. 1 infection in the wet season ranged from 52 to 100%, while in the dry season, infection ranged from 11 to 80%, compared to the treated seed which had zero infection in both seasons. On DMR Comp. 2, untreated seeds in the wet season had infection ranging from 10 to 48%, while no infection occurred from the treated seed. In the dry season, on DMR Comp. 2, untreated seed had infection ranging from 4 to 25%. On the other hand, treated seed had zero infection.

Trials made on hybrids at Pili, Camarines Sur showed that infection on untreated seeds at 30 and 60 days after planting ranged from 1.6 to 40.3% compared to the treated seeds which had no infection. Significant differences in yields between treated and untreated seeds and among hybrids were obtained. Yields of more than 5 tons/ha were obtained from some hybrids.

At General Santos, South Cotabato infection from untreated seeds ranged from 34 to 100% at 32 and 38 days after planting, compared to no infection from treated seeds. Yield obtained from treated seeds ranged 3.88 to 5.50 tons/ha.

Some Factors Affecting the Efficacy of Apron 35 SD as Seed-Dressing Fungicide

A number of factors that may affect the efficacy of Apron 35 SD as a seed-dressing fungicide to control Philippine corn downy mildew has been studied (Molina and Exconde, 1981 a & b). This includes methods of seed dressing and frequency of rainfall and amount of water used in the preparation of slurry, storage duration and temperature. Germination of treated seeds and subsequent downy mildew infection in the field under high inoculum pressure (spreader rows had 40 to 50% mildewed plants) and moderate inoculum pressure (spreader rows had 5 to 15% mildewed plants) were considered in evaluating the efficacy of each treatment combination.

Methods of seed-dressing. — Apron 35 SD was evaluated when applied as dust or slurry through some crude but seemingly practical ways. Under condition of high inoculum density, the slurry treatment was more efficient than dusting. Infection ranged from 6.2 to 18.2% and 0 to 5.7% for dusting and slurry, respectively. Among the several methods tested in applying the slurry, the wide mouth gallon jar and cement mixer appeared to be more efficient than shoveling, plastic bag and plastic pail.

Under moderate inoculum density, however, slurry and dusting were equally effective, except when the fungicide was applied as dust by shoveling wherein an infection of 4.3% was obtained. On the other hand, all plants in the other treatment combination were completely free from downy mildew infection as compared to the untreated check which had 67.8% infection.

Duration of rainfall. — Effects of frequency and duration of rainfall on the effectiveness of Apron 35 SD showed that the frequency of heavy rainfall did not affect the effectiveness of Apron 35 SD. The efficacy of seed treatment subjected to daily rainfall of 20 mm/day for 3 weeks starting immediately after seeding was not different from that of lesser frequency. Plants grown from treated seeds were completely free from mildew under different rainfall conditions compared to the untreated check which had 97.6% infection.

Storage duration and amount of water. — Results showed that seed germination ranged from 96 to 100% among seeds treated with Apron 35 SD either as dust or as a slurry with the use of either 5 ml or 10 ml water/kg seed. When the amount of water was increased to 20 ml, 30 ml and 40 ml/kg seed, seed germination was 86, 33, and 16%, respectively after storage of 150 days. However, the depressive effect on seed germination was not noticeable regardless of the amount of water used in the preparation of slurry, when treated seeds were not stored.

The depressive effect of high amount of water added to the seeds in relation to duration of storage showed that even without treating the seeds with Apron 35 SD, seed germination was adversely affected by the addition of 20, 30, and 40 ml water/kg seed.

The germination of seeds treated with Apron applied as dust or slurry with either 5 or 10 ml water/kg seed was comparable to the untreated regardless of the storage duration.

Rate, storage temperature and duration. — Results on seed germination as affected by rate of Apron 35 SD, storage temperature, and duration showed that seed germination was not affected by any of the treatments. Seed germination ranged from 93 to 100%.

Efficacy of each treatment combination against downy mildew under field condition showed that untreated seeds sustained as high as 97.8% infection. On seeds treated with Apron 35 SD at the rate of 0.5 g a.i./kg seed and stored at two temperature levels and duration of storage periods, infection ranged from 7.8 to 23.8%. Infection at this rate started as early as 14 days after emergence and increased thereafter until about 35 days after emergence when no increment in infection occurred. On the other hand, treatment combinations with 2.0 g a.i./kg seed were completely free from downy mildew from seedling emergence until harvest, regardless of storage duration and temperature.

Apparently, storage duration as well as temperature at storage did not influence the infection percentage. The differences on mildew infection were more of a function of the rate of Apron 35 SD, rather than duration and temperature at storage.

Corn Downy Mildew Control. Now a History

The recent breakthrough in the chemical control of Philippine corn downy mildew caused by *Peronosclerospora philippinen-*

sis with the use of Apron 35 SD has answered the long sought solution to this most destructive disease of corn in the country. As a seed-dressing fungicide, the use of Apron 35 SD apparently agrees with the common belief that the more practical way of controlling diseases of cereals, such as corn, by chemical means is by seed-treatment. Its effectiveness in controlling corn downy mildew, the ease by which this chemical is applied, and the small amount needed to sustain 100% control will surely make its application acceptable and adaptable by farmers.

Hand-in-hand with the use of Apron 35 SD is the development and release of resistant varieties/hybrid to downy mildew plus the wide-scale planting of these resistant varieties/hybrid is another key factor that would ultimately provide solution to the once dreaded downy mildew of corn. With the use of the above control strategies, we can truly say now that we cannot afford to lose millions of pesos worth of potential production every year due to downy mildew alone.

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DISCUSSION ON THE QUEST FOR THE CONTROL OF PHILIPPINE CORN DOWNY MILDEW

Manuel M. Lantin, Discussant

The downy mildew disease caused by *Perenosclerospora philippinensis* (Weston) has been one of the major constraints to corn production in the country. The estimated loss in yield, as pointed out by Dr. Exconde, is indeed staggering. The amount (over 200,000 metric tons) is only slightly less than our current yellow corn importation. An effective and inexpensive means of control of this disease will definitely improve productivity and income in our corn growing areas.

The importance of Philippine corn downy midew disease has been fully recognized in the agricultural research community. For many years corn research was concentrated on the development of effective means of controlling the disease. Solution to the problem was approached basically from two distinct directions. The first was through genetically endowed resistance to the disease and the other was through chemical control.

Varietal improvement efforts at U.P. at Los Baños have been primarily aimed at the development of downy mildew resistant cultivars. For a long time, this has been the single most important objective of the breeding program. Through the concerted efforts of the maize breeder and pathologist several varieties/populations with relatively high degree of resistance to the disease have been produced and released for commercial production.

On the other hand, efforts to control the disease through chemical means consisted of screening/testing of a large number of chemical toxicants. The long years of search met very little success until four years ago when the fungicide Ridomil (now Apron 35 SD) was found to provide effective control when used as seeddressing. The discovery of Ridomil is indeed a "breakthrough" in chemical control research and may be considered one of the most significant outputs of agricultural research in the Philippines during the late 1970's.

The availability of a fungicide that provides practical and effective control of downy mildew disease has some important implications on other control strategies particularly on the use of varietal resistance. Breeding for downy mildew resistance has been and will remain a major objective of maize varietal improvement program in the Philippines. However, with the breakthrough in chemical control, some efforts can now be focused on other breeding problems. The use of chemical could compensate for the low to moderate resistance usually possessed by the higher yielding or elite maize genotypes/populations. Normally, such genotypes are excluded and forever lost in a selection program where downy mildew resistance is given a high priority.

An almost immediate consequence of the discovery of Apron 35 SD is the advent of "new" technology concerning the varietal component of the production package for corn. The chemical has made possible the use of downy mildew-susceptible but high yielding corn hybrids. Four of such hybrids are currently being used in the Maisagana Program.

After all is said about the now available technologies for the control of downy mildew, could we claim that the downy mildew pathogen has finally been licked? During the past 2 or 3 years little incidence of downy mildew disease in the corn fields was reported. The findings are very encouraging and could lead one to believe that the downy mildew problem has indeed been solved. I believe that we would be grossly naive and appear uninitiated to think along this line. We know that we are dealing with a dynamic living organism (pathogen) with a capacity to adapt to changes in conditions surrounding it. We have heard stories about resistant crop varieties succumbing to the same species of pathogen (presumably of different race). In much the same way, pathogens could evolve races or strains to which a certain chemical would prove ineffective. Development of resistance of pathogens to certain chemicals has been reported. This is a distinct possibility that we in corn research should consider.

Fernando Sanchez, Ph.D., Discussant

The long search for an answer to the corn downy mildew problem has all the way been an uphill battle. For many years there was little progress, then came the downy mildew—resistant varieties that helped the corn farmers in this country to increase their production. However, the degree of resistance to the disease was only low, to at most moderate, so losses persisted despite the availability of these downy mildew resistant varieties.

The discovery and development of Apron (metalaxyl) after many years of work by Dr. Exconde and his group was indeed a great contribution. Used at the recommended rate, it provided 100% protection against the disease. Be that as it may, it is a discovery that has really not been fully exploited. It means it has not really filtered down to most of the corn farmers. Why is this?

There are many problems related to the adoption of this important discovery. First, there is distribution problem. It is not available to most because it is not readily available in the market. And if it is available there is the problem of lack of purchasing power on the part of the farmer. Or otherwise the farmer is not able to exploit this development. To some extent, the Maisagana Program has solved some of these restraints to the full utilization of this important discovery.

Like most chemical control methods, there is a distinct possibility of development of resistance as Dr. Lantin has earlier alluded to. We cannot really stop at this point with the discovery of this important fungicide. We can say that we have won a battle but the war is still on.

There is need for new chemicals to replace APRON. That is definite. If and when resistance comes we should be ready. But the prospects for new chemicals is not that good. About a decade ago, to produce a chemical from the synthetic laboratory to commercialization cost about 2-3 million dollars. Nowadays it may cost from 40-45 million dollars. So, who's willing to invest capital money of that magnitude? The prospects for new developments is really not too good.

In the crop protection field there is no such thing as a permanent solution. Resistance to pest/disease in resistant varieties break down and pests and pathogens develop pesticide resistance that confer to them immunity from previously effective pesticides. It is a never ending battle between pests and man. We can only hope to be a few steps ahead of the pests.