CONTROL OF CHINESE CABBAGE DOWNY MILDEW (*Peronospora parasitica*) BY METALAXYL (RIDOMIL) AND OTHER FUNGICIDES

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Abstract

Four fungicides, i.e. Curzate-M, mancozeb (Dithane M-45), chlorothalonil (Daconil) and metalaxyl (Ridomil) in the WP formulations at various rates and times of application were evaluated for their effectiveness in the control of Chinese cabbage downy mildew caused by *Peronospora parasitica* under epiphytotic conditions with reinforced artificial inoculation in the field. Ridomil 25 WP applied three times at one week interval at a rate of 2.0 kg/ha, beginning 28 days after transplanting was found to be the best agent among the 4 fungicides tested for the control of downy mildew of Chinese cabbage. Ridomil treatment resulted in a 65% increase in yield of marketable cabbage while affording complete protection, by preventing the causal organism of the disease from developing, throughout the entire crop growth season. The data obtained from this study are highly significant at P = 0.01 level. At 125 ppm and higher levels of Ridomil application, both conidial spore germination and growth of germ tubes of *P. parasitica* were completely inhibited.

Introduction

Downy mildew, caused by *Peronospora parasitica*, together with bacterial soft rot and turnip mosaic virus, constitute the three most serious diseases of Chinese cabbage in the Asian tropics and elsewhere in the world (Yang, 1980). Heavy infection with downy mildew often results in a 50% seasonal yield loss in Chinese cabbage. Although single conidia of *P. parasitica* cause slight infection, the degree of infection increases with the number of conidia in the inoculum preparation (Krober, 1969). Generally, downy mildew is considered a cool season disease in the temperate region. However, in the tropical and subtropical regions, it can occur year-round in the fields. Systemic infection could take place at the cotyledon stage (Polyakov and Vladimirskaya, 1964), but the most severe disease damage usually occurs later in the season, during the heading stage of the Chinese cabbage. The pathogen has a wide host range in both cultivated and weed cruciferous species. Several species of *Brassica*, such as *B. juncea, B. pekinensis, B. oleracea* var. *acephala, B. chinensis*, and *B. oleracea* var. *capitata*, Chinese turnip (*Ralphanus sativus* var. *crispa*), and many others can be infected with this pathogen. Downy mildew predisposes the crop to bacterial soft rot infection in transit and storage. Cruciferous crop previously infected with turnip mosaic virus can become more susceptible to downy mildew (Bains and Jhooty, 1978). Although cruciferous crop varieties with resistance to downy mildew have been sought the world over, controlling the downy mildew of Chinese cabbage with fungicides is still an important measure in order to secure good crop production. Up to the present, there is no effective and economical chemical, particularly under high humidity and temperature growth conditions, which controls the disease.

The objective of this study was to evaluate the effectiveness of several systemic fungicides, including Ridomil, in controlling the Chinese cabbage downy mildew caused by *Peronospora*

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parasitica under heavy epiphytotic conditions in the fields, and, to determine whether Ridomil in the WP formulation could inhibit the spore germinability of the causal fungal pathogen of the disease.

Materials and methods

Experiment I

Three fungicides, i.e., Curzate-M 72 WP, Dithane M-45 80 WP and Daconil 75 WP, were tested for their effectiveness in controlling the downy mildew disease of Chinese cabbage in the field. The rates used for these fungicides are as follows: Curzate-M 72 WP, 1.2, 1.5 and 1.8 kg/ha; Dithane M-45 80 WP, 2.5 kg/ha; and, Daconil 75 WP, 2.0 and 2.5 kg/ha. The unsprayed plot was used as the control.

Chinese cabbage variety Ping-luh, susceptible to downy mildew but resistant to bacterial soft rot, was chosen for this experiment, using the randomized complete block design with 4 replications. Spacing between rows was 60 cm; and, between plants, 50 cm. A total of 42 plants was planted in a plot of 13.5 m^2. In order to eliminate the border effect, only 20 heads of Chinese cabbage per treatment of each replication were harvested for the evaluation of fungicide effects.

Five weekly sprays, starting 28 days after transplanting, were carried out under artificially enhanced epiphytotic conditions. The volumes of fungicide suspension, following the timetable of spray schedules, were also increased according to the growth of Chinese cabbage to 6.1, 8.1, 10.1 and 10.1 for the total area of the 54 m^2 plots. The pH value of the water used as diluent of the fungicide was adjusted from 7.5 to 5.7 by adding glacial acetic acid at 0.25 ml/liter before dispensing. An amount of 0.25-ml triton B-1956, a sticker, was added to 1 liter of each fungicide suspension to improve its performance.

In order to create a heavy infection of downy mildew, Chinese cabbage was inoculated twice with a spore suspension of *P. parasitica* at a concentration of 10,000 spores per ml: 1) at 30 days after transplanting, 2) one week after the first inoculation. Four weekly irrigations, starting immediately after the first inoculation, were given to maintain the high humidity that is conducive to the rapid development of downy mildew. Lannate, an insecticide, was also applied weekly to minimize insect infestation.

At harvest, disease index (%) was determined for the evaluation of the effectiveness of the fungicides. Twenty plants per plot were harvested as samples to be evaluated. The leaves wrapped outside the marketable head of each of the 20 samples were detached and each single leaf was rated according to the following standard scales: 0 (no infection), 1 (0 to 1/8 leaf area infected), 2 (1/8 to 1/4 leaf area infected), 3 (1/4 to 1/2 leaf area infected), and 4 (more than 1/2 leaf area infected).

After the ratings were made, the disease index (%) was calculated according to the formula:

$$P = \frac{\text{Sum}(n \times v) \times 100}{N}$$

where; P = degree of downy mildew infection,
N = total leaves being rated,
n = number of leaves in each infection category,
and, v = numerical values of infection categories.

Experiment II

Using experimental methods similar to those of Experiment I, three fungicides, i.e., Dithane M-45, Curzate-M and Ridomil, were evaluated for their effectiveness against the Chinese cabbage downy mildew disease caused by *P. parasitica* in this experiment. Chinese cabbage variety Ping-luh was again chosen as the test plant. The randomized complete block design with 4 replications was adopted as described in the previous experiment.

Four weekly sprays of Dithane M-45, Curzate-M and Ridomil were individually tested, beginning 28 days after transplanting. In addition, one (1) foliar spray of Ridomil, beginning 49 days after transplanting, and 3 weekly sprays of Ridomil beginning 35 days after transplanting were also tested. Triton B-1956 in 1:5,000 dilution (v/v) was added to each formulation in order to improve the spread of the fungicides. The insecticides hostathion 40% E.C. and Pirimor 50 WP were sprayed whenever they were needed to minimize insect damage.

Downy mildew was observed to appear from the 4th week after transplanting onward. Additional artificial inoculations with conidial spore suspensions at a concentration of 10,000 spores per ml and 4 weekly irrigations following the inoculation were carried out in order to enhance the development of the downy mildew on the tested Chinese cabbage plants. Disease indices of 20 plants in each treatment from all plots were determined as described in the previous experiment and the data obtained were analysed by Duncan's Multiple Range Test at $P = 0.01$ level.

Experiment III

Apron (35 SD), a seed dressing formulation of Ridomil, has been proved very effective against the pathogen *Sclerospora philippinensis* which causes the downy mildew of corn (Exconde and Molina, 1978). We decided to test the effect of this fungicide, Ridomil 25 WP, on the spore germination of *P. parasitica*, since this pathogen is also a member of the fungal family Oomycetes.

Before commencing the germination tests, fresh crops of conidial spores of *P. parasitica* were induced in the laboratory according to the following procedures. First, Chinese cabbage leaves infected with downy mildew disease were excised and blotted dry with cheese cloth. These leaves were then dipped in beakers that contained distilled water and were exposed to 60–100 watt incandescent lights at a distance of 1 foot for 6 hours in order to promote photosynthesis of the leaves. Afterwards, they were transferred to a plastic moist chamber on top of a plastic wire rack. The chamber was enclosed in a moisture-saturated case. This case was placed inside a 20°C constant temperature incubator for 12 hours in complete darkness. Profuse sporulation was thus induced on the diseased Chinese cabbage leaves.

Ridomil 25 WP at concentrations of 25, 75, 125, 175, 225, 275, and 325 ppm was tested against the untreated distilled water control for its effect on the spore germination and the growth of germ tubes of the freshly induced conidial spores. The method of standard glass-slide test was used to determine the dosage effect on the spore germination. One hundred conidial spores were tested against each dosage of the fungicide and each dosage was replicated three times. The slides containing samples were incubated in the moist chamber at 20°C for various lengths of time before the observations and measurements were made under a compound microscope. The percentage of spore germination was determined at 3 and 12 hours after incubation. The length of germ tube extension in μ was measured at 24 hours after incubation.

Results and discussion

Results of Experiment I are presented in Table 1. The data indicate that treatments with Curzate-M 72 WP at all 3 concentrations gave the best control of the downy mildew of Chinese cabbage among the three fungicides tested. Curzate-M gave a 30 to 35% increase in yield of marketable Chinese cabbage compared to the unsprayed control. This yield increase was statistically significant at the 5% level. Although Daconil provided some control compared to the unsprayed materials, the slight reduction in disease index value and the small yield increase of the marketable portion of Chinese cabbage make its effectiveness in the control of downy mildew insignificant. The 50% disease index calculated from the unsprayed plot indicates that only a mild epiphytotic condition existed in the fields when Experiment I was carried out.

Results of Experiment II are summarized in Table 2. The three fungicides tested in this experiment all gave significantly better control of downy mildew and higher marketable yields

Table 1 Effect of 3 fungicides on the control of Chinese cabbage downy mildew caused by *Peronospora parasitica.*

Fungicide	Rate (kg/ha)	Disease index (%)	Marketable yield (kg/head)
Curzate-M 72 WP	1.2	37.2*	1.57*
	1.5	36.4*	1.60*
	1.8	35.2*	1.62*
Daconil 75 WP	2.0	44.0	1.29
	2.5	41.9	1.42
Dithane M-45 80 WP	2.5	39.3*	1.28
None	0	50.0	1.20

* The difference between sprayed and unsprayed plots is statistically significant at the 5% level.

Table 2 Effect of Ridomil and other fungicides on the control of Chinese cabbage downy mildew caused by *Peronospora parasitica.*

Fungicide	Rate (kg/ha)	Spray (DAT**)	No. of sprays	Disease index (%)	Marketable yield (kg/head)
Ridomil 25 WP	2.0	28	4	0 c	1.37 a
	2.0	35	3	0 c	1.35 a
	2.0	49	1	0.1 b	1.30 a
Curzate-M 72 WP	1.8	28	4	36.7 b	1.17 ab
Dithane M-45 80 WP	2.0	28	4	39.8 b	1.05 b
None	0	0	0	77.5 a	0.83 c

* Statistically significant at P – 0.01 level.
** Days after transplanting.

when compared to the unsprayed control. It is statistically significant that the novel fungicide Ridomil in the formulation of 25 WP demonstrated complete control over the downy mildew disease in Chinese cabbage. This seems to substantiate the claims made by the manufacturers that Ridomil can provide both preventive and curative effects against the infection caused by the pathogen *P. parasitica*. This fact is particularly interesting in view of the heavy epiphytotic conditions of downy mildew infection on Chinese cabbage, as evidently manifested by the 77.5% disease index calculated from the control plots. When compared with Curzate-M and Dithane M-45, which both provided a disease index exceeding 35%, Ridomil 25 WP, with 3 applications at the rate of 2.0 kg/ha, gave 0% disease index, or, total control over downy mildew on Chinese cabbage in the field. The control by Ridomil not only provided 56% more marketable yield of Chinese cabbage, but also more importantly, it suppressed the perpetuation of the source of inoculum for the disease to develop in the field. Our preliminary trials during the early stage of Chinese cabbage growth indicated that excessive application of Ridomil may result in slight phytotoxicity to the young seedlings. However, this phytotoxic effect can be avoided if the amount of Ridomil is carefully administered according to the spraying program. Although Ridomil had been reported to control the downy mildews of a number of economic crops, we believe that this is the first report on its effectiveness in the control of downy mildew of Chinese cabbage under heavy epiphytotic conditions in the field.

The effects of Ridomil 25 WP on conidial spore germination and germ tube growth of *P. parasitica* are presented in Table 3. The data indicate that only a slight inhibition of the conidial

Table 3 Effect of Ridomil 25 WP on conidial spore germination and germ tube growth of *Peronospora parasitica*.

Concentration, ppm	% germination at		Germ tube length (μ) at 24th hour
	3rd hour	12th hour	
0	40.2	70.2	600–900
25	37.1	68.2	120–450
75	12.0	33.0	20–100
125	0	0	0

spore germination of *P. parasitica* was obtained with the addition of 25 ppm of Ridomil to the spore suspension when observed after 3 and 12 hours of incubation. At a level of 75 ppm of Ridomil application, both the percentage of spore germination and the growth of spore germ tubes were greatly reduced. At 125 ppm and higher concentrations of Ridomil, however, spore germination was completly inhibited. When the spores were treated with low levels of Ridomil, a slight measurable increase in spore germination and germ tube growth of *P. parasitica* was found at both 12 and 24 hours after the treatments. This seems to indicate that some degree of resistance to Ridomil was developed by *P. parasitica*, at least at the low dosage levels. Further sophisticated laboratory tests may enable to analyse this effect.

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Discussion

Obien, S.R. (The Philippines): Comment: Ridomil (metalaxyl) is quite effective in the control of maize downy mildew and dew mold of tobacco. Moreover Ridomil is not too expensive and the farmers can afford it. It is often used in combinations with other fungicides so as to avoid the development of resistance.

Kajiwara, T. (Japan): I observed many times that downy mildew of Chinese cabbage and cabbage in the tropics occurs very severely just after emergence on the cotyledons or first and second leaves. Is it not preferable to apply the chemical just after emergence? Also could you use Ridomil as material for seed treatment as in the case of maize downy mildew?

Answer: We have observed that the application of Ridomil at the very early stages of growth of Chinese cabbage was often associated with phytotoxicity. Also heavy attack of Chinese cabbage takes place chiefly after head formation. It is certainly a good suggestion to use Ridomil as material for seed treatment although it might be difficult due to the small size of Chinese cabbage seeds compared with that of maize seeds.