Reappearance and Control of Onion Downy Mildew Epidemics in New York

R. W. SMITH, Graduate Research Assistant, J. W. LORBEER, Professor, and A. A. ABD-ELRAZIK, Visiting Professor, Department of Plant Pathology, New York State College of Agriculture and Life Sciences, Cornell University, Ithaca 14853

ABSTRACT

Smith, R. W., Lorbeer, J. W., and Abd-Elrazik, A. A. 1985. Reappearance and control of onion downy mildew epidemics in New York. Plant Disease 69: 703-706.

Epidemics of downy mildew of onion, caused by *Peronospora destructor*, severely damaged commercial onion fields in western and central New York during the 1977–1979 growing seasons. On greenhouse-grown plants, when applied to onion leaves 24 hr before inoculation with *P. destructor*, chlorothalonil and mancozeb at rates equivalent to 1.07 L/ha (1.5 pt/acre) and 3.54 kg/ha (1 lb/acre) of formulated material, respectively, completely prevented infection. Greenhouse-grown plants were less susceptible to infection by *P. destructor* than outdoor-grown plants. Chlorothalonil and mancozeb at formulated rates equivalent to 3.08 L/ha (4.25 pt/acre) and 7.08 kg/ha (2 lb/acre), respectively, differed greatly in their residual effectiveness against infection of outdoor-grown onion plants. Mancozeb at that relatively low rate provided superior control over chlorothalonil at that relatively high rate when applied 2, 4, 7, or 10 days before inoculation. During 1980, onion growers in western and central New York generally used mancozeb to control downy mildew, and the incidence and severity of the disease was greatly reduced. From 1981 to 1984, incidence was nil when mancozeb was used.

Epidemics of downy mildew of onion (*Allium cepa* L.), caused by *Peronospora destructor* (Berk.) Caspary, occurred at economically damaging levels in many commercial onion fields in western and central New York during 1977–1979 for the first time since the mid-1950s (1). Downy mildew has been one of the most serious diseases of onion worldwide (2,3,5,8,9). Typically, epidemics of the disease have been sporadic (2,8). The epidemics of downy mildew from 1977 to 1979 were suspected from the start to have resulted from lack of effective fungicidal control rather than from other causes.

The purpose of our study was to explore the nature of the 1977–1979 epidemics of downy mildew in central and western New York by examining the histories of the reappearance of the disease and of grower control practices, the effects of chlorothalonil and mancozeb on germination of sporangia of *P. destructor*, and protection of onion leaves by these fungicides from infection by the pathogen.

Accepted for publication 2 January 1985.

The publication costs of this article were defrayed in part by page charge payment. This article must therefore be hereby marked "*advertisement*" in accordance with 18 U.S.C. § 1734 solely to indicate this fact.

MATERIALS AND METHODS

Extensive field observations on the occurrence of commercially important outbreaks of downy mildew in central and western New York were made from 1977 to 1980. Observations were made in Steuben County (Prattsburg), Yates County (Potter), Orleans and Genesee counties (Elba area), Oswego County (several locations), and Madison County (Canastota). Commercial onion fields at these locations were monitored for *P. destructor*. Commercial onion growers and extension personnel were interviewed to determine control measures used.

A typical culture of *P. destructor* was obtained from an infected onion plant in a commercial onion field at Prattsburg, NY. The fungus was isolated and maintained using the procedure of Abd-Elrazik and Lorbeer (1).

Chlorothalonil (tetrachloroisophthalonitrile) (Bravo 500, 4.17F) and mancozeb (a zinc manganese salt of ethylene bisdithiocarbamate) (Manzate 200, 80WP) were compared for their toxicity to sporangia of *P. destructor* on 1% water agar amended with different concentrations (1–1,000 mg/L) of each fungicide. One-day-old sporangia suspended in tap water were sprayed on the amended agar plates. Unamended 1% water agar served as the control. The percentage of germinated sporangia and the average germ tube length were determined after 24 hr at 10 C.

The surface wax of the leaves of 3-wk-old onion plants sprouted from bulbs in a greenhouse was removed by lightly rubbing the leaves six times unidirectionally (tip to base) with a dry pad of cotton. The leaves then were sprayed with either fungicide at different concentrations. In each experiment, 18 treatments were used, each consisting of four plants sprayed with one of nine concentrations of each of the two fungicides. Four control plants in each experiment were sprayed with tap water.

Triton B-1956 (a surfactant) was added to the mancozeb solutions and the water control at 0.47 ml/L (6 oz/100 gal). The solutions were sprayed on the leaves at 0.56 kg/cm^2 (8 psi) with a Gast air-pressure/vacuum pump connected to a DeVilbiss 127 atomizer (DeVilbiss Co., Toledo, OH). Twenty-four hours later, the plants were inoculated with *P. destructor* and incubated for 12 days. Inoculation, incubation, and sporulation inducement were performed following the methods of Abd-Elrazik and Lorbeer (1). After sporulation, percent diseased plants, percent diseased leaves, and sporulation intensity were measured. Percent diseased leaves was determined on the five outermost leaves of each plant by noting the number diseased. Sporulation intensity was rated on a scale of 0–4, where 0 = no sporulation and 4 = abundant sporulation.

The susceptibility of plants grown outside and inside the greenhouse to infection by *P. destructor* was compared. In preliminary experiments, leaves of greenhouse-grown plants not wiped with cotton often were difficult to infect. We wished to determine if infection was increased when plants with naturally weathered leaves were used. Two groups of plants were grown outside for 21 days, and two groups were grown inside for 21 days. The plants outside were grown at 15 C (average), winds of 3.2–22.4 km/hr (2–14 mi./hr), and 4.8 cm (1.98 in.) of rain. The greenhouse plants were grown at 18 C and watered automatically without wetting the leaves. One group of outside plants and one group of greenhouse plants were inoculated with *P. destructor* without prior manual removal of leaf surface wax. The leaf surface wax of the plants of the remaining two groups was manually removed before inoculation. After 12 days of incubation, incidence of diseased plants and leaves and sporulation intensity were measured.

The residual effectiveness of chlorothalonil and mancozeb against infection by *P. destructor* was tested in the greenhouse by inoculating groups of plants (grown outside the greenhouse) 0, 2, 4, 7, and 10 days after spraying with fungicide. Triton B-1956 (0.47 ml/L) was used as the surfactant with mancozeb. Plants sprayed with water and surfactant served as controls. After 12 days, incidence of diseased plants and leaves and sporulation intensity were measured.

RESULTS

History of reappearance. The first of the recent epidemics of onion downy mildew in New York occurred at Prattsburg in 1977. The first epidemic began during the first week of August at one farm, continued throughout August and early September on a neighboring farm, and resulted in severe economic losses on both farms. The disease also occurred at different levels on all other onion farms at Prattsburg during 1977. In 1978, downy mildew at Prattsburg was first detected on 31 July. Economic damage was much less than in 1977; however, at harvest in mid-September, large areas of one farm were diseased.

Widespread epidemics of downy mildew in western and central New York occurred during 1979 at Elba, Canastota, Potter, and in Oswego County. A mild outbreak was noticed at Prattsburg on 29 July but was effectively controlled by a rigid fungicide spray schedule. Economic losses during 1979 generally were slight because the disease developed late in the season after most bulb growth had occurred. The near-total loss of a 4-acre field in Oswego County was an exception.

Fields in Oswego County and at Canastota were affected by downy mildew in 1980, but losses were negligible. The disease was not detected at Prattsburg, Potter, or Elba during 1980.

History of control practices. Different procedures including fungicide sprays with Bordeaux mixture have been used or recommended for control of downy mildew (2,3,5–7). Newhall and Rawlins (6) in 1952 reported good control of downy mildew in New York with an ethylene bisdithiocarbamate under optimal field conditions for disease development. Extensive use of ethylene bisdithiocarbamate foliar sprays on commercially grown onions in New York became common during the 1950s. This type of fungicide also effectively controlled Botrytis leaf blight and was used almost exclusively for onion leaf disease control in New York from the early 1950s until 1976 (4).

Effective control of Botrytis leaf blight by the ethylene bisdithiocarbamates weakened in New York in the early 1970s when ineffective control on a number of onion farms in Orange County (southeastern New York) occurred from 1972 to 1975 (4). Chlorothalonil became widely used in commercial onion fields throughout New York starting in 1976 as an alternative to the ethylene bisdithiocarbamates, and during 1976–1978, it was the only foliar fungicide used by many onion growers. Downy mildew epidemics reappeared in western and central New York starting in 1977, and we have determined that chlorothalonil usually was the primary or only fungicide used on farms where the epidemics occurred.

Toxicity. Germination of sporangia of *P. destructor* in vitro was completely inhibited by both chlorothalonil and mancozeb when concentrations of 1 mg/L or more of the fungicides were amended to agar. More than 40% of the sporangia germinated in the unamended control, with an average germ tube length of 1,182 μm.

Effectiveness of fungicides against *P. destructor* on greenhouse-grown plants after 24 hr. Both chlorothalonil and mancozeb protected greenhouse-grown plants from infection by *P. destructor* in a typical experiment when applied 24 hr before inoculation (Table 1). Chlorothalonil gave complete protection at formulated rates equivalent to 1.07 L/ha (1.5 pt/acre) and higher, and mancozeb gave complete protection at formulated rates equivalent to 3.54 kg/ha (1 lb/acre) and higher (Table 1). At lower rates of application, both fungicides gave some protection compared with the control (Table 1).

Comparison of susceptibility of plants grown inside the greenhouse with plants

Table 1. Effectiveness of chlorothalonil and mancozeb in controlling *Peronospora destructor* on greenhouse-grown onion plants inoculated 24 hr after fungicide application

Fungicide	Rate[a]	Percent disease		Sporulation intensity[c]
		Plants	Leaves[b]	
Chlorothalonil	3.000	0	0	0.0
	2.500	0	0	0.0
	2.000	0	0	0.0
	1.500	0	0	0.0
	1.000	50	20	0.3
	0.500	50	20	0.3
	0.250	75	35	0.5
	0.125	75	50	0.9
	0.063	100	55	1.6
Mancozeb	3.000	0	0	0.0
	2.500	0	0	0.0
	2.000	0	0	0.0
	1.500	0	0	0.0
	1.000	0	0	0.0
	0.500	25	5	0.1
	0.250	50	10	0.2
	0.125	50	25	0.7
	0.063	50	20	0.6
Control	0.000	100	100	4.0

[a] Rate expressed in pints per acre of chlorothalonil 4.17F and pounds per acre of mancozeb 80WP.
[b] Percent disease determined by the number of plants infected and the number of the five oldest leaves on each plant that was infected (four plants per treatment).
[c] Sporulation intensity based on a scale of 0–4, where 0 = no sporulation and 4 = abundant sporulation.

grown outside the greenhouse. The method employed in the previous experiment included the manual removal of the surface wax from leaves of plants grown in the greenhouse by rubbing them with a dry pad of cotton before inoculation with *P. destructor*. Plants grown outside had substantially less surface wax on their leaves than did plants grown inside. Manual removal of the surface wax greatly increased the susceptibility of greenhouse-grown plants to *P. destructor* and resulted in a substantial increase in both percentage of leaves diseased and sporulation intensity (Table 2). In all categories, manual removal of leaf surface wax had a greater effect on plants grown inside than on plants grown outside. Although no difference in the susceptibility to *P. destructor* of plants grown inside and outside was demonstrated when the leaf surface wax of all plants was removed manually, plants grown outside were more susceptible than those grown inside when the leaf surface was not altered on plants of either group (Table 2).

Residual effectiveness of chlorothalonil and mancozeb against *P. destructor* on leaves of plants grown outdoors. Both chlorothalonil and mancozeb generally reduced incidence of diseased plants and leaves and sporulation intensity on outdoor-grown plants inoculated 2, 4, 7, and 10 days after fungicide application (Table 3). All plants sprayed with either fungicide and inoculated on the same day were completely protected. In addition, mancozeb prevented infection of plants inoculated 2 or 4 days after fungicide application and gave substantially better control than chlorothalonil on plants inoculated 7 and 10 days after fungicide application. Chlorothalonil failed to prevent infection on plants inoculated 2, 4, 7, and 10 days after fungicide application. Mancozeb was much more effective than chlorothalonil in depressing the level of subsequent sporulation by *P. destructor* (Table 3).

DISCUSSION

The reappearance of epidemics of downy mildew in New York coincided with the substitution of chlorothalonil for ethylene bisdithiocarbamate fungicides for onion leaf disease control. This substitution was prompted by the failure of the ethylene bisdithiocarbamates to control Botrytis leaf blight beginning in the early 1970s (4). The first of the recent epidemics of downy mildew occurred in 1977, 1 yr after chlorothalonil was label registered and recommended as a foliar spray for controlling Botrytis leaf blight in New York. The downy mildew epidemic of 1977 occurred on farms where chlorothalonil was used as the sole fungicide in foliar sprays. The severity of this epidemic was enhanced by poor coverage with chlorothalonil resulting from aircraft application of the fungicide and an extended spray schedule (10-day intervals).

Over the range of concentrations tested in vitro, no difference in toxicity was found between chlorothalonil and mancozeb; thus the recurrent epidemics appear to be related to a factor(s) other than toxicity. This conclusion is further supported by the fact that both fungicides completely inhibited germination of sporangia of *P. destructor* at concentrations of 1 mg/L or higher. Chlorothalonil and mancozeb applied at formulated rates greater than or equal to 1.07 L/ha (1.5 pt/acre) and 3.54 kg/ha (1 lb/acre), respectively, completely protected greenhouse-grown onions from infection by *P. destructor* when plants were inoculated 24 hr after fungicide application.

Through natural weathering processes, the amount of surface wax on leaves of onion plants grown outdoors appears to be maintained in a diminished condition compared with that on leaves of greenhouse-grown plants. This weathering results in outdoor-grown plants being more uniformly susceptible to infection by *P. destructor* than greenhouse-grown plants. The leaf surface wax does not appear to be altered on greenhouse-grown plants. Thus it appears that onion plants grown outside can be used for fungicide evaluation studies without manual removal of the leaf surface wax to increase susceptibility to *P. destructor*.

The incidence of diseased plants and leaves and the sporulation intensity on onion plants grown outside and inoculated with *P. destructor* was reduced when plants were sprayed with either chlorothalonil at a formulated rate equivalent to 3.08 L/ha (4.25 pt/acre) or mancozeb at a formulated rate equivalent to 7.08 kg/ha (2 lb/acre). Complete protection of plants treated with chlorothalonil from infection by *P. destructor* began to

Table 2. Susceptibility of onion plants grown either outside or inside the greenhouse to infection by *Peronospora destructor*

Growing conditions of plants	Condition of surface wax before inoculation	Percent disease		Sporulation intensity[b]
		Plants	Leaves[a]	
Outside greenhouse	Removed[c]	100	100	3.9
	Present	100	88	1.5
Inside greenhouse	Removed[c]	100	100	3.9
	Present	60	24	0.3

[a] Percent disease determined by the number of plants infected and the number of the five oldest leaves on each plant that was infected (five plants per treatment).
[b] Sporulation intensity based on a scale of 0–4, where 0 = no sporulation and 4 = abundant sporulation.
[c] Surface wax manually removed by rubbing leaves with a dry cotton pad six times (unidirectional strokes, tip to base).

Table 3. Residual efficacy of chlorothalonil and mancozeb against *Peronospora destructor* on onion plants grown outdoors before fungicide application and inoculation

Fungicide	Days to inoculation after fungicide application	Percent disease		Sporulation intensity[b]
		Plants	Leaves[a]	
Chlorothalonil[c]	0	0	0	0.0
Mancozeb[d]		0	0	0.0
Control		100	100	3.2
Chlorothalonil[c]	2	25	10	0.1
Mancozeb[d]		0	0	0.0
Control		100	85	2.4
Chlorothalonil[c]	4	25	5	0.1
Mancozeb[d]		0	0	0.0
Control		100	85	2.9
Chlorothalonil[c]	7	100	55	1.0
Mancozeb[d]		25	10	0.2
Control		100	85	3.2
Chlorothalonil[c]	10	75	25	0.6
Mancozeb[d]		25	10	0.2
Control		100	90	2.6

[a] Percent disease determined by the number of plants infected and the number of the five oldest leaves on each plant that was infected (five plants per treatment).
[b] Sporulation intensity based on a scale of 0–4, where 0 = no sporulation and 4 = abundant sporulation.
[c] Chlorothalonil 4.17F applied at a rate equivalent to 3.08 L/ha (4.25 pt/acre).
[d] Mancozeb 80WP applied at a rate equivalent to 7.08 kg/ha (2 lb/acre).

dissipate 2 days after fungicide application, and at 7 and 10 days after application, provided little control. On plants sprayed with mancozeb, however, protection from infection by *P. destructor* was still complete 4 days after application and provided good control up to 10 days after application. The extended retention of efficacy by mancozeb on onion leaves as shown in this study may also partly explain the superior performance of mancozeb to that of chlorothalonil in controlling onion downy mildew in a recent study by Teviotdale et al (7). Ethylene bisdithiocarbamates have been reported to control downy mildew in other studies (2,5). This control can now be explained at least partly on the basis of residual efficacy for periods of up to 10 days and possibly somewhat longer. In addition, the fact that mancozeb is much more effective than chlorothalonil in decreasing sporulation of *P. destructor* further explains the superior control of downy mildew under field conditions by mancozeb compared with chlorothalonil on the basis of greatly reducing the amount of potential inoculum.

Since chlorothalonil was effective in controlling downy mildew for only 1–2 days after fungicide application in this study, and because growers generally employ either a 4-, 7-, or 10-day spray schedule, the ineffectiveness of chlorothalonil in controlling downy mildew under field conditions in western and central New York from 1977 to 1979 can now be explained on the basis of poor residual action after more than 2 days from the time of application. Starting in 1979, ethylene bisdithiocarbamates have been recommended for use in combination with chlorothalonil for simultaneous control of Botrytis leaf blight and downy mildew in New York. The result of grower usage of this recommendation in 1979 was the rapid decrease in the occurrence of downy mildew epidemics in all onion-growing areas in the western and central areas of the state except for the Elba area, where growers generally continued to use only chlorothalonil. In 1980, the recommendation generally was followed and the occurrence of downy mildew was greatly reduced. From 1981 to 1984, incidence of downy mildew in New York was nil when mancozeb was used.

LITERATURE CITED

1. Abd-Elrazik, A. A., and Lorbeer, J. W. 1980. A procedure for isolation and maintenance of *Peronospora destructor* on onion. Phytopathology 70:780-782.
2. Bekhit, M. R., Abd Elghany, A. K., El Yamany, T. M., and Soud, M. B. 1963. Control of downy mildew and purple blotch of onion by fungicides. Agric. Res. Rev. 41(3):47-51.
3. Chupp, C., and Sherf, A. F. 1960. Vegetable diseases and their control. Ronald Press, New York. 693 pp.
4. Lorbeer, J. W., and Ellerbrock, L. A. 1976. Failure of ethylene bisdithiocarbamate to control Botrytis leaf blight of onion. Proc. Am. Phytopathol. Soc. 3:75-84.
5. Mirakhur, R. K., Dhar, A. K., and Kawm, R. 1978. Downy mildew of *Allium cepa* and its control with fungicides in Kashmir Valley. Indian Phytopathol. 30:576-577.
6. Newhall, A. G., and Rawlins, W. A. 1952. Control of onion blast and mildew with carbamates. Phytopathology 42:212-214.
7. Teviotdale, B. L., May, D. M., Harper, D., and Jorde, D. 1980. New fungicide apparently controls onion mildew. Calif. Agric. 34:22-23.
8. Viranyi, F. 1975. Studies on the biology and ecology of onion downy mildew (*Peronospora destructor* (Berk.) Fries) in Hungary. III. Epidemiology of the disease. Acta Phytopathol. Acad. Sci. Hung. 10:321-328.
9. Yarwood, C. E. 1943. Onion downy mildew. Hilgardia 14:595-691.