Efficacy of Metalaxyl and Metalaxyl Tank Mixes in Controlling *Albugo occidentalis* and *Peronospora effusa* on Spinach (*Spinacea oleracea*)

R. K. JONES, Plant Pathologist, Texas Agricultural Extension Service, and F. J. DAINELLO, Research Horticulturist, Texas Agricultural Experiment Station, Uvalde 78801

ABSTRACT

Jones, R. K., and Dainello, F. J. 1983. Efficacy of metalaxyl and metalaxyl tank mixes in controlling *Albugo occidentalis* and *Peronospora effusa* on spinach (*Spinacea oleracea*). Plant Disease 67:405-407.

Foliar sprays of metalaxyl and ethylene bisdithiocarbamate (EBDC) effectively reduced percent infected leaves and yield loss of spinach attributed to *Albugo occidentalis* and *Peronospora effusa*. Chlorothalonil sprays were effective in reducing losses to *A. occidentalis* but were ineffective against *P. effusa*. A reduced-rate tank mix of metalaxyl plus EBDC was as effective in controlling both diseases as full rates of the individual compounds. A reduced-rate tank mix of metalaxyl plus chlorothalonil was as effective as the individual compounds in controlling *A. occidentalis* but was ineffective in controlling *P. effusa*. The implications of tank mixing metalaxyl on the development of resistant strains are discussed.

Additional key words: blue mold, downy mildew, white rust

White rust (caused by *Albugo occidentalis* G. W. Wils.) and blue mold (caused by *Peronospora effusa* Grev. ex Desm.) are major diseases of spinach (*Spinacea oleracea* L.) in the Texas Wintergarden (6,9,15,17) and other areas where spinach is grown (1,5,13,18). About 40% of the fresh-market spinach and 23% of the processing spinach acreage in the United States is harvested annually in the Wintergarden (3,14). Historically, white rust has been managed through the use of rotation, horizontal (multigenic) resistance (1), and protective fungicides, particularly the ethylene bisdithiocarbamates (EBDC). Control of blue mold has been achieved through the use of vertical (monogenic) resistance. This resistance, developed in the early 1950s, remained stable for more than 20 yr (16). In 1977, however, a new race of blue mold (designated race 3) appeared in the Wintergarden area (6).

In August 1977, the Environmental Protection Agency issued a Rebuttal Presumption Against Registration (RPAR) on EBDC. Although the RPAR was unresolved as of August 1982, a residue tolerance of 10 ppm is in effect for U.S. markets. In May 1980, the Canadian government issued a restriction on the importation of spinach with residues that exceed 0.1 ppm of EBDC (any detectable quantity). Canada consumes about 50% of the fresh-market spinach and a significant proportion of the processing spinach produced in the Wintergarden. Consequently, the ability of Wintergarden producers to chemically control white rust and blue mold on spinach grown for Canadian markets is severely limited.

Surveys of fresh-market fields resulted in yield-loss estimates of 20 and 10% in 1980 and 30 and 5% in 1981 for blue mold and white rust, respectively (R. K. Jones, *unpublished*). The increasing yield loss attributed to blue mold and the potential spread of race 3 to other spinach-producing areas prompted field tests to examine the efficacy of metalaxyl (CGA-48988 or Ridomil) in controlling blue mold and white rust. Recent reports of metalaxyl-resistant strains of downy mildews (2,4,7,10) resulted in the investigation of reduced-rate tank mixes of this material with other suitable fungicides to control both diseases. Steps to reduce the potential buildup of resistance seem appropriate in the spinach blue mold system considering the reported latent period of 6–7 days (11), the efficacy of metalaxyl, and the speed with which *P. effusa* spreads in unsprayed fields (12). Tank mixes should prove more effective than alternating sprays in reducing the buildup of metalaxyl-resistant strains on spinach because of the relatively few (two or three) fungicide applications required per season. In addition, tank mixing would be easier to regulate and enforce than alternating sprays.

Mention of a product used in these studies does not constitute a recommendation of the product by the Texas Agricultural Extension Service or the Texas Agricultural Experiment Station.

Accepted for publication 15 September 1982.

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

Field trials. Experimental plots were established in a randomized complete-block design with four replicates on a Uvalde silty clay loam. Plots were four beds (3.9 × 6.1 m) with two seeded rows per bed. The spinach cultivar Iron Duke (susceptible to white rust and race 3 of blue mold) was seeded and thinned to a population of 2.1×10^5 plants per hectare. The plots received 55.1 kg/ha of actual N as urea between the rows and 89.7 kg/ha of P as 0-46-0 applied 5.1 cm below the seed. Fall plots were planted on 12 October and harvested on 18 December. Spring plots were planted on 9 December and harvested on 9 March.

Metalaxyl (Ridomil 2E), chlorothalonil (Bravo 500 F), and all tank mixes were applied at 14-day intervals beginning at the four- to six-leaf stage (18 November and 26 January, respectively, for fall and spring trials). EBDC (Dithane M-22 80WP) was applied at 7-day intervals beginning on the same dates. Four applications of EBDC and two applications of all other treatments were made during the fall trials. Six applications of EBDC and three applications of all other treatments were made during the spring trial. Fungicides were applied with MINI-ULVA hand-held sprayers (Micromax Corporation, Houston, TX 77024) in 46.8 L/ha of water.

Assessing disease severity. At harvest, 40 mature plants were collected at 0.3-m intervals on each of the inner two beds of each plot. Marketable sized leaves (about 30 cm^2 or greater) from these samples were hand-sorted into four classes: 1) infected with *A. occidentalis* only, 2) infected with *P. effusa* only, 3) infected with both fungi, or 4) disease-free. Leaves in each classification were counted and weighed. Percent infected leaves and yield reduction attributed to infection by white rust or blue mold were determined.

RESULTS

The incidence of white rust-infected leaves in untreated plots was 37.5% in the fall and 45.6% in the spring. Blue mold was not present in fall plantings but developed to high levels (42.4%) in the spring. The figures for disease incidence in spring-planted control plots include 28% leaves that were simultaneously infected with both organisms. The infected leaves in spring-planted control plots totaled 60% (Fig. 1). Metalaxyl and EBDC significantly improved marketable yield over the control in both the spring and fall plantings (Table 1). Chlorothalonil reduced yield loss from white rust but did not control blue mold. Reduced-rate tank mixes of metalaxyl and EBDC were as effective as full-rate spray schedules of the individual fungicides in controlling white rust and blue mold. A reduced-rate tank mix of metalaxyl and chlorothalonil was as effective as the individual compounds in controlling white rust but not blue mold.

Although the EBDC, metalaxyl, and metalaxyl plus EBDC reduced-rate tank-mix spray schedules resulted in significant reductions in disease incidence, economic yield losses were still evident. The metalaxyl plus EBDC reduced-rate tank mix allowed for extension of the spray interval from 7 to 14 days and provided equivalent control of both diseases when compared with EBDC alone.

DISCUSSION

White rust and blue mold currently pose a serious economic threat to spinach production in the Wintergarden. Economic loss in Arkansas to white rust is also significant (1). Although damage from blue mold has not reached severe proportions in Arkansas (M. J. Goode, *personal communication*), the proliferation of inoculum in the Wintergarden and the shipments of spinach from the Wintergarden to freezer pack plants in Arkansas and Oklahoma could establish blue mold in that area. Commercially grown cultivars in Arkansas are susceptible to race 3.

EBDC was registered by EPA for use on spinach in 1955. It was widely used in the Wintergarden against epiphytotics caused by race 1 of *P. effusa* that developed in the 1950s (16). After the development of vertical resistance to blue mold (13,16), EBDC continued to be used on spinach to control white rust. Ciba-Geigy Corporation is currently pursuing a federal label for metalaxyl on spinach (G. Holt, *personal communication*). The experimental results in this study revealed that metalaxyl and EBDC were equally effective in controlling both white rust and blue mold. The registration of metalaxyl could provide an alternative disease-control agent that would circumvent the problem of EBDC residues.

This study provides data on the use of metalaxyl in field situations both alone and in combination with effective and ineffective reduced-rate tank-mix partners. The development of metalaxyl-resistant genotypes of downy mildews is well documented (2,4,7,10). Bruck et al (2) suggested that metalaxyl-resistant isolates of *Peronospora hyoscyami* de Bary exist in nature and the use of metalaxyl may select for resistant genotypes. The 11.3% incidence of blue mold-infected leaves in metalaxyl-treated plots observed in this study may be the result of escape (incomplete coverage) or the presence of metalaxyl-resistant genotypes. Such background levels of disease could hinder the speed with which resistant genotypes can be detected if they develop and proliferate. If the background levels are a result of escape, they may be overcome with shortened intervals or increased rates. In this study, however, a *reduced* rate of metalaxyl did not result in significantly (P = 0.05) more disease when tank mixed with an effective compound.

The speed of selection of metalaxyl-resistant isolates in other similar host-parasite systems argues against deployment of metalaxyl against blue mold and white rust of spinach without a suitable tank-mix partner. Although EBDC is effective, it will not meet Canadian residue requirements when used at any rate on spinach. Although chlorothalonil is effective against white rust, it will not control blue mold. Future studies will examine the effectiveness of fixed copper fungicides when tank mixed with metalaxyl and the effectiveness of metalaxyl-chlorothalonil tank mixes on recently developed spinach hybrids resistant to *P. effusa* (race 3).

Table 1. Efficacy of three fungicides and two reduced-rate tank mixes on reducing yield loss from *Albugo occidentalis* and *Peronospora effusa*

	Yield loss (%)[a]		
	White rust		Blue mold
Treatment rate (kg a.i./ha)	Fall	Spring	Spring
Metalaxyl, 0.28	5.2	0.9	8.6
EBDC, 3.59	7.0	0.8	11.9
Metalaxyl/EBDC, 0.14–1.79	7.7	0.4	12.7
Metalaxyl/chlorothalonil, 0.14–0.58	6.6	2.0	31.0
Chlorothalonil, 1.17	10.5	3.0	41.0
Control	40.0	49.6	45.2
LSD (P = 0.05)	7.6	5.7	8.2

[a] Based on weight of marketable leaves from 160 plants per treatment.

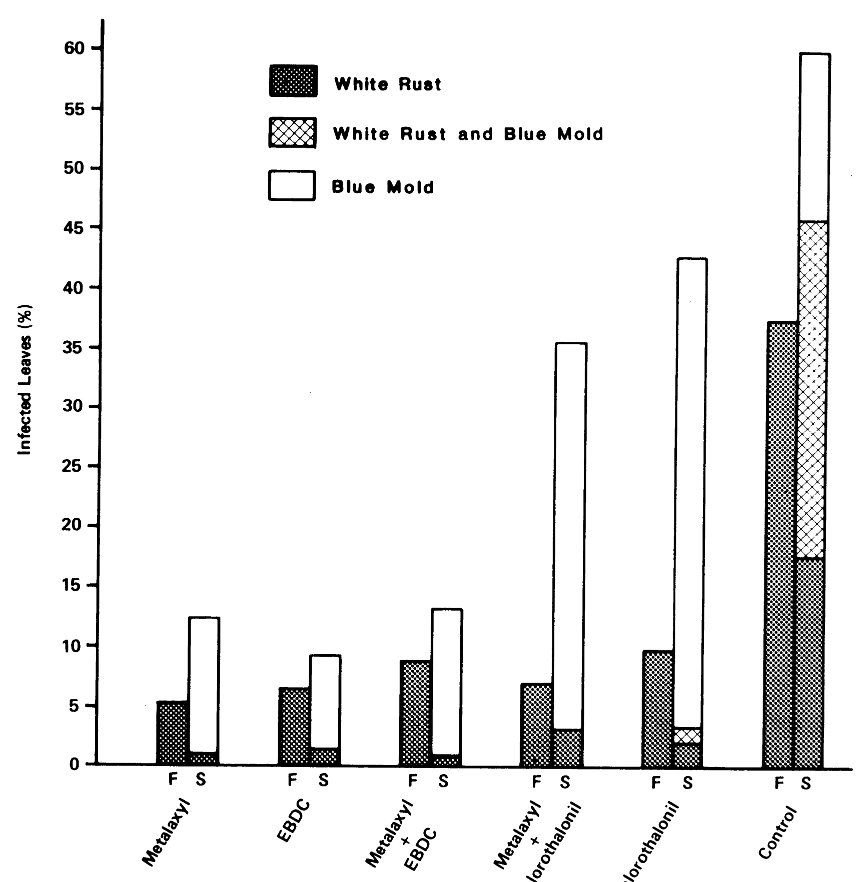

Fig. 1. Incidence of white rust and blue mold in plots of spinach treated with three fungicides and two reduced-rate fungicide tank mixes in fall (F) and spring (S) trials. LSD (P = 0.05) = 7.6 and 5.7 for white rust in fall and spring trials, respectively, and 6.5 for blue mold in the spring trial.

LITERATURE CITED

1. Bowers, J. L., and Goode, M. J. 1980. Ozarka and Greenvalley: New disease resistant spinach cultivars. Ark. Farm Res. 24:6.
2. Bruck, R. I., Gooding, G. V., and Main, C. E. 1982. Evidence for resistance to metalaxyl in isolates of *Peronospora hyoscyami*. Plant Dis. 66:44-45.
3. Dainello, F. J., Heineman, R. R., and Jones, R. K. 1981. Relative white rust resistance and adaptability of spinach varieties in southwest Texas. Tex. Agric. Exp. Stn. Prog. Rep. 3878.
4. Georgopoulos, S. G., and Grigoriv, A. C. 1981. Metalaxyl resistant strains of *Pseudoperonospora cubensis* in cucumber greenhouses of southern

Greece. Plant Dis. 65:729-731.
5. Guba, E. F. 1930. Susceptibility of spinach varieties to downy mildew (*Peronospora effusa*) as observed in Massachusetts, 1929. Plant Dis. Rep. 14:68-69.
6. Jones, R. K., and Dainello, F. J. 1982. Occurrence of race 3 of *Peronospora effusa* on spinach in Texas and identification of sources of resistance. Plant Dis. 66:1078-1079.
7. Katan, T., and Bashi, E. 1982. Resistance to metalaxyl in isolates of *Pseudoperonospora cubensis*, the downy mildew pathogen of cucurbits. Plant Dis. 65:798-800.
8. Raabe, R. D., and Pound, G. S. 1952. Relation of certain environmental factors to initiation and development of the white rust disease of spinach. Phytopathology 42:448-452.
9. Raabe, R. D., and Pound, G. S. 1952. Morphology and pathogenicity of *Albugo occidentalis*, the incitant of white rust of spinach. (Abstr.) Phytopathology 42:473.
10. Reuveni, M., Eyal, H., and Cohen, Y. 1980. Development of resistance to metalaxyl in *Pseudoperonospora cubensis*. Plant Dis. 64:1108-1109.
11. Richards, M. C. 1938. Downy mildew of spinach and its control. N.Y. Agric. Exp. Stn., Ithaca, Bull. 718. 29 pp.
12. Skylakakis, G. 1982. Epidemiological factors affecting the rate of selection of biocide-resistant genotypes of plant pathogenic fungi. Phytopathology 72:271-273.
13. Smith, P. G., Webb, R. G., and Luhn, C. H. 1962. Immunity to race 2 of spinach downy mildew. Phytopathology 52:597-599.
14. Texas Department of Agriculture. 1980. Texas Crop and Livestock Reporting Service. Texas Veg. Stat. 48 pp.
15. Thomas, C. E. 1970. Epidemiology of spinach white rust in South Texas. (Abstr.) Phytopathology 60:588.
16. Webb, R. E., and Thomas, C. E. 1978. Development of F_1 spinach hybrids. HortScience 11:546.
17. Wiant, J. S., Ivanoff, S. S., and Stevenson, J. A. 1939. White rust of spinach. Phytopathology 29:616-623.
18. Wright, C. M., and Yerkes, W. D. 1950. Observations on the overwintering of the pathogen causing downy mildew of spinach in the Walla Walla area. Plant Dis. Rep. 34:28.