Evaluation of Use-Pattern Alternatives with Metalaxyl to Control Foliar Diseases of Spinach

F. J. DAINELLO, Horticulturalist, Texas Agricultural Experiment Station, Uvalde 78801, and R. K. JONES, Plant Pathologist, Texas Agricultural Extension Service, College Station 77843

ABSTRACT

Dainello, F. J., and Jones, R. K. 1986. Evaluation of use-pattern alternatives with metalaxyl to control foliar diseases of spinach. Plant Disease 70:240-242.

Metalaxyl at rates of 0.1–3.7 kg a.i./ha, applied in-furrow as granules or to the soil surface as a bed spray, controlled white rust of spinach for 48–60 days after planting. Seed treatments with metalaxyl at rates of 0.5–1.0 g a.i./kg of seed controlled white rust and blue mold of spinach for 30 days. Such use patterns may provide alternate strategies to foliar sprays in the deployment of metalaxyl on spinach.

Additional key words: *Albugo occidentalis*, *Peronospora effusa*

White rust, caused by *Albugo occidentalis* G. W. Wils., and blue mold, caused by *Peronospora effusa* Grev. ex Desm., are limiting factors in the production of fresh-market spinach in Texas and other states (2,3,5,15). Yield loss in excess of 30% has been reported for each disease individually, although the diseases rarely occur simultaneously at such levels (4,12). White rust is initiated by soilborne oospores that splash onto the plant surface (17). *P. effusa* has been demonstrated to be seedborne (10). Secondary infections in both diseases originate from airborne conidia (14,15).

Resistance to white rust is inherited polygenically and has been incorporated into the open-pollinated cultivars Greenvalley and Ozarka (2). These cultivars also possess dominant linked genes M_1 and M_2 for resistance to races 1 and 2 of the blue mold fungus.

Race 3 of *P. effusa*, identified in 1980 in the Texas Wintergarden, caused epidemics of blue mold in 1981 and 1982 (11). Although resistance to race 3 is available in commercial cultivars (5), their susceptibility to white rust (3) has severely limited their adoption by Texas producers.

Chemical control of *A. occidentalis* and *P. effusa* has been hampered by the lack of registration of effective materials and Canadian import restrictions (12) for spinach treated with ethylenebisdithiocarbamate (EBDC or maneb). Canadian markets purchase about 50% of the spinach produced in the Texas Wintergarden, but shipments have been declining because of producers' inability to control diseases with the registered alternatives (captan or sulfur-copper).

Metalaxyl has been shown to provide effective control of white rust and blue mold when applied alone or in combination with effective tank-mix partners (12). Antiresistance strategies have resulted in marketing decisions for metalaxyl to be sold commercially as a package mix with mancozeb (Ridomil MZ 58). Though effective, such decisions do not circumvent Canadian import restrictions on maneb residues. Additionally, tank-mix strategies to reduce the development of resistance are severely limited in spinach by the lack of registration of materials as effective as metalaxyl (6,12,16).

Seed treatment and soil application of metalaxyl have been effective in reducing the incidence of diseases caused by oomycetous fungi on a wide range of annual (8,13,18) and perennial (1,7,9) crops. The purpose of this study was to evaluate alternative use patterns for metalaxyl, including seed treatment, in-furrow granular application at planting, and preplant bed-spray applications, on the development of white rust and blue mold of spinach.

Accepted for publication 26 August 1985.

MATERIALS AND METHODS

Field trials. Seed treatment and in-furrow granular treatments were evaluated in experiment 1; bed-spray treatments were evaluated in experiment 2. All experimental plots were established in a randomized complete block design with four replicates on a Uvalde silty clay loam soil. Untreated seeds of the spinach cultivar Dixie Market (susceptible to *A. occidentalis* and race 3 of *P. effusa*) were sown at the rate of 40 seeds per row meter. All plots received 61.6 kg/ha of actual nitrogen as urea band applied at the fourth-true-leaf stage. Diazinon was applied at 135 g a.i./ha as needed for insect control.

Experiment 1. Treatment plots consisted of single beds (0.98 × 6.1 m) with one plant row per bed. Seeds were treated with metalaxyl (Apron 25WP) in a water slurry (0.44 L/kg of seed) and dried before planting. In-furrow granules of metalaxyl (Ridomil 5G) were applied with a Gandy insecticide applicator (model S902EM, Gandy Company, Owatonna, MN) modified to deliver material into the planter seed drops so that seed and granules would be drilled together into a single furrow.

Spring plots were planted on 2 February 1983 and 27 January 1984, and fall plots, on 14 October 1983 and 27 September 1984. Treatment efficacy was evaluated 60 days after planting (DAP) in all tests except the planting on 2 February 1983, which was indexed at 30 DAP. The planting on 14 October 1983 was cut back at 60 DAP and the regrowth reindexed at 120 DAP.

Disease incidence was determined from 20 plants collected at 30-cm increments per plot. Marketable sized leaves (about 30 cm^2 or larger) were stripped from each plant and sorted into symptomatic and asymptomatic lots and the percent diseased leaves calculated.

Experiment 2. Experimental plots consisted of four beds (3.9 × 6.1 m) with two plant rows per bed. Bed-spray treatments of metalaxyl (Ridomil 2E) were applied preplant with a tractor-mounted plot sprayer calibrated to deliver 374 L/ha and rototill-incorporated to a 7.5-cm depth. The postemergence foliar treatment was applied with a MINI-ULVA hand-held sprayer (Micromax Corp., Houston, TX) in 46.8 L/ha of water. Fall plots were established on 25 and 2 October, respectively, in 1983 and 1984. Treatments were indexed at 120 DAP in 1983 and at 60 DAP in 1984. Efficacy was determined in a similar manner as in experiment 1, except the 20-plant sample was collected at 60-cm increments alternating between double plant rows of the two inner beds per plot.

RESULTS

Experiment 1. Weather conditions prevalent after planting on 2 February 1983 favored the development of blue mold over white rust; white rust was not observed in this study. The incidence of blue mold-diseased leaves in untreated plots at 30 DAP was 15.8%. Sporulation

Table 1. Effectiveness of seed treatments and in-furrow granules on the incidence of blue mold and white rust in spinach

Treatment[a]	Rate (a.i.)	Blue mold (%)[b] Spring-planted (2 February 1983) 30 DAP	White rust (%)[b] Fall planted (14 October 1983) 60 DAP	White rust (%)[b] Fall planted (14 October 1983) 120 DAP	White rust (%)[b] Fall-planted (27 September 1984) 60 DAP
Seed treatment					
Metalaxyl 25WP	1 g/kg	2.0	0.5	9.6	75.0
Captan 80WP	2 g/kg	···	14.8	28.5	77.6
In-furrow granules					
Metalaxyl 5G	1 kg/ha	0.7	0.0	4.4	49.1
PCNB 10G	1 kg/ha	···	7.5	31.0	72.3
Metalaxyl + PCNB 11G (1:10)	1 kg/ha	···	0.0	0.1	59.2
Untreated control	···	15.8	10.3	31.0	77.6
LSD ($P = 0.05$)		8.0	6.4	13.3	9.1

[a] Seed of cultivar Dixie Market treated with water slurry (0.44 L/kg seed) and dried before planting. Granular rates applied in-furrow at planting.
[b] Percentages of diseased leaves were determined at specified days after planting (DAP) on 20 plants per replicate per treatment at 30-cm intervals. Plants with visible sporulation were considered diseased.

Table 2. Effectiveness of metalaxyl 2E bed-spray applications on incidence of white rust in spinach

Treatment[a]	Rate (kg a.i./ha)	White rust (%)[b] Fall-planted 25 October 1983 (120 DAP)	White rust (%)[b] Fall-planted 2 October 1984 (60 DAP)
Preplant	3.67	1.1	36.3
Postemergence	0.46	0.1	20.6
Untreated control	···	32.0	62.6
LSD ($P = 0.05$)		10.0	13.7

[a] Preplant application in 374 L/ha of water was rototill-incorporated to a 7.5-cm depth before planting. Postemergence treatment applied in 46.8 L/ha of water at 7-day intervals until harvest beginning at fourth-true-leaf stage.
[b] Percentages of diseased leaves were determined at specified days after planting (DAP) on 20 plants per replicate per treatment at 60-cm increments alternating between the double plant rows per bed. Leaves with visible sporulation were considered diseased.

was observed on cotyledons of untreated plants at 14 DAP. Seed treatment with metalaxyl at 0.25, 0.5, and 1 g a.i./kg reduced the incidence of leaves with visible sporulation of *P. effusa* by 0.3, 8.9, and 13.8%, respectively, compared with the control. The 0.25-g a.i./kg rate did not significantly reduce disease ($P = 0.05$) compared with the control. The lowest incidence of disease was afforded by metalaxyl 5G applied in-furrow (0.7% diseased leaves).

Weather conditions prevalent after planting on 14 October 1983 favored the development of white rust over blue mold; blue mold was not observed in these plots. Incidence of white rust-diseased leaves at 60 DAP was 10.3%. All metalaxyl treatments significantly reduced disease incidence ($P = 0.05$) compared with untreated controls. A standard seed-treatment fungicide (captan) failed to reduce disease incidence significantly (Table 1). Regrowth, evaluated at 120 DAP, showed that an acceptable level of white rust control (<5% of leaves with visible sporulation) was still maintained in plots treated with metalaxyl as in-furrow granules.

Environmental conditions conducive to white rust infection occurred in spring and fall of 1984. As a result, the duration of efficacy of metalaxyl was shorter than in 1983. All plots developed a high incidence of disease within fewer than 60 DAP. Extensive sporulation was observed about 15 days earlier in untreated plots than in metalaxyl-treated plots. In the spring plots, sporulation was evident at 41 DAP in the control but was not observed until 59 DAP in the metalaxyl plots. No significant differences were found among treatments at the 60-DAP indexing.

Similar results were observed in the fall planting. The metalaxyl 5G treatments, however, significantly reduced the percentage of white rust-diseased leaves harvested from these plots (Table 1). Sporulation was noted at 34, 49, and 53 DAP, respectively in the untreated, metalaxyl seed-treated, and metalaxyl in-furrow granular plots.

Experiment 2. At 120 DAP, 32% of the leaves sampled from the control plots showed visible sporulation of the white rust fungus compared with 1.1% of the leaves from the preplant bed-spray treatment (Table 2). The postemergence foliar spray treatment resulted in the lowest disease incidence (0.1%) but was not significantly different from the preplant granular treatment ($P = 0.05$).

As in experiment 1, severe early disease limited the duration of efficacy of the preplant bed-spray treatments in 1984. The incidence of white rust at 60 DAP within the preplant treatments ranged from 36.3% (3.7 kg/ha) to 36.5% (1.8 kg/ha) to 53.4% (0.9 kg/ha). About 62% diseased leaves were observed in control plots. Sporulation began at 29 DAP in the control and at 48 DAP in the bed-spray treatments. All metalaxyl treatments except the 0.9-kg/ha per-plant treatment significantly reduced infection compared with the control ($P = 0.05$). Foliar sprays were significantly more effective in controlling white rust than the 3.7-kg/ha preplant treatment. However, 20.6% disease incidence would be unacceptable for commercial harvest.

DISCUSSION

White rust and blue mold continue to pose a serious economic threat to spinach production in the Texas Wintergarden. Metalaxyl applied in-furrow as granules (5G) or to soil as a bed spray (2E) controlled white rust for 48–60 days at rates of 0.1–2.2 kg a.i./ha. In-furrow granules were more rate effective. Seed treatments (metalaxyl 25WP) controlled white rust and blue mold up to 30 DAP (fourth-true-leaf stage).

Spinach in the Texas Wintergarden is a multiharvest crop that typically requires 60 days to reach sufficient growth for initial harvest and is then cut at 21- to 35-day intervals thereafter depending on weather and market conditions. Metalaxyl seed treatment should prove valuable in reducing the incidence of blue mold on susceptible cultivars where the primary inoculum is seedborne. White rust can be reduced with seed, soil, or in-furrow applications of metalaxyl in first-harvest spinach, but repeated applications or supplemental foliar sprays may be necessary to provide control in subsequent harvests or during seasons when conditions are optimal for disease development.

Concern must be expressed over the use of metalaxyl alone for control of foliar diseases of any crop but particularly for genera of the class Oomycetes that have demonstrated the propensity for developing resistant strains like *Peronospora* and *Albugo* spp. However, the proliferation of resistant strains has not developed in the tobacco blue mold system after 4 yr of commercial use of soil-applied metalaxyl, and metalaxyl registration has been federally approved on many crops that are attacked by downy mildews despite the fact that other fungi are the targeted pests.

It would seem appropriate to monitor the sensitivity of *A. occidentalis* and *P. effusa* before and after registration to allow for early detection of resistant strain development.

LITERATURE CITED

1. Bailey, A. M., and Coffey, M. D. 1985. Biodegradation of metalaxyl in avacado soils. Phytopathology 75:135-137.
2. Bowers, J. L., and Goode, M. J. 1980. Ozarka and Greenvalley: New disease resistant spinach cultivars. Ark. Farm Res. 24:6.
3. Dainello, F. J., Heineman, R. R., and Jones, R. K. 1981. Relative white rust resistance and adaptability of spinach varieties in southwest Texas. Texas Agric. Exp. Stn. Prog. Rep. 3878.
4. Dainello, F. J., and Jones, R. K. 1984. Continuous hours of leaf wetness as a parameter for scheduling fungicide applications to control white rust in spinach. Plant Dis. 68:1069-1072.
5. Dainello, F. J., Jones, R. K., and Heineman, R. R. 1983. Relative blue mold resistance and adaptability of spinach varieties to southwest Texas. Texas Agric. Exp. Stn. Prog. Rep. 4184.
6. Dainello, F. J., Jones, R. K., and Heineman, R. R. 1983. Efficacy of selected fungicides in controlling spinach blue mold (*Peronospora effusa*). Texas Agric. Exp. Stn. Prog. Rep. 4183.
7. Davis, R. M. 1982. Control of Phytophthora root and foot rot of citrus with systemic fungicides metalaxyl and phosethyl aluminum. Plant Dis. 66:218-220.
8. Fortnum, B. A., Csinos, A. S., and Dill, T. R. 1982. Metalaxyl controls blue mold in flue-cured tobacco seedbeds. Plant Dis. 66:1014-1016.
9. Hamm, P. B., Cooley, S. J., and Hansen, E. M. 1984. Response of *Phytophthora* spp. to metalaxyl in forest tree nurseries in the Pacific Northwest. Plant Dis. 68:671-673.
10. Inaba, T., Takahashi, K., and Morinaka, T. 1983. Seed transmission of spinach downy mildew. Plant Dis. 67:1139-1141.
11. 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.
12. 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 Dis. 67:405-407.
13. Odvody, G. N., and Frederiksen, R. A. 1984. Use of systemic fungicides metalaxyl and fosetyl-Al for control of sorghum downy mildew in corn and sorghum in South Texas. I: Seed treatment. Plant Dis. 68:604-607.
14. 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.
15. Ryder, E. J. 1979. Leafy Salad Vegetables. Avi, Westport, CT. 266 pp.
16. Staub, T., and Sozzi, D. 1984. Fungicide resistance: A continuing challenge. Plant Dis. 68:1026-1031.
17. Thomas, C. E. 1970. Epidemiology of spinach white rust in South Texas. (Abstr.) Phytopathology 60:588.
18. Yuen, J. E., and Lorbeer, J. W. 1983. Metalaxyl controls downy mildew and supplements horizontal resistance to *Bremia lactucae* in lettuce grown on organic soil in New York. Plant Dis. 67:615-618.