Seed-Treatment Fungicides for Control of Seedborne *Ascochyta lentis* on Lentil

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ABSTRACT

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The efficacy of chemical treatments and thermotherapy in controlling seedborne *Ascochyta lentis* was tested on naturally infected lentil seeds. Lentil plants from infected seeds had fewer branches, smaller roots and shoots, reduced vigor, and lower seed yields. In laboratory studies, the most effective of 12 seed-treatment fungicides were thiabendazole and etaconazole (CGA-64251), which reduced the incidence of *A. lentis* in lentil PI 438516 from 80.5% in the untreated seeds to 0 and 1.5%, respectively, in treated seeds. When fungicide-treated seeds were tested under field conditions, emergence of *A. lentis*-infected seeds treated with thiabendazole and benomyl was significantly greater than with the other treatments, and yields were significantly higher with the thiabendazole treatment. Seed-treatment fungicides that adversely affected plant growth, vigor, and yields included triadimefon, triadimenol, etaconazole, and thiram (as a soak treatment). There was some evidence of a phytotoxic response to thiabendazole at 3.0 and 6.0 g a.i./kg of seed. Mycelial growth of four isolates of *A. lentis* was completely inhibited on potato-dextrose agar amended with thiabendazole at 10 μg a.i./ml. Infusion of thiabendazole and benomyl into infected lentil seeds, using acetone or dichloromethane, was not effective in controlling seedborne *A. lentis*. Treatment of infected seeds with aerated steam or hot water at 45–75 C for 30 min did not control *A. lentis*.

The USDA lentil (*Lens culinaris* Medik.) germ plasm collection is maintained at the Western Regional Plant Introduction Station in Pullman, WA. Identification and control of foreign and domestic diseases are important in maintenance of the *Lens* collection, because it is frequently impossible to replace an accession once it is lost. In 1981, *Ascochyta lentis* Vassiljevsky, the cause of a foliar blight disease, was isolated from seeds of 46 lentil plant inventory (PI) accessions from 16 countries (6,8). The only previous report of this seedborne pathogen in North America was from Canada in 1981 (15).

Lentil accessions must be increased periodically in field plantings at Pullman to replenish depleted seed supplies. There was concern that Ascochyta blight might spread from infected PI accessions to healthy accessions in the increase plots, particularly during cool, wet weather, which favors spread of the disease.

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The objectives of this study were to determine if the seedborne phase of *A. lentis* could be controlled by seed-treatment fungicides or thermotherapy, and to observe the effect of seedborne *A. lentis* on emergence, growth, and yield of lentil under greenhouse and field conditions. At present, the only fungicides registered by the U.S. Environmental Protection Agency for use on lentil in the Pacific Northwest are captan, metalaxyl, and thiram. A preliminary report on part of this study has been published (7).

MATERIALS AND METHODS

Lentil seeds. Healthy and infected seeds of lentil PI 438516 from Turkey were used in this study. Seeds naturally infected (>80%) with *A. lentis* were obtained from a 1980–1981 cold-tolerance trial at Pullman (8). Lentil seed free of *A. lentis* was obtained from plants grown in the greenhouse. The disease-free seed was increased in 1982 in an isolated field planting at Central Ferry, WA.

Effect of seed infection on growth and survival. The effect of seedborne *A. lentis* on emergence, growth, yield, and survival of lentil was studied under greenhouse and/or field conditions. Seeds of lentil PI 438516 naturally infected with *A. lentis* were surface-sterilized in 0.25% NaOCl for 5 min and plated on 2% water agar (WA). After 10–12 days, infected and healthy seedlings were planted in sterile potting medium (55% peat moss, 35% pumice, and 10% sand). In the greenhouse test, five healthy or infected seedlings were planted in 15-cm-diameter plastic pots, with 10 pots per treatment. After 58 days, data were taken on the survival, branching, and length and fresh weight of shoots and roots. In the field test, infected or healthy seedlings were planted in 5-cm-diameter plastic pots (one plant per pot). Plants were incubated in the greenhouse for 11–15 days and another 11 days outdoors in a lathhouse before being transplanted to the field at Central Ferry in 3-m-long, one-row plots of either all healthy or all infected plants. A randomized complete block (RCB) design with four replicates and 30 plants per plot was used. Survival and seed yields were determined for each plot. The field trials were conducted in a Spofford silt loam soil with the following properties: pH 6.6, conductivity 0.6 mmhos/cm, 27% sand, 53.8% coarse silt, 2.8% fine silt, 16.4% clay, and 1.6% organic matter.

Seed treatment. Fungicides used to treat *A. lentis*-infected lentil seeds in laboratory, greenhouse, and field trials were benomyl (Benlate 50W), captan (Orthocide 50W), quintozene (Terraclor 75W), ethazol (Truban 30W), ethazol + thiophanate-methyl (Banrot 40W), etaconazole (CGA-64251), thiabendazole (Mertect 340F), thiabendazole (Antimycotic A, 99+%, Merck & Co., Inc.), carboxin (Vitavax 75W), triadimefon (Bayleton 50W), thiram (Thiram 65W), triadimenol (BAY KWG 0519 25W), and thiophanate-methyl (Topsin M 70W). Seeds were treated in a slurry prepared by mixing weighed amounts of each fungicide in 2 ml of distilled water in 500-ml Erlenmeyer flasks and agitating 20 g of seed for 2 min before air-drying on paper towels at 20–23 C. Water control seeds were treated with 2 ml of distilled water, and dry controls were not treated. In one treatment with thiram, seeds were soaked in a 0.2% solution for 24 hr at 30 C in a water-bath shaker (100 rpm). Also tested were the effects of surface disinfestation of seeds in 0.25 and 1% sodium hypochlorite (NaOCl) for 5 min.

Field fungicide trial. Fungicide-treated and untreated seeds of lentil PI 438516 naturally infected with *A. lentis* were planted in Spofford silt loam soil at Central Ferry. Seeds were planted in 5.3-m-long, one-row plots with 1.5 m between rows in an RCB design with three replicates of 50 seeds per row per replicate. Final emergence counts were taken after 34 days, then seedlings were rated for vigor (on a scale of 1–5 where 1 = >75% plants stunted and 5 = 0% plants

stunted). Seed yields were determined for each plot. Two hundred seeds from each treatment were also plated on 2% WA, and data were taken on germination and infection by *A. lentis*.

Greenhouse fungicide trial. Spofford silt loam soil from Central Ferry was used in some of the greenhouse studies. Experiments using field soil were conducted in a ground bed (1.5 m wide × 3.5 m long × 0.3 m deep) that had heating cables to maintain a temperature of 15–17 C at a depth of 15 cm. In companion experiments using field soil, comparative control studies were carried out in sterile potting medium. Greenhouse temperatures ranged from 15 to 25 C. In the laboratory, 100 seeds were plated on 2% WA and readings were taken on germination and seed infection.

Phytotoxicity study. Healthy and *A. lentis*-infected seeds of lentil PI 438516 were treated with thiabendazole at rates of 0.3, 1.5, 3.0, and 6.0 g a.i./kg of seed. In the laboratory, 200 seeds from each treatment were plated on 2% WA to test for germination and control of seedborne *A. lentis*. In a split-plot RCB design with five replicates, 75 seeds from each treatment were planted in the greenhouse in sterile potting medium (15 seeds per 15-cm-diameter plastic pot). Measurements were made on emergence, vigor, and biological yield (fresh weights of shoots and roots) of plants. The test was terminated after 18 days. The data were analyzed using orthogonal polynomial contrasts ($P = 0.05$) on the treatment rates.

Sensitivity of *A. lentis* to thiabendazole. The sensitivity of four isolates of *A. lentis*, one each from India, Turkey, United States, and USSR, to thiabendazole (99+%) was determined by incorporating the fungicide into autoclaved potato-dextrose agar (PDA) after cooling. The fungicide was tested at 0.01, 0.10, 1.00, 10.00, and 100.00 μg a.i./ml of PDA. Each of five 9-cm-diameter plates per thiabendazole concentration was divided into four quadrants, and each quadrant was seeded with a different isolate of *A. lentis*, using a 3-mm-diameter plug from the edge of an actively growing colony on PDA. Seeded plates were incubated in the dark at 18 C. The effect of thiabendazole on mycelial growth of each isolate was determined by measuring colony diameters every 2 days for 14 days.

Solvent infusion study. Benomyl and thiabendazole were dissolved in 20 ml of acetone and dichloromethane, each at rates of 0.75, 1.5, 3.0, and 6.0 g a.i./kg of seed. Lentil seeds naturally infected with *A. lentis* were soaked in each solution for 3 hr at 20–22 C on a rotary shaker (90 rpm). After 3 hr, the solution was decanted and the seeds were dried overnight in a fume hood. Solutions of acetone and dichloromethane without fungicides served as controls. Benomyl and thiabendazole at 3 g a.i./kg of seed were also applied to seeds in a water slurry. Two hundred seeds per treatment were plated on 2% WA, and germination and infection counts were made after 10 days.

Thermotherapy. Infected lentil seeds were treated with aerated steam at temperatures ranging from 45 to 72 C (increments of 3–5 C) for 30 min. The seeds were treated in a pressure-flow apparatus designed by K. F. Baker (1). Treatments were applied to dry seeds or seeds exposed to 100% relative humidity for 48 hr before treatment (humidified seed). Control seeds were treated at 20–22 C. Another set of treatments was in hot water at temperatures ranging from 45 to 75 C (increments of 5 C) for 30 min. Seeds were enclosed in nylon screen envelopes, which were submerged in a circulating hot-water bath. Dry or humidified seeds were treated at each temperature. Immediately after treatment, seeds were cooled in running tap water (18 C) for 4 min, then dried on paper towels at 22–24 C. Two hundred seeds from each treatment were plated on 2% WA, and germination and infection counts were made after 10 days.

RESULTS

Effect of seedborne *A. lentis* on growth and survival of lentils. In greenhouse studies, survival of seedlings from clean seed was significantly better than from infected seed (Table 1). Lentils from seed infected with *A. lentis* had 47% fewer branches than healthy plants of the same age. Frequently, no symptoms were observed on the aboveground tissues of plants arising from infected seed even though these plants were less vigorous than healthy plants of comparable age (Fig. 1). The lengths and fresh weights of shoots and roots of infected plants were significantly less than those of healthy plants. Under field conditions, there was no significant difference in survival of healthy and infected plants, but seed yield of infected plants was decreased by 43% (Table 1). Although most infected plants were stunted, no symptoms of Ascochyta blight were observed on the foliage.

Field seed-treatment trial. Under field conditions, seedling emergence of treated and untreated seeds ranged from 23 to 73% (Table 2). Emergence in the thiabendazole and benomyl treatments was significantly better than in all other treatments. Seedling emergence was lowest in the thiram soak treatment. There was a significant difference in seedling vigor among treatments. Seedlings with the highest vigor were associated with the thiabendazole, benomyl, ethazol, captan, and thiram slurry treatments. The poorest vigor ratings were obtained with the thiram soak, triadimefon, triadimenol, and etaconazole treatments (Table 2), which adversely affected plant growth and appeared to be phytotoxic to lentil at the rates used. Several seed treatments significantly increased yields over the untreated control. Yield of seed treated with thiabendazole was significantly higher than in all other treatments. Significant increases in yield over the control, but less than with thiabendazole, were found in the thiophanate-methyl, ethazol, quintozene, captan, and ethazol + thiophanate-methyl treatments. Yields of seeds treated with triadimefon, etaconazole (1.0 g a.i.), and thiram soak were significantly lower than in the untreated control.

Several seed treatments significantly reduced the incidence of seedborne *A.*

Table 1. Effect of seedborne *Ascochyta lentis* on growth and survival of lentil PI 438516 in greenhouse and field trials

	Greenhouse[w]						Field[x]	
			Length (cm)		Mean fresh weight (g)			
Treatment[v]	Survival (%)	No. branches	Shoot	Root	Shoot	Root	Survival (%)	Seed yield[y] (g)
Healthy	100 a[z]	13 a	27.7 a	26.3 a	7.6 a	3.8 a	80 a	102 a
Infected	84 b	7 b	14.6 b	19.9 b	2.8 b	2.1 b	73 a	58 b

[v] Seeds naturally infected with *A. lentis* were surface-sterilized in 0.25% NaOCl for 5 min and plated on 2% water agar. After 10–12 days, healthy and *A. lentis*-infected seedlings were transplanted to sterile potting medium in the greenhouse.
[w] Based on five seedlings transplanted to 10 15-cm-diameter plastic pots. Measurements were made after 58 days.
[x] Seedlings grown in sterile potting medium in 5-cm-diameter plastic pots in the greenhouse and lathhouse for 22–26 days were transplanted to the field in a Spofford silt loam at Central Ferry, WA. Based on four replicates of 30 seedlings.
[y] Based on four replicates of one-row plots 3 m long.
[z] Numbers in the same column followed by the same letter do not differ significantly ($P = 0.05$) according to a protected LSD.

lentis in laboratory tests (Table 2). The most effective seed treatments were thiabendazole and etaconazole (CGA-64251), which reduced the level of seedborne *A. lentis* from 80.5% in the untreated control to 0 and 1.5%, respectively, in treated seeds. The highest incidence of *A. lentis* occurred on seeds treated with thiophanate-methyl (Topsin M), which was not significantly different than the untreated control. Germination of seeds treated with thiabendazole and benomyl (Benlate) was significantly better than all other treatments, except carboxin (Vitavax), captan, and thiram. The etaconazole (1.0 g a.i./kg of seed) and the thiram soak treatments were phytotoxic to lentil seedlings. Phytotoxicity in both cases was expressed as severe hypocotyl stunting and deformation.

Greenhouse seed-treatment trial. When infected seeds were treated with thiabendazole, benomyl, captan, and NaOCl, incidence of seedborne *A. lentis* in laboratory studies ranged from 0 to 56% compared with 88% in the untreated control (Table 3). The fungus was not isolated from seeds treated with thiabendazole. Although there was no significant difference in germination of treated and untreated seeds on 2% WA in greenhouse trials, emergence in sterile potting medium was significantly higher in the treated seeds than in the untreated control (Table 3). Emergence of treated and untreated seeds in field soil ranged from 53 to 81%. Emergence of seeds treated with thiabendazole was significantly greater than in all other treatments, and the poorest emergence occurred in the untreated control. Very few blight symptoms were observed on the foliage of lentil seedlings in the greenhouse trials.

Fig. 1. Stunting and poor vigor frequently associated with lentil plants from seed infected with *Ascochyta lentis*. Seeds of (left) healthy and (right) infected lentil PI 370633 were planted 27 days earlier in sterile potting medium in the greenhouse.

Phytotoxicity studies. When thiabendazole was tested at 0.3, 1.5, 3.0, and 6.0 g a.i./kg seed, analysis of variance of the laboratory tests indicated a highly significant difference between the healthy and *A. lentis*-infected seeds for both germination data and percent seedborne *A. lentis* (Table 4). The 0.3-g a.i./kg seed treatment had such little effect on *A. lentis* that infected seeds germinated at a level comparable to the untreated control. For the thiabendazole treatments at rates of 1.5 g a.i./kg seed and higher, the chemical had no significant effect on germination in either healthy or infected seeds as determined by the linear orthogonal polynomial contrast.

In laboratory tests, thiabendazole at

Table 2. Effectiveness of seed-treatment chemicals in controlling seedborne infection of lentil PI 438516 naturally infected by *Ascochyta lentis* and their effects on emergence, vigor, and yield in field studies

		Laboratory[u]		Field[v]		
Treatment	Rate (g a.i./kg seed)	Germination (%)	*A. lentis* isolated (%)	Emergence (%)	Vigor[w]	Yield (% of control)
Untreated control	...	74.5 b[x]	80.5 cd	67 b	3.0 b	100 f
NaOCl[y]	0.25	74.5 b	72.5 c	62 c	3.5 bc	181 c
NaOCl[y]	1.0	68.5 bc	67.0 c	53 d	3.0 b	178 cd
Carboxin	3.0	81.5 ab	59.0 bc	69 b	3.5 bc	145 e
Quintozene	3.0	75.5 b	68.5 c	64 bc	2.0 c	195 b
Captan	3.0	79.5 ab	46.0 b	69 b	4.0 a	195 b
Thiram	3.0	79.5 ab	51.5 bc	63 bc	4.0 a	132 e
Thiram soak[z]	0.2	45.5 d	54.0 bc	23 e	1.0 d	31 h
Ethazol	3.0	78.5 b	60.0 bc	69 b	4.0 a	199 b
Ethazol + thiophanate-methyl	3.0	78.0 b	43.0 b	65 bc	3.5 b	191 bc
Thiophanate-methyl	3.0	75.0 b	96.0 d	62 c	2.5 bc	209 b
Thiabendazole	3.0	84.0 a	0.0 a	73 a	4.0 a	241 a
Benomyl	3.0	82.0 a	34.0 b	73 a	4.0 a	159. e
Triadimefon	3.0	55.5 c	45.5 b	62 c	1.0 d	85 g
Triadimenol	3.0	65.0 bc	36.5 b	61 c	1.5 d	129 e
Etaconazole	0.25	66.5 bc	27.0 b	59 cd	1.5 d	107 f
Etaconazole	1.0	64.5 bc	1.5 a	55 d	1.0 d	64 gh

[u] Based on 10 replicates of 20 seeds plated on 2% water agar.
[v] Planted in Spofford silt loam at Central Ferry, WA. Based on three replicates of 50 seeds planted in one-row plots 5.3 m long.
[w] Vigor ratings of 1–5, where 1 = >75% plants stunted and 5 = 0% plants stunted (normal growth).
[x] Numbers in the same column followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's new multiple range test.
[y] Seeds surface-sterilized in a 0.25 or 1.0% sodium hypochlorite (NaOCl) solution for 5 min.
[z] Seeds soaked in a 0.2% aqueous solution of thiram for 24 hr at 30 C.

1.5, 3.0, and 6.0 g a.i./kg seed significantly reduced the levels of *A. lentis* isolated from the infected seed over the 0.3-g treatment and the two controls (Table 4). In the analyses of variance of emergence, seedling vigor, and biological yield in the greenhouse experiment, there were highly significant differences between the healthy and *A. lentis*-infected seed. Within these two classes, there was little difference in emergence and seedling vigor among treatments, but in an orthogonal polynomial contrast of foliage plus root fresh weights, there was a significant linear *F*-ratio and no significance in the quadratic or cubic components.

Sensitivity of *A. lentis* to thiabendazole. Mycelial growth of the four isolates of *A. lentis* was completely inhibited at 10 μg a.i. of thiabendazole per milliliter of PDA. None of the isolates resumed growth when mycelial plugs were transferred after 14 days from the 10-μg medium to PDA without thiabendazole. At 1.0 μg a.i. of thiabendazole per milliliter of PDA, colony diameters of the four isolates were decreased by 47–73% over the 0.1-μg rate. There were no significant differences in mycelial growth rates or colony diameters of each isolate at 0, 0.01, and 0.1 μg a.i. of thiabendazole per milliliter of PDA. No colony to colony growth interference was observed in any of the treatments at 14 days.

Solvent infusion study. Infusion of benomyl and thiabendazole into naturally infected lentil seeds with acetone and dichloromethane at rates of 0.75–6.0 g a.i./kg of seed did not control seedborne *A. lentis*. When benomyl or thiabendazole were infused into infected seed with either solvent, *A. lentis* was isolated from 31 and 43% of the seeds, respectively. In contrast, benomyl and thiabendazole applied in water slurries gave 34 and 0% infection, respectively.

Thermotherapy. Treatment of *A. lentis*-infected lentil seeds with aerated steam or hot water was not effective in reducing the incidence of seedborne *A. lentis* without adversely affecting germination. The aerated-steam treatment was significantly more effective in reducing the level of seed infection than the hot-water treatment. None of the hot-water or aerated-steam treatments reduced the level of seedborne *A. lentis* to <18% without reducing germination to <60%. Exposing seeds to a humid atmosphere for 48 hr before treatment at 50–75 C in water or at 60–72 C in aerated steam resulted in a significant reduction in the incidence of seeds infected with *A. lentis* compared with the dry seed treatment.

DISCUSSION

Stunting and low vigor were the most obvious symptoms in lentil plants developing from seed naturally infected with *A. lentis*. Many of the infected seeds used in this study had necrotic, discolored lesions that frequently contained whitish mycelium and pycnidia of the fungus. It is well documented that seed germination and vigor are adversely affected by fungal infection (5,16) and that certain biochemical changes associated with seed deterioration often occur in infected seed (5). The biochemical and physiological changes in lentil seed infected with *A. lentis* may have contributed significantly to the poor growth and vigor shown by lentil plants in the greenhouse and field, particularly in the absence of foliar infection. Ascochyta blight lesions seldom developed on the foliage of lentil plants under greenhouse and field conditions, even though >80% of the untreated seeds were infected with the pathogen. Cool, wet weather favors spread and infection of the blight

Table 3. Efficacy of different chemicals in controlling seedborne *Ascochyta lentis* in lentil PI 438516 on agar medium in the laboratory and on emergence in sterile potting medium (SPM) and field soil in the greenhouse

		Laboratory[v]		Greenhouse (emergence [%])	
Treatment	Rate (g a.i./kg seed)	Germination (%)	Seed infected (%)	SPM [w]	Field soil[x]
Thiabendazole	3.00	73 a[y]	0 d	86.3 a	80.8 a
Benomyl	3.00	83 a	30 c	90.0 a	65.0 bc
Captan	3.00	77 a	43 bc	85.5 a	63.3 bc
NaOCl[z]	0.25	75 a	56 b	87.5 a	67.5 b
Untreated control	···	77 a	88 a	77.5 b	53.3 c

[v] Based on five replicates of 20 seeds plated on 2% water agar.
[w] Based on 20 seeds planted in sterile potting medium in five 15-cm-diameter plastic pots. Final emergence counts were taken 19 days after planting.
[x] Seeds (30 per row) were planted in a large soil bed containing Spofford silt loam soil from Central Ferry, WA. Four 1.5-m rows per treatment were used, and final emergence counts were taken 21 days after planting.
[y] Numbers in the same column followed by the same letter do not differ significantly ($P = 0.05$) according to Duncan's new multiple range test.
[z] Seeds were surface-sterilized in 0.25% sodium hypochlorite (NaOCl) for 5 min.

Table 4. Effect of thiabendazole in controlling seedborne *Ascochyta lentis* in lentil PI 438516 and on emergence, vigor, and biological yield of plants in sterile potting medium in the greenhouse

		Laboratory[w]				Greenhouse[x]					
		Germination (%)		*A. lentis* isolated (%)		Emergence (%)		Seedling vigor		Mean biological yield (g)[y]	
Treatment	Rate (g a.i./kg seed)	H a[z]	I b	H a	I b	H a	I b	H a	I b	H a	I b
Thiabendazole	0.3	91.0	65.0	0	66	90.7	89.3	4.0	2.4	1.2	0.8
	1.5	96.0	80.0	0	2	97.3	80.0	4.2	3.2	1.1	0.8
	3.0	91.0	77.0	0	0	96.0	88.0	3.8	2.8	0.9	0.8
	6.0	96.0	75.0	0	0	94.7	86.7	4.2	2.8	0.9	0.7
Untreated H_2O control	···	90.0	64.0	0	87	96.0	78.7	4.6	2.6	1.3	0.9
Untreated dry control	···	94.0	64.0	0	67	92.0	86.7	4.4	2.8	1.2	0.8

[w] Based on 10 replicates of 20 seeds plated on 2% water agar. H = healthy seed and I = *A. lentis*-infected seed.
[x] Based on 15 seeds planted in sterile potting medium in five 15-cm-diameter plastic pots. Test terminated 18 days after planting.
[y] Fresh weights of shoots and roots.
[z] Letters following H and I indicate significant difference at $P = 0.05$ in the ANOVA *F* ratio.

pathogen (8,15). It appears that the environmental conditions required for transmission of *A. lentis* from infected seed to the developing seedling were suboptimal during our greenhouse and field trials. Gossen and Morrall (4) suggest that seed transmission of *A. lentis* is greater at low soil temperatures. Our field tests were conducted under hot, dry weather conditions at Central Ferry during the spring and summer of 1982.

Infected lentil seed is the main means by which *A. lentis* is spread over great distances and introduced into previously disease-free areas where it may also serve as initial inoculum for disease development. Infected seed also provides the fungus with an important survival mechanism. We initiated this seed-treatment study to prevent further introduction of *A. lentis* on imported seeds and to restrict spread of the fungus with lentil seeds distributed from the USDA lentil germ plasm collection at Pullman. In laboratory tests, the systemic fungicides generally were more effective than nonsystemic ones in reducing the level of seedborne inoculum. Thiabendazole, a benzimidazole, was the most promising fungicide tested in these studies. Although thiabendazole seems to eradicate *A. lentis* from intact diseased seed in laboratory tests, seed dissection indicates that this fungicide is not 100% effective in eradicating the pathogen from the cotyledons (*unpublished*). Benomyl and thiophanate-methyl, both benzimidazoles, provided only poor to fair control of seedborne *A. lentis*. Thiabendazole may be absorbed more readily and rapidly by infected lentil seeds than benomyl or thiophanate-methyl and thus control deep-seated infection beneath the seed coat. Furthermore, thiabendazole or the chemical moiety that is toxic to *A. lentis* may be more fungitoxic than the other benzimidazole compounds tested to the mycelium and reproductive structures of the pathogen present in or on lentil seed. Additional studies are needed to identify other compounds more effective than thiabendazole in eradicating the fungus from infected lentil seeds under laboratory and field conditions without being phytotoxic to the plant.

Although Ascochyta blight of lentil has been reported from eight countries and isolated from lentil seeds from another nine (7), little research has been done on the chemical control of the seedborne phase of the disease. Davatzi-Helena (3) reported that the fungus was not isolated from infected seeds treated with 0.06% a.i. of benomyl. In greenhouse tests, Mitidieri (10) reported increased germination of 6–21% when infected seeds were treated with different fungicides, including benomyl, captafol, captan, carboxin, and thiram. Morrall and co-workers (11–15) evaluated several seed-treatment fungicides, including benomyl, carbendazim, carboxin, iprodione, and thiabendazole, for control of seedborne *A. lentis* under field conditions. The results of their seed-treatment tests were inconsistent, and usually there were no significant differences in emergence or yield among treatments when seeds were planted on stubble or summer-fallow land. In our laboratory studies, only two of 12 fungicides tested (thiabendazole and etaconazole) reduced seedborne inoculum of *A. lentis* to $<2\%$. Etaconazole was highly phytotoxic to lentil seedlings at the rate required to control seedborne *A. lentis*. With intact seeds, thiabendazole gave complete control of *A. lentis* at 3.0 and 6.0 but not at 1.5 g a.i./kg of seed. In greenhouse tests, however, thiabendazole at the higher rates appeared to be slightly phytotoxic, although the response was not as severe as that observed with the etaconazole, triadimefon, triadimenol, and thiram soak treatments.

All of the funigicide trials (except one) were carried out in the laboratory and greenhouse with lentil seeds heavily infected with *A. lentis*. The efficacy of thiabendazole and other systemic and protective compounds needs to be tested more extensively in the field, preferably under weather conditions that favor disease development. Fungicides effective in controlling seedborne pathogens in laboratory bioassays may not perform as well under field conditions, where the interactions of environmental conditions, soil, and seed treatment may affect the chemicals' efficacy in controlling subsequent seedling infection (2). This was demonstrated by Kharbanda and Bernier (9), who tested the effects of different fungicides on control of seedborne *A. fabae* in faba bean (*Vicia faba* L.) seed. Several seed-treatment compounds effectively controlled the pathogen in laboratory tests but were ineffective in reducing seedling infection in field tests. Additionally, the rate of seed transmission is influenced by soil conditions during germination (4).

In lentil-growing areas where weather conditions are conducive to development of blight, control of only one aspect of the disease cycle, such as seed transmission, may not prevent significant reductions in yield and/or seed quality. An integrated approach to disease control may be required to prevent serious economic losses.

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