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Research note

Trial of a granular etridiazole and thiophanate-methyl mixture to control *Fusarium* root disease of container-grown Douglas-fir seedlings

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Application. A granular formulation of an etridiazole and thiophanate-methyl fungicide (Banrot®), incorporated into peat: vermiculite medium, was ineffective in controlling *Fusarium* infection of container-grown Douglas-fir seedlings. Seedling growth was often decreased by the fungicide.

Abstract. *Fusarium* root disease is a common and often serious problem in the production of container-grown seedlings. Fungicide treatments applied late in the growing season, i.e. during bud initiation stress, are relatively ineffective against the disease. Incorporating a granular mixture of etridiazole and thiophanate-methyl fungicide (Banrot®) into the medium prior to sowing was tested for its efficacy of control against the disease. The fungicide was unable to sufficiently reduce *Fusarium* infection and infection intensity enough to warrant its use in root rot management. Some phytotoxic effects were observed.

Introduction

Fusarium root disease is a serious problem in the production of reforestation seedlings in the northern Rocky Mountains, infecting nearly all western conifer species (Bloomberg 1981). It is especially widespread and damaging to container-grown Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) (James and others 1987). Although seed may be an important inoculum source (James 1986), recent studies indicate inoculum was carried from crop to crop on the interior walls of reused containers (James and others 1988; Sturrock and Dennis 1988), with inoculum most concentrated at cell bottoms despite efforts to clean the cells (James and Gilligan 1988).

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In container nurseries, controlling *Fusarium* root disease with fungicides late in the growing season is generally ineffective because the chemicals do not reach infection sites (lower roots) at high enough concentrations. Further, *Fusarium* commonly colonizes root cortical cells and its thereby inaccessible to contact fungicides.

Our study objective was to determine the effects of a granular formulation of an etridiazole and thiophanate-methyl fungicide (ETM) on incidence and severity of *Fusarium* infection and growth of container-grown Douglas-fir seedlings. We felt incorporation of granular ETM into the growing mix prior to sowing may reduce seedling infection because

- the fungicide would be distributed throughout the growing medium;
- ETM is both a contact and system fungicide;
- the product used has a slow-release formulation and has been reported to remain active in the granular form for at least three months (Mallinckrodt, Inc., St. Louis, MO).

Materials and methods

Using a rotary cement mixer, granular ETM (Banrot 8G® Mallinckrodt, Inc., St. Louis, MO) was thoroughly incorporated into standard peat: vermiculite (1:1) forestry mix (W.R. Grace & Co., Portland, OR) at a rate of 454 g per 0.76 m^3 (1 lb per yard) of medium. Forestry mix, with and without ETM, was sent to three nurseries in northern Idaho and one in western Montana. Nurseries were located between 46 and 48° latitude and 115 and 117° longitude. At each nursery, previously used styroblock 4A's and/or Ray Leach® pine cells (Canby, OR), both 66 cm^3, were filled with treated and untreated forestry mix, and sown with one or more lots of Douglas-fir seed. Each treatment/container-type/seedlot combination was replicated three times. Seedlings were cultured under the normal growing regimes of each nursery, including usual fungicide treatments.

Seedlings were sampled after six or seven months of growth, depending on the sowing date and cropping system of the individual nurseries. For each seedlot, 60 seedlings were measured for height (from ground line to tip of terminal bud) and root collar diameter (RCD). Another sample of 15 seedlings per seedlot were measured for shoot biomass production after drying 24 h at 60° C. Ten healthy-appearing seedlings were randomly selected per seedlot and treatment and were assayed for *Fusarium* root infection. Root systems of sampled seedlings were washed thoroughly and 10 randomly-selected root tips were excised, surface sterilized in a 10% bleach (5.25% sodium hypochlorite) solution for 1 min, rinsed with sterile distilled water and placed on a selective medium for *Fusarium*

(Komada 1975). Percentage root colonization was calculated for infected seedlings by determining the number of root pieces colonized. Isolated fusaria were identified using the taxonomic methods of Nelson and others (1983).

Seedling height, RCD, oven-dry weight and root colonization data were analyzed by seedlot with a t-test. Fisher's exact test was used to compare percentage infected seedlings by seedlot.

Results and discussion

Although most decreases in height and RCD between treatments were statistically significant, the magnitude of the differences was often quite small (Table 1). However, some serious reductions in height and RCD growth were observed, especially in pine cells. In most cases, shoot dry weight was significantly reduced by the treatment. Incorporated ETM significantly reduced the percentage of seedlings infected with *Fusarium* in two of four seedlots at one nursery, but was ineffective against the disease at the other nurseries. For all nurseries, in only one of every six seedlots was the number of infected trees significantly reduced by the granular ETM treatment. Granular ETM was somewhat effective in reducing intensity of root colonization by *Fusarium*; significant reductions were noted in one of every three seedlots. For all seedlots at all nurseries in all containers, granular ETM was unable to reduce seedling infection by *Fusarium*, however the subsequent level of infection was significantly reduced.

Most *Fusarium* isolates from the roots of non-diseased seedlings were identified as *F. oxysporum* Schlecht. and *F. acuminatum* Ell. & Ev. Other species isolated less frequently included *F. sambucinum* Fuckel, *F. avenaceum* (Fr.) Sacc., *F. tricinctum* (Corda) Sacc. and *F. chlamydosporum* Wollenw. & Reinking. From an earlier study (James and others 1989), it is likely *F. oxysporum* and *F. acuminatum* were pathogens whereas the other species were probably saprophytes.

Our results indicate granular ETM was ineffective in adequately controlling *Fusarium* root disease in container-grown Douglas-fir. One factor that may have lowered the efficacy of the chemical mixture was uneven distribution throughout the peat: vermiculite medium. At the label rate, the volume of chemical to medium is small. Uneven mixing of incorporated chemicals into container medium is common (Whitcomb 1988), and the problem is further compounded because dry incorporated amendments easily separate out from dry medium during handling (Bartok 1985). Poor performance may also have been caused by high inoculum levels within

Table 1. Morphological characteristics of Douglas-fir seedlings and *Fusarium* infection.

Seed lot	Treatment	Shoot height (cm)	Root collar diameter (mm)	Shoot dry Wt. (gms)	Seedlings infected[1,4] (%)	Seedling root colonization intensity[2] (%)
		------ n = 60 ------		n = 15	N = 15	
Styroblock 4A						
8002	Control	20.6	1.99	1.06	100	74.0
	ETM	19.1**[3]	1.92	0.86**	53**	21.2**
8022	Control	20.4	1.87	1.12	60	38.8
	ETM	19.0*	1.87	0.87**	0**	0.0**
8024	Control	17.6	1.95	1.10	47	28.6
	ETM	16.4**	1.87	0.90**	40	25.0
8250	Control	15.3	1.86	1.13	60	30.0
	ETM	15.3	1.78	0.86**	33	23.3
8033	Control	9.1	2.13	0.83	100	100.0
	ETM	8.3**	1.96**	0.75**	100	94.5
8215	Control	9.1	1.85	0.85	100	93.5
	ETM	9.1	1.79	0.86	100	92.5
8717	Control	10.5	2.56	0.84	100	98.5
	ETM	9.5**	2.43	0.81	95	58.4**
8733	Control	10.2	2.38	0.95	100	100.0
	ETM	9.2*	2.19	0.78*	100	85.3**
3-Bovill	Control	19.2	2.02	1.56	7	10.0
	ETM	19.0	2.01	1.55	27	21.2
Ray Leach pine cells						
3-Bovill	Control	19.0	2.07	1.46	15	40.0
	ETM	16.9**	1.95**	1.47	25	32.2
1781	Control	13.8	1.82	1.06	73	29.1
	ETM	13.1	1.58**	0.81**	67	30.0
4787	Control	12.8	1.99	1.05	100	70.7
	ETM	9.7**	1.70**	0.72*	93	66.0
All	Control	14.8	2.04	1.08	72	59.4
	ETM	13.7**	1.92**	0.94**	61	45.8*

[1] Percentage of seedlings with one or more infected root tips.

[2] For infected seedlings, the percentage of root tips (10 sampled per seedling) colonized by *Fusarium* spp.

[3] Treatment values for each seedlot followed by an asterisk are significantly different using a t-test at the $p \leqslant 0.05$ level. Values followed by two asterisks are significantly different at the $p \leqslant 0.01$ level.

[4] Treatment values for seedlings infected were carried out using Fisher's exact test. Values for each seedlot followed by two asterisks are significantly different at the $p \leqslant 0.01$ level.

seedling containers at some of the nurseries as well as leaching of the chemical during irrigation.

Management implications

For container nurseries in the Intermountain West, granular ETM (Banrot 8G®) was not sufficiently effective in decreasing seedling infection, or in reducing root colonization, by *Fusarium* root disease. Although complete elimination of infection is probably unnecessary considering outplanting performance, subtle to drastic phytotoxic reactions and a lack of consistent disease control make this treatment an unattractive alternative to growers.

Because chemical fungicide treatments are usually ineffective against root disease, other approaches are needed. Growers can reduce disease incidence by sanitizing seeds, containers and greenhouses, and by rogueing dead seedlings to minimize infection of neighboring seedlings and reduce inoculum build-up in containers.

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