Effect of Seed Treatments on Stand Establishment, Root Necrosis, and Yield of *Lupinus albus*

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ABSTRACT

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Treatment of seed of white lupine (*Lupinus albus*) with maneb, captan, thiram, metalaxyl, carboxin, PCNB + ethazol, streptomycin sulfate, or chitosan was evaluated for effect on stand establishment, seedling root discoloration and necrosis, and yield. Seed treatments did not consistently improve stand establishment or affect the number of roots with lesions, constrictions, tip necrosis, or discoloration. *Fusarium* spp. were isolated more frequently than *Rhizoctonia solani* AG-4, *Pythium* spp., *Pleiochaeta setosa*, or *Ascochyta* sp., with *F. solani* being isolated most often. Seed treatment did not consistently result in an increase in yield.

Poor stand establishment has been a problem in lupine (*Lupinus* spp.) even in seed lots with high germination (10, 19). A number of pathogenic fungi have been isolated from lupine seed, including *Alternaria alternata* (Fr.:Fr.) Keissl., *Botrytis paeoniae* Oudem., *Chaetomium bostrychodes* Zopf, *Colletotrichum gloeosporioides* (Penz.) Penz. & Sacc. in Penz., *Fusarium avenaceum* (Fr.:Fr.) Sacc., *F. culmorum* (Wm.G. Sm.) Sacc., *F. merismoides* Corda, *F. moniliforme* J. Sheld., *F. oxysporum* Schlechtend.: Fr., *F. solani* (Mart.) Sacc., *Glomerella cingulata* (Stoneman) Spauld. & H. Schrenk, *Phoma glomerata* (Corda) Wollenweb. & Hochapfel, *Pleiochaeta setosa* (Kirchn.) S.J. Hughes, *Scopulariopsis brevicaulis* (Sacc.) Bainier, and *Stemphylium botryosum* Wallr. (1,5, 8,15). Bacteria can also significantly reduce seed germination and stand establishment (19).

Seed treatments have been found to be effective against seedborne and soilborne fungi responsible for seedling blights or root rots in lupine species in various geographic areas. Fahim et al (7) controlled soilborne *F. oxysporum* in Egyptian-grown *L. angustifolius* L. and *L. luteus* L. with seed-applied benomyl and thiophanate-methyl/thiram. Soilborne *Pleiochaeta setosa* and *Rhizoctonia* spp. were controlled in *L. angustifolius* with iprodione in Australia (6,20). Benomyl and benomyl mixtures have been successful at eradicating *Phomopsis leptostromiformis* (Kühn) Bubák in Kab. & Bubák from seeds of *L. angustifolius* (4) and have improved emergence of the white lupine (*L. albus* L.) cultivar Kievsky (17). No literature is available on the organisms that cause disease on lupine in Minnesota or on the effectiveness of seed treatments.

At the time this study was initiated, white lupine was being tested as an alternative crop and the indigenous organisms capable of causing root rots under Minnesota conditions were unknown. The objective of this research was to evaluate the effect of seed treatments (seven fungicides and a bactericide) on stand establishment, root discoloration or necrosis, and yield of white lupine. Fungi associated with root lesions, tip necrosis, and discoloration were also isolated and identified.

MATERIALS AND METHODS

Treatment of seed. Seed treatments were dissolved or diluted in distilled water at recommended rates (Table 1). Seed was mixed in a rotating drum as the treatment was atomized into the mixer.

Field plot preparation. Three test plots were established in 1989 and 1990. Two plots were at the Staples Irrigation Center, University of Minnesota, Staples, and one plot was at the University of Minnesota, St. Paul. Three planting periods were used: early, normal, and late. Staples site 1 was planted 26 April 1989 and 18 April 1990 (early) and site 2 was planted 1 June 1989 and 23 May 1990 (late). The St. Paul plot was planted 11 May 1989 and 7 May 1990 (normal). The cultivar Ultra was planted at all three locations. Soil samples were collected to a 15-cm depth before plots were planted. The soil at the Staples sites was a Verndale sandy loam (Udic Argiborolls, coarse-loamy, mixed) with a pH of 6.8. Soil from Staples site 1 contained 61 ppm of phosphorus (P) and 112 ppm of potassium (K). Soil from Staples site 2 was the same type but had a pH of 7.3 and P and K levels of 59 and 61 ppm, respectively. The St. Paul plot was located on a Waukegan silt loam (Typic Hapludolls, fine-silty over sandy or sandy-skeletal, mixed, mesic) and had a pH of 7.3 and P and K levels of 100+ and 120 ppm, respectively. No fertilizer was applied to the plots. In 1989 at Staples site 2, the insecticide diazinon was applied in-furrow (11 kg/ha) to control seedcorn maggot.

Seven fungicides and one bactericide were evaluated (Table 1). The control received no treatment. The treatments were selected for their activity against organisms known as common problems on other crops in Minnesota. Treatments were arranged in a randomized block with five replicates. A Winter Steiger Plotman cone planter was used to plant the plots. Each subplot consisted of 10 rows 15 cm apart and was seeded 3.8 cm deep at a rate of 12 seeds per meter, except at Staples site 2 in 1989, when the rate was 15 seeds per meter. Both Staples sites had overhead irrigation, whereas the St. Paul site was not irrigated.

***Rhizobium* inoculation.** Seed was inoculated at planting with *Bradyrhizobium* (Wolf River Valley Seed, White Lake, WI). Seed was placed in a con-

Table 1. Seed treatments applied to *Lupinus albus*

Common name	Trade name	Rates/kg of seed	Target organisms
Maneb	Dithane M-22	2.5 g	Damping-off, seed rot
Captan	...	1.3 ml	Seedling blights
Thiram	...	0.7 ml	Seedling blights
Metalaxyl	Apron 2.66	1.0 ml	Phytophthora root rot, Pythium damping-off
Carboxin	Vitavax 34	1.3 ml	*Rhizoctonia solani*
PCNB + ethazol	Terra-Coat	1.8 g + 4.4 g	Rhizoctonia damping-off, *Pythium, Fusarium, Sclerotinia sclerotiorum*
Steptomycin sulfate	Agri-Strep	0.4 g	Bactericide
Chitosan	YEA	10.4 ml	*Fusarium solani*

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tainer, sprinkled with tap water, dusted with inoculum (4 g/1 kg of seed), and mixed by hand until all seeds were speckled in appearance.

Stand and disease evaluations. Stands were counted every week for 4 wk after emergence because of the extended germination period and emergence pattern common in white lupine. Six 1.5-m lengths of row were randomly selected within each plot and marked with stakes. The same staked portions of the row were counted every week. Stand was also counted in the staked areas just before harvest.

During the same 4-wk period after emergence, roots of 12–18 plants randomly collected outside the staked areas were assessed for lesions on roots and hypocotyls as well as root discoloration and necrosis for each treatment and plot. Roots were washed under running water for 1 hr and then examined for lesions, constrictions, tip necrosis, and discoloration. Portions (approximately 0.5 cm) of roots with symptoms were excised from the diseased tissue, surface-treated in 0.5% sodium hypochlorite for 1 min, and triple rinsed in sterile distilled water. The tissue was then placed on Difco malt agar (pH 5.6). Fungi that grew from tissues were isolated and maintained as pure cultures. Fungi were identified to genus using the keys of Barnett and Hunter (2) and Barron (3). *Fusarium* and *Pythium* species were identified using the keys of Nelson et al (14), Waterhouse (21), and Robertson (16). The anastomosis group of *Rhizoctonia solani* Kühn isolates was determined in pairings against known AG-4 isolates by the method described by Martin and Lucas (12).

Weather data. Daily maximum and minimum temperatures and precipitation were recorded from planting to 4 wk after emergence. The plots were not irrigated during the 4 wk after emergence because of sufficient soil moisture during both years.

Germination testing of seed. To determine if seed treatment affected germination, tests were conducted with a Seedboro Newstyle Deluxe seed germinator maintained at 23 C and 100% relative humidity. Fifty seeds from each treatment were placed between wet paper towels and laid flat in glass containers. Towels were moistened with sterile distilled water as needed.

Harvest data. Yield data were collected by harvesting a 4.6 × 1.5 m section in the center of each subplot with a Winter Steiger Nursery Master Elite plot combine. Seed from each subplot was collected separately, dried at 74 C to 5% moisture, and weighed. Harvest dates were 29 August 1989 and 12 September 1990 at Staples site 1, 25 October 1989 and 26 September 1990 at Staples site 2, and 24 August 1989 and 5 September 1990 at St. Paul.

Data analysis. Data collected for emergence and root disease were subjected to analysis of variance (SAS User's Guide release 6.03, SAS Institute, Cary, NC). Means were compared by Duncan's multiple range test. All data were analyzed at $P = 0.1$ in both years. Pearson's correlation coefficents were calculated to determine if total root disease was related to temperature and rainfall.

RESULTS

Stand counts. Emergence counts between treatments differed significantly in all plots in 1989 and 1990, but results varied (Table 2). Emergence of seed treated with maneb or carboxin was significantly greater than emergence of untreated seed at Staples site 1 in 1989. When the seed was planted early at site 1 in 1990, however, seed treated with metalaxyl resulted in significantly better stands than did the untreated seed. Seed treated with captan, metalaxyl, thiram, or chitosan had better emergence than untreated seed sown at the St. Paul plot in 1989, but none of the treatments was significantly better than the control in 1990. At Staples site 2, seed treated with carboxin or metalaxyl resulted in significantly better stands than did untreated seeds in 1989, but there were no significant differences in stand for treated or untreated seed in 1990.

Fungi isolated. *Fusarium* spp. were the fungi most frequently isolated from *L. albus* roots with lesions, tip necrosis, or discoloration (Table 3). *F. solani* predominated, accounting for 57% of the *Fusarium* species isolated from root lesions, 46% of those isolated from roots with tip necrosis, and 73% of those isolated from discolored roots. *F. subglutinans* (Wollenweb. & Reinking) P.E. Nelson, T.A. Toussoun, & Marasas, *F. oxysporum, F. acuminatum* Ellis & Everh., and *F. avenaceum* were also isolated.

R. solani isolates collected from roots anastomosed with known *R. solani* AG-4 isolates. *Ascochyta* sp., *Pleiochaeta setosa*, and *Pythium* spp. were also isolated occasionally.

Disease evaluation. Most plants collected in the field appeared healthy. After the roots were washed free of soil, however, several symptoms were observed. Root diseases were reported as percentages of plants with symptoms for each seed treatment (Tables 4, 5, and 6), i.e., the total number of plants with root symptoms was divided by the total number of roots collected for each treatment. Root rot symptoms tended to occur more frequently during 1990 at Staples sites 1 and 2 than at St. Paul (Tables 4, 5, and 6). No trends were observed between percentage of roots with rot symptoms

Table 2. Emergence of *Lupinus albus* 'Ultra' seeds treated or not treated and planted on early, normal, or later dates at three sites during 1989 and 1990[x]

	Average stand per 9.1-m row[y]					
	Staples site 1		St. Paul		Staples site 2	
Seed treatment	1989	1990	1989	1990	1989	1990
Maneb	73.2 a[z]	76.2 bc	67.2 cde	78.0 ab	87.6 cd	69.6 a
Carboxin	70.2 ab	75.0 bc	69.0 cde	80.4 a	97.8 a	64.2 bc
Captan	65.4 bc	77.4 bc	76.2 ab	78.0 ab	79.2 e	66.0 abc
Metalaxyl	63.3 c	84.0 a	72.0 bcd	75.6 ab	96.0 ab	61.2 c
Thiram	62.4 c	81.0 ab	79.8 a	76.8 ab	91.2 bc	67.2 ab
PCNB + ethazol	60.6 c	73.8 c	64.8 e	73.2 b	84.6 de	69.6 a
No treatment	60.6 c	76.2 bc	64.8 e	75.0 ab	85.2 cd	66.6 abc
Streptomycin sulfate	54.5 d	73.2 c	65.4 de	75.0 ab	90.0 cd	63.6 bc
Chitosan	53.4 d	73.2 c	69.6 d	69.6 ab	85.8 cd	61.2 c

[x] Staples site 1, early planting, 26 April 1989 and 18 April 1990; St. Paul, normal planting, 11 May 1989 and 7 May 1990; Staples site 2, late planting, 1 June 1989 and 23 May 1990. Planting rate was 12 seeds per meter except at Staples site 2 in 1989, when the rate was 15 seeds per meter.

[y] Stands for 4-wk period after emergence were averaged.

[z] For each column, values followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.1$).

Table 3. Percent isolation of fungi from root lesions, root tip necrosis, and root discoloration on *Lupinus albus* during 1989 and 1990

Fungi	Root lesions[x] (%)	Root tip necrosis[y] (%)	Root discoloration[z] (%)
Rhizoctonia solani AG-4	34	6	15
Fusarium spp.	51	76	77
Pythium spp.	2	2	2
Pleiochaeta setosa	9	15	4
Ascochyta sp.	4	2	2

[x] Isolations from 97 root segments.

[y] Isolations from 57 root segments.

[z] Isolations from 53 root segments.

(lesions, tip necrosis, or discoloration) and seed treatment. Plants from untreated seed often had fewer diseased roots than plants from treated seed. At Staples site 1, more diseased roots were observed 1 and 2 wk after emergence than 3 and 4 wk after emergence (Table 4). However, diseased roots were observed more commonly at later readings at St. Paul (Table 5) and Staples site 2 (Table 6).

Weather did not influence early season stands or root symptoms.

Germination testing. Treatments did not have a phytotoxic effect on the germinating seeds. The average germination rate was 95% with or without treatments.

Harvest data. Yield and stand data were collected at harvest in both years. Yields where seed had been treated were not significantly greater than yields from untreated seed except in 1989 at Staples site 2, where yield with the captan treatment was 152 kg/ha more than yields with the other treatments (*data not shown*). In 1990 at St. Paul and Staples site 2, final stands at harvest were significantly better with the PCNB + ethazol treatment than with the untreated control.

DISCUSSION

In this study, seed treatment did not consistently improve stand establishment of lupine. Results varied with planting dates, locations, and years, although variability of results is not uncommon with the use of seed treatments (11). Disease variability at Staples site 1 in 1989 may have been increased by the heavy infestation of the seedcorn maggot. Wounds caused by seedcorn maggot feeding were often colonized by soil microorganisms, mainly bacteria, resulting in rotted and injured hypocotyls.

In vitro germination tests showed no differences among treated and untreated seed. When seed was planted in the field, however, it is uncertain if the treatments affected germination of fungal propagules or vulnerability of seed to infection by soilborne pathogens.

The lack of a yield increase with an increase in stand may be explained by

Table 4. Percent *Lupinus albus* roots with symptoms of root rot from seeds treated or not treated and planted on 26 April 1989 and 18 April 1990 at Staples site 1[x]

	1989								1990									
	Roots with lesions (%)				Roots with tip necrosis (%)				Roots with lesions (%)				Roots with tip necrosis (%)				Discolored roots (%)[y]	
Seed treatment	Wk 1	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 2	Wk 3
Maneb	7 bc[z]	0 a	6 a	7 ab	53 ab	53 a	19 ab	7 a	15 b	7 ab	0 a	24 ab	92 a	40 ab	67 a	53 a	0 b	13 ab
Captan	7 bc	13 a	0 a	13 ab	47 ab	47 ab	20 ab	25 a	7 b	25 a	6 a	39 a	40 bcd	8 cd	35 bc	6 c	0 b	0 b
Thiram	0 c	13 a	13 a	0 b	33 ab	38 ab	7 b	6 a	7 b	25 a	8 a	7 b	20 de	6 d	50 ab	33 abc	0 b	0 b
Metalaxyl	14 abc	13 a	13 a	20 a	50 ab	20 bc	33 ab	13 a	19 b	13 ab	12 a	13 b	19 de	56 a	29 bc	19 abc	0 b	0 b
Carboxin	25 ab	7 a	8 a	7 ab	50 ab	27 abc	8 b	7 a	56 a	12 ab	7 a	24 ab	0 e	18 bcd	33 bc	29 bc	0 b	0 b
PCNB + ethazol	27 a	13 a	13 a	0 b	60 a	53 a	31 ab	24 a	13 b	12 ab	0 a	0 b	31 cd	35 abc	24 bc	29 bc	0 b	6 b
Streptomycin sulfate	0 c	19 a	13 a	0 b	40 ab	31 abc	47 a	13 a	22 b	16 ab	0 a	17 ab	56 bc	21 bcd	31 bc	6 c	0 b	0 b
Chitosan	7 bc	13 a	8 a	6 ab	20 a	19 bc	8 b	24 a	11 b	0 b	13 a	24 ab	67 ab	38 ab	13 c	35 ab	0 b	25 a
No treatment	3 c	3 a	10 a	3 b	23 a	7 c	29 ab	15 a	16 b	9 ab	16 a	9 b	29 cd	21 bcd	13 c	24 bc	13 a	15 ab

[x] Roots were collected at weekly intervals for 4 wk after emergence.
[y] No discolored roots were collected during 1989 and at weeks 1 and 4 in 1990.
[z] Each data point represents 12–18 plants. For each column, values followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.1$).

Table 5. Percent *Lupinus albus* roots with symptoms of root rot from seeds treated or not treated and planted on 11 May 1989 and 7 May 1990 at St. Paul[x]

	1989										1990								
	Roots with lesions (%)				Roots with tip necrosis (%)				Discolored roots (%)[y]		Roots with lesions (%)				Roots with tip necrosis (%)				Discolored roots (%)[y]
Seed treatment	Wk 1	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 3
Maneb	19 ab[z]	0 b	6 b	0 b	0 b	40 ab	6 b	0 b	0 a	25 a	0 a	0 a	0 a	0 a	0 b	19 a	25 a	22 ab	19 a
Captan	7 ab	0 b	0 c	6 ab	7 ab	13 bc	29 a	0 b	6 a	6 ab	6 a	0 a	0 a	0 a	0 b	12 a	25 a	17 ab	0 b
Thiram	0 b	7 ab	6 bc	0 b	0 b	7 c	6 b	13 ab	6 a	7 ab	0 a	0 a	7 a	11 a	13 ab	16 a	27 a	32 ab	0 b
Metalaxyl	25 a	19 a	31 a	25 a	13 a	44 a	6 b	0 b	6 a	13 ab	5 a	6 a	0 a	0 a	5 b	18 a	13 a	13 ab	7 ab
Carboxin	7 ab	0 b	7 bc	13 ab	0 b	31 abc	13 ab	13 ab	13 a	27 a	6 a	6 a	7 a	7 a	6 b	0 a	27 a	13 ab	0 b
PCNB + ethazol	7 ab	0 b	0 c	13 ab	0 b	27 abc	6 b	7 ab	0 a	7 ab	0 a	0 a	7 a	6 a	0 b	13 a	20 a	6 b	0 b
Streptomycin sulfate	7 ab	20 a	24 ab	19 ab	7 ab	47 a	24 ab	25 a	0 a	0 b	0 a	0 a	13 a	10 a	24 a	0 a	7 a	14 ab	7 ab
Chitosan	0 b	6 ab	0 c	13 ab	0 b	44 a	13 ab	19 ab	7 a	6 ab	6 a	0 a	7 a	5 a	0 b	12 a	20 a	35 a	0 b
No treatment	13 ab	3 b	23 ab	18 ab	0 b	33 abc	6 b	9 ab	3 a	12 ab	0 a	0 a	3 a	0 a	4 b	5 a	16 a	26 ab	10 ab

[x] Roots were collected at weekly intervals for 4 wk after emergence.
[y] No discolored roots were collected at weeks 1 and 2 in 1989 and at weeks 1, 2, and 4 in 1990.
[z] Each data point represents 12–18 plants. For each column, values followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.1$).

Table 6. Percent *Lupinus albus* roots with symptoms of root rot from seeds treated or not treated and planted on 1 June 1989 and 23 May 1990 at Staples site 2[x]

	1989											1990							
	Roots with lesions (%)				Roots with tip necrosis (%)				Discolored roots (%)[y]			Roots with lesions (%)				Roots with tip necrosis (%)			
Seed treatment	Wk 1	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4	Wk 1	Wk 2	Wk 3	Wk 4
Maneb	0 a[z]	13 a	13 a	7 b	13 b	13 ab	0 c	20 a	0 b	47 a	53 a	0 a	0 b	6 a	11 a	22 b	50 ab	41 ab	67 a
Captan	0 a	7 a	20 a	25 ab	0 b	13 ab	0 c	13 ab	7 ab	33 ab	44 ab	11 a	0 b	0 a	0 a	26 ab	44 ab	19 b	25 b
Thiram	7 a	0 a	20 a	27 ab	0 b	7 ab	7 bc	20 a	7 ab	20 abc	20 bc	6 a	0 b	12 a	6 a	53 a	38 ab	59 a	18 b
Metalaxyl	0 a	7 a	7 a	27 ab	13 b	20 ab	27 a	0 b	0 b	20 abc	40 ab	0 a	0 b	0 a	0 a	35 ab	41 ab	33 ab	17 b
Carboxin	7 a	7 a	20 a	40 a	13 b	7 b	7 bc	0 b	13 a	20 abc	7 c	5 a	0 b	0 a	0 a	32 ab	27 b	44 ab	24 b
PCNB + ethazol	7 a	0 a	0 a	27 ab	7 b	13 ab	0 c	0 b	0 b	40 ab	47 ab	0 a	13 a	0 a	17 a	19 b	40 ab	19 b	22 b
Streptomycin sulfate	7 a	7 a	20 a	20 ab	7 b	7 b	20 ab	0 b	0 b	13 bc	33 abc	6 a	0 b	0 a	13 a	31 ab	38 ab	28 ab	19 b
Chitosan	7 a	7 a	20 a	47 a	40 a	33 a	0 c	13 ab	0 b	0 c	53 a	0 a	6 ab	0 a	18 a	38 ab	69 a	40 ab	29 b
No treatment	0 a	13 a	23 a	33 ab	3 b	20 ab	0 c	10 ab	0 b	13 bc	17 bc	3 a	3 b	8 a	9 a	30 ab	65 a	46 ab	35 b

[x] Roots were collected at weekly intervals for 4 wk after emergence.
[y] No discolored roots were collected at week 1 in 1989 or during 1990.
[z] Each data point represents 12–18 plants. For each column, values followed by the same letter are not significantly different according to Duncan's multiple range test ($P = 0.1$).

the apparent ability of lupines to compensate for thin stands by producing more branches. This ability is also found in other legumes, such as lentils (13).

Many plants collected for root rating were found to have various degrees of root disease even though they appeared healthy above ground. Moisture was available both years during emergence, allowing the actively growing plants to develop an extensive root system to compensate for root loss. Because of adequate moisture, plants were not stressed, and the amount of root necrosis observed had little or no effect on aboveground plant parts and yield.

Plants at Staples site 1, seeded early both years, had more root necrosis than plants in plots seeded later. Cool soil temperatures, common with April planting dates, slow the rate of emergence, thus allowing fungi more time to infect, and favor pathogens active under cool temperatures, such as *Pythium* (9).

Both Staples sites had more root lesions than the St. Paul site (Tables 4, 5, and 6). There may have been site differences in species of soil pathogens present, number of infective propagules, or presence of organisms capable of decreasing activity of certain seed treatments. Soil type may also have been a factor, by affecting the mobility, uptake, and adsorption of the seed treatment (11).

In 1990, the St. Paul site received 22.43 cm of rain during the first 4 wk after emergence of lupines. Despite this excessive amount of rainfall, the total number of infected roots was less than that observed at the same site in 1989 with 7.01 cm of rain. The saturated soil conditions may have been inappropriate for infection by the pathogens present. This may also explain why *Pythium* was infrequently isolated from symptomatic roots in this plot. While conditions may not have been appropriate for fungal growth, the plants may have been actively growing with the availability of soil moisture.

The mode of action and the target organism of the seed treatments must also be considered when interpreting the results. Carboxin is a systemic fungicide for control of *R. solani*. Since 34% of the root lesions were caused by *R. solani* and 51% by *Fusarium* spp., fewer lesions would be expected to occur on roots of plants treated with carboxin. Instead, there was no significant decrease in root lesions that was consistent throughout the sampling dates or plots (Tables 4, 5, and 6).

Metalaxyl is also a systemic fungicide seed treatment with activity against pythiaceous fungi. *Pythium* was only occasionally isolated from lupine during this 2-yr period. Disease pressure from *Pythium* appears to have been low at the three plots both years, thereby not fully testing the benefits of metalaxyl.

Chitosan is a plant growth regulator and fungicide with some activity against *F. solani*, the most commonly isolated fungus during this study. Chitosan did significantly reduce the number of lesions occasionally, but not consistently.

Maneb, captan, thiram, and PCNB are broad-spectrum protectant fungicides, but none consistently decreased the incidence of root symptoms in field studies. Our results are similar to those of Salt and Smalley (18), who tested seed treatments on field beans (*Vicia faba* L.); none of the seed treatments affected disease ratings on roots in the field.

In conclusion, seed treatments did not consistently improve stand establishment in white lupine during 1989 and 1990. When treated seed resulted in better stands than untreated seed, there was no increase in yield. Root disease was not consistently reduced with the application of seed treatments. On the basis of data collected from this study, the economic value of applying treatment to the seed of white lupine is questionable.

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