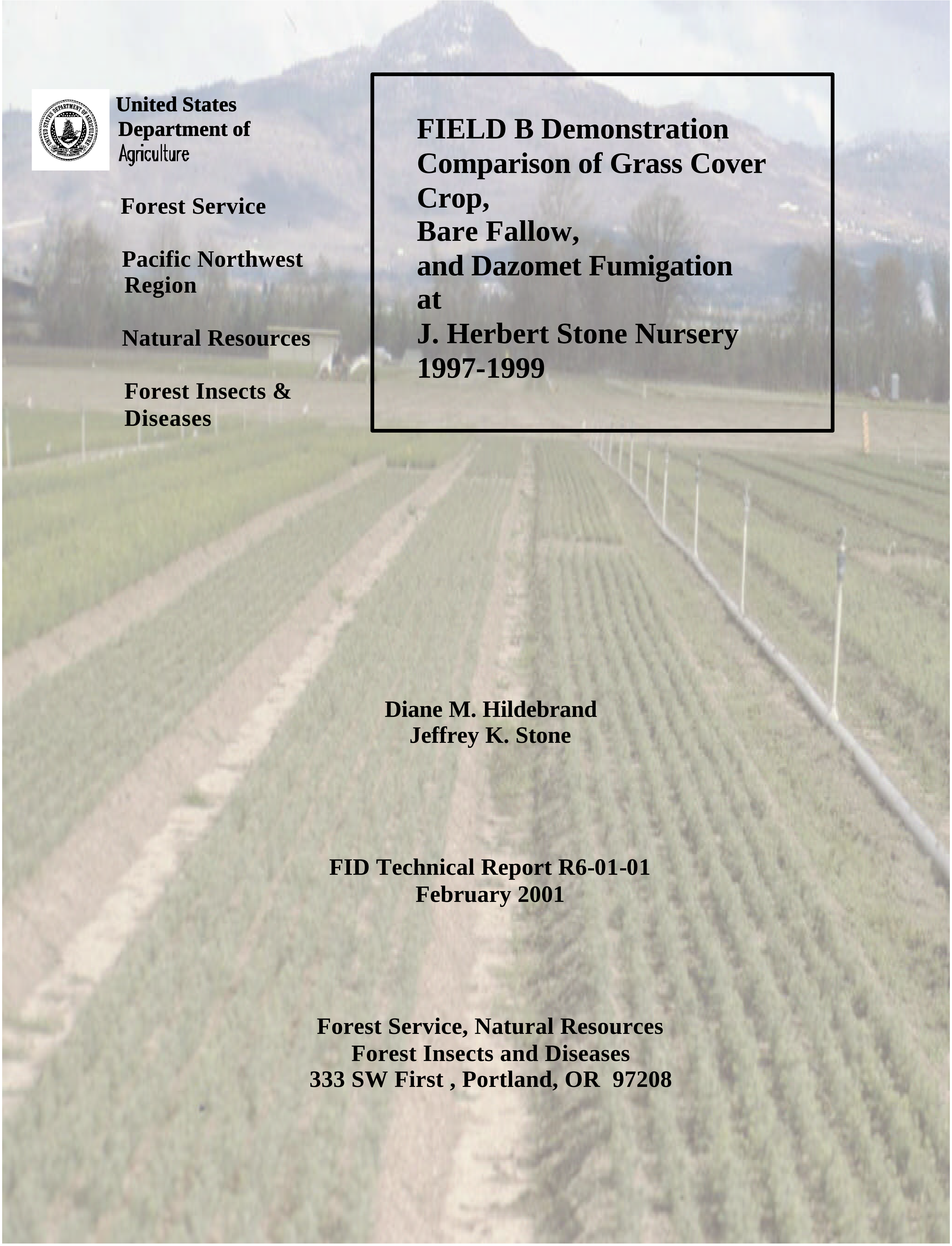


United States
Department of
Agriculture

Forest Service

Pacific Northwest
Region

Natural Resources

Forest Insects &
Diseases

FIELD B Demonstration Comparison of Grass Cover Crop, Bare Fallow, and Dazomet Fumigation at J. Herbert Stone Nursery 1997-1999

Diane M. Hildebrand
Jeffrey K. Stone

FID Technical Report R6-01-01
February 2001

Forest Service, Natural Resources
Forest Insects and Diseases
333 SW First , Portland, OR 97208

FIELD B Demonstration
Comparison of Grass Cover Crop, Bare Fallow, and Dazomet Fumigation

at

J. Herbert Stone Nursery

1997-1999

Diane M. Hildebrand

Jeffrey K. Stone[1]

FID Technical Report R6-01-01

February 2001

United States Department of Agriculture

Forest Service, Pacific Northwest Region

Natural ResourcesForest Insects and Diseases

333 SW First , Portland, OR 97208

[1]Dept of Botany and Plant Pathology, Oregon State University, Corvallis, OR 97331

ABSTRACT

This demonstration compared the effects of grass cover crop, bare fallow, and fumigation, as pre-plant treatments, on density and size of conifer seedlings. Based on measurements of seedling density, diameter, and height, trends in the data suggested that for Douglas-fir, ponderosa pine, and lodgepole pine, one of the best treatments was **bare fallow with dazomet**. Trends also suggested that **rye cover crop with dazomet** was among the best treatments for Douglas-fir. **Sudan cover crop with dazomet** tended to be the best treatment for Shasta red fir. Disease pressure in Field B was fairly low, as usual for this Field.

INTRODUCTION

J. Herbert Stone Nursery routinely uses dazomet as a soil fumigant in the early fall prior to sowing. Occasionally, the nursery fumigates in the spring with methyl bromide/chloropicrin (67 % methyl bromide with 33% chloropicrin), as needed for some crops. Fumigation is used primarily to control soil-borne fungal pathogens, weeds, and some insects.

Soil fumigation with chemical biocides is not only expensive, but hazardous to human health and to the environment. . Methyl bromide has a high potential to deplete stratospheric ozone, and will not be available for soil fumigation in the United States by 2005 (USDA 2000a). The amount of methyl bromide available for soil fumigation as of January 1, 2001, is 50 percent of the 1991 production level (USDA 2000b). Furthermore, fumigation severely disrupts the soil microbiota, eliminating both beneficial and detrimental organisms (Munnecke and Van Gundy, 1979). Opportunistic pathogens, including *Fusarium*, may be among the first microorganisms to re-colonize fumigated soil, either from residual survivors in roots and debris, from blowing dust, or from soil fragments on equipment (Vaartaja 1967). Populations of some beneficial microorganisms, including those antagonistic to pathogens, develop slowly, while the populations of many opportunistic pathogenic fungi can increase rapidly under favorable conditions (Hansen et al., 1990)

J. Herbert Stone nursery has cooperated in many studies aimed at reducing or eliminating the need for chemical fumigants and other pesticides. Previous Alternatives to Fumigation trials (1993-1997) have shown benefits from bare fallowing, sawdust soil amendment without additional nitrogen, early sowing, and covering seed with non-soil mulch (Stone, et al., 1997; Stone, et al., in press). We report here the results of a demonstration trial in Field B at J. Herbert Stone Nursery, comparing the effects on seedling density and size from preplant treatments: three grass cover crops and bare fallow with and without dazomet fumigation.

MATERIALS AND METHODS

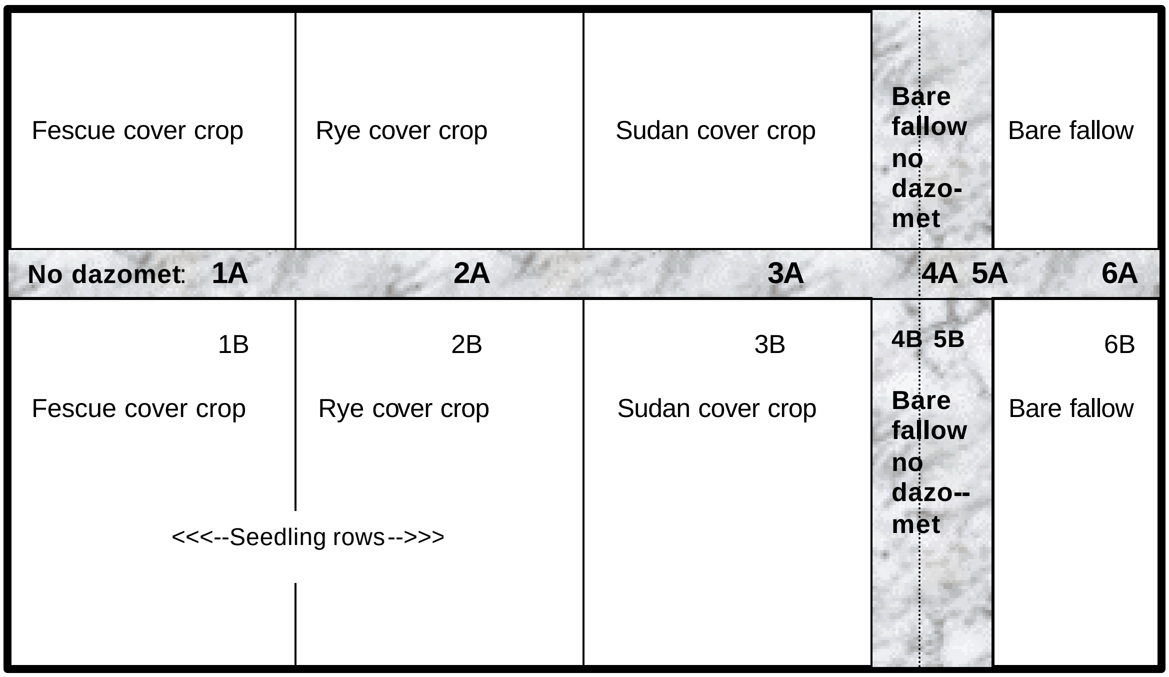
In April 1997, Field B was amended with one inch of sawdust without additional nitrogen. Four treatments were applied in strips perpendicular to the seedling beds: three different grass species (fescue, rye, and sudan) as cover crops and bare fallow with periodic tilling. The cover crops were sown June 2. Cover crops were fertilized June 21 and July 19, with 100 pounds of nitrogen per acre. Cover crops were irrigated every 10 days, and mown every 14 days. Bare fallow areas were tilled approximately every 30 days. The fescue cover crop area was plowed under after 30 days because of poor germination, and then tilled as bare fallow with irrigation. At the end of August, cover crops were incorporated into the soil. In early October, dazomet was applied to the entire field at 350 lb per acre, except in Unit 23, Beds A, B, and C; and a 72 ft strip within the bare fallow treatment, running perpendicular the beds. See Figure 1 for general treatment arrangement. The part of the bare fallow strip without dazomet that was adjacent to the cover crop, received irrigation while the cover crop was growing. The rest of the bare fallow area was not irrigated during the summer. The following tabulation lists the treatments.

Treatments in Field B, Summer 1997
1a Fescue cover crop plowed under after 30 days then bare fallow with irrigation, without dazomet (FescueBF);
1b Fescue cover crop plowed under after 30 days then bare fallow with irrigation, with dazomet (FescueBFDazomet);
2a Rye cover crop, without dazomet (Rye);
2b Rye cover crop, with dazomet (RyeDazomet);
3a Sudan cover crop, without dazomet (Sudan);
3b Sudan cover crop, with dazomet (SudanDazomet);
4a Bare fallow with irrigation, without dazomet (4a BFIrrigated);
5a Bare fallow without irrigation, without dazomet (BF);
6a Bare fallow without irrigation, without dazomet (BF);
6b Bare fallow without irrigation, with dazomet (6b BFDazomet)

In general, treatments 1, 2, and 3 were grass cover crop, while treatments 4, 5, and 6 were bare fallow. In general, treatments followed by "a" were without dazomet, while treatments followed by "b" were with dazomet. Treatment 6a was the same as 5a. Treatment labeled "4b" was a duplicate of 4a, without dazomet; while treatment labeled "5b" was a duplicate of 5a, without dazomet (see Figure 1).

Before sowing, soil samples were taken from each treatment area for assay of population levels of *Fusarium* spp., (see Appendix for procedures). In April 1998, test seedlots of Douglas-fir and ponderosa pine were sown in Unit 23, Beds B and C (no dazomet) and Unit 24 (with dazomet) for the length of the field. The rest of Field B was sown operationally.

Figure 1. Pre-sow treatments in Field B at J. Herbert Stone Nursery, summer 1997. Textured areas are without dazomet fumigation. The vertical strip including 4A and 4B is the bare fallow area that was irrigated while the cover crops were growing.



Seedling density, or number of seedlings in a ½ foot by four foot sampling frame (2 square feet), and height and diameter from a sample of 50 trees, were taken in three subsamples per treatment. Seedling height and diameter were measured using "Machine Vision," a line-scanning image-analysis system developed by the University of Oklahoma for seedling inspection. For the test seedlots of Douglas-fir and ponderosa pine, density and morphology were measured for every treatment at the end of the second growing season (2+0) in Fall 1999. For one seedlot of lodgepole pine and one of Shasta red fir, density was measured at the end of the 2+0 year in the sudan cover crop with dazomet (3b), bare fallow with irrigation (4b), bare fallow without irrigation (5b), and bare fallow with dazomet (6b) treatments. For the lodgepole pine and Shasta red fir seedlots, morphology was measured at the end of the 2+0 year for every treatment corresponding to 1b, 2b, 3b, 4b, 5b, and 6b. For one larch seedlot, density was measured at the end of the first growing season (1+0) in the bare fallow with dazomet (6b) and bare fallow without irrigation (5b) treatments. Larch were lifted as 1+0. Seedlots measured in this demonstration are identified by number and location in the tabulation below.

Identification and Location of Seedlots Measured in Field B
Douglas-fir JHSN19-309-8 PSME-10-10032--1525-87 SIA, Unit 23, Bed C, and Unit 24, Bed B.
Ponderosa pine JHSN19-420-8 PIPO-1010713--2030-85 SIA, Unit 23, Bed B, and Unit 24, Bed A.
Lodgepole pine Group PICO 2SB @ 5-15I/4 mm, 060103-548-8 108-01-682-02000-50-78 SIA, Unit 09, Bed E.
Shasta red fir Group ABMAS 2SB @ 4-14I/4 mm, 061503-557-8 ABMAS-15-491-03000-55-85 SIA, Unit 32, Bed A.
Western larch Seedlot not recorded, Unit 35; probably Group LAOC 1SB-1TB @ 6-20I/5mm, 00BI02-811-8 LAOC-SUMMIT-104-4.7, Bed E.

Treatment effects on seedling size and density were analyzed with SYSTAT 8.0 (Systat 1998) or SAS software (SAS 1992). Analysis of Variance (ANOVA) with Tukey's multiple comparison or Fisher's Least-Significant-Difference procedures were used for comparisons of seedling quality factors between treatments. Seedling density data were logit transformed as recommended for proportional data containing zeros (Sabin and Stafford, 1990) and analyzed using ANOVA. Mean population levels of *Fusarium* species for each treatment were analyzed using the Kruskal-Wallis procedure, and the Mann-Whitney U statistic for comparisons between treatments.

RESULTS

Treatment effects were not apparent to an observer looking across the field along the edges of the treatments for any of the seedlots (Figures 2, 3, and 4).

Presow Fungal Population Densities

Population levels of *Fusarium* species were not uniform between treatments before seed was sown (Table 1). Levels that could be expected to cause disease-related mortality were found in the full season cover crops, with or without dazomet (treatments 2a, 2b, 3a, and 3b). However, where seedling densities in these treatments were measured, densities were not consistently or significantly lower than in other treatments.

Table 1. Population Levels of *Fusarium* Before Sowing

Treatment	Colony Forming Units	Significance*
1a FescueBF	107	c
1b FescueBFDazomet	21	c
2a Rye	4939	a
2b RyeDazomet	1568	b
3a Sudan	2773	ab
3b SudanDazomet	1408	b
4a BFIrrigated	107	c
5a BF	64	c
6a BF	138	c
6b BFDazomet	21	c

*Means followed by a different letter are significantly different ($P < 0.05$).

Figure 2. J. Herbert Stone Nursery, Field B, Unit 30, Beds E and F, looking east along Shasta red fir, in spring of 2+0 year, March 1999. Treatment in the immediate foreground is sudan cover crop with dazomet (3b). In the rightmost bed (F), the sprinkler head on the right edge of the picture is the 11th from the end. Between the 7th and 8th sprinkler heads, there is a gap visible between different seedlots. The 9th sprinkler head is at the transition between the sudan cover crop with dazomet and bare fallow with irrigation (4b) treatments. Differences between treatments are not apparent.

Figure 3. J. Herbert Stone Nursery, Field B, Unit 24 (6 beds in the foreground before sprinkler head), looking south across ponderosa pine (Bed A) and Douglas-fir (Beds B-F) in spring of 2+0 year, March 1999. The boundary between the sudan cover crop with dazomet (3b) and bare fallow with irrigation (4b) treatments, runs vertically across the center of the picture and is not apparent. Color and texture differences at irregular intervals are seedlot differences.

Figure 4. J. Herbert Stone Nursery, southern edge of Field B, looking north, in spring of 2+0 year, March 1999. The boundary between the bare fallow (5b) and bare fallow with dazomet (6b) treatments, runs vertically across the center of the picture. Treatment effect is not apparent.

Douglas-fir

2+0 Density

Table 2 gives the mean density of Douglas-fir for each treatment. Treatments 6a (bare fallow), 6b (bare fallow with dazomet), and 4a (bare fallow with irrigation) had significantly higher densities than treatments 1a (fescue/bare fallow), 3a (sudan), and 3b (sudan with dazomet). Treatment 2b (rye with dazomet) had significantly higher density than 3a. However, treatment 5a was the same cultural treatment as 6a (bare fallow), but had lower density, equivalent with all other treatments. This indicates high variability within treatments, and that differences in density may have been due to factors other than treatment effects.

Table 2. Mean Density of 2+0 Douglas-fir (seedlings per 2 sq ft).

Treatment	Mean	Treatments Ranked by Mean*		
1a FescueBF	23.0	6a BF	32.7	a
1b FescueBFDazomet	27.0	6b BFDazomet	32.0	a
2a Rye	27.0	4a BFIrrigated	31.7	a
2b RyeDazomet	29.3	2b RyeDazomet	29.3	ab
3a Sudan	21.3	2a Rye	27.0	abc
3b SudanDazomet	24.0	1b FescueBFDazomet	27.0	abc
4a BFIrrigated	31.7	5a BF	26.0	abc
5a BF	26.0	3b SudanDazomet	24.0	bc
6a BF	32.7	1a FescueBF	23.0	bc
6b BFDazomet	32.0	3a Sudan	21.3	c

*Means followed by a different letter are significantly different as determined by Fisher's Least-Significant-Difference Test ($P<0.06$).

2+0 Diameter

Table 3 gives the mean diameters of Douglas-fir for each treatment. The range in diameter differed by approximately 1.1 mm. Treatments 3a (sudan), and 3b (sudan with dazomet) had significantly larger diameters than Treatment 4a (bare fallow with irrigation). Treatment 3b also had significantly larger diameter than 6a (bare fallow). However, treatments 3a and 3b also had some of the lowest densities, and differences in seedling size may be confounded with differences in density.

Table 3. Mean Diameter of 2+0 Douglas-fir by Treatment (mm).				
Treatment	Mean	Treatments Ranked by Mean*		
1a FescueBF	6.9	3b SudanDazomet	7.6	a
1b FescueBFDazomet	7.1	3a Sudan	7.3	ab
2a Rye	7.1	6b BFDazomet	7.2	abc
2b RyeDazomet	7.2	2b RyeDazomet	7.2	abc
3a Sudan	7.3	1b FescueBFDazomet	7.1	abc
3b SudanDazomet	7.6	2a Rye	7.1	abc
4a BFIrrigated	6.5	5a BF	7.0	abc
4b BFIrrigated	6.9	1a FescueBF	6.9	abc
5a BF	7.0	4b BFIrrigated	6.9	abc
5b BF	6.9	5b BF	6.9	abc
6a BF	6.7	6a BF	6.7	bc
6b BFDazomet	7.2	4a BFIrrigated	6.5	c

*Means followed by a different letter are significantly different as determined by Tukey's Multiple Comparison Test (P<0.10).

In Table 4, diameters of Douglas-fir are ranked against a reverse ranking of density. If all other factors were equal then treatment means for both density and diameter should fall in the same half of the table (above or below the middle line), because lower densities yield larger seedlings. Table 4 indicates that Treatments 6b and 2b may have had larger diameters not due to lower densities (because they had relatively higher densities as well as larger diameters), but differences were not significant.

Table 4. Douglas-fir Density Ranked in Reverse Order against Diameter.					
Reverse Ranking by Mean Density			Ranking by Mean Diameter		
Low	3a Sudan	21.3	3b SudanDazomet	7.6	High
	1a FescueBF	23.0	3a Sudan	7.3	
	3b SudanDazomet	24.0	6b BFDazomet	7.2	
	5a BF	26.0	2b RyeDazomet	7.2	
Middle	1b FescueBFDazomet	27.0	1b FescueBFDazomet	7.1	
	2a Rye	27.0	2a Rye	7.1	Middle
	2b RyeDazomet	29.3	5a BF	7.0	
	4a BFIrrigated	31.7	1a FescueBF	6.9	
	6b BFDazomet	32.0	4b BFIrrigated	6.9	
High	6a BF	32.7	5b BF	6.9	
			6a BF	6.7	
			4a BFIrrigated	6.5	Low

2+0 Height

Table 5 gives the mean height of Douglas-fir by treatment. The range in mean heights among treatments differed by over 7.4 cm. Treatments 1b (fescue/bare fallow with dazomet) and 3b (sudan with dazomet) had significantly greater heights than treatments 1a (fescue/bare fallow), 4a (bare fallow with irrigation), and 5a and 6a (bare fallow). However, treatment 3b had relatively low density, while treatment 1b had medium density. As with diameter, height tends to increase with lower seedling density. Also, although treatment 4a was the same cultural treatment as 4b (bare fallow with irrigation), treatment 4a had the shortest height, while treatment 4b had height similar to all other treatments except 4a. Treatment 5a was the same cultural treatment as 5b and 6a (bare fallow without irrigation), and these three treatments together had heights similar to all other treatments.

Table 5. Mean Height of 2+0 Douglas-fir by Treatment (cm).

Treatment	Mean	Treatments Ranked by Mean*		
1a FescueBF	31.2	1b FescueBFDazomet	35.8	a
1b FescueBFDazomet	35.8	3b SudanDazomet	35.8	a
2a Rye	32.7	6b BFDazomet	34.0	ab
2b RyeDazomet	33.4	4b BFIrrigated	33.5	ab
3a Sudan	32.6	2b RyeDazomet	33.4	ab
3b SudanDazomet	35.8	2a Rye	32.7	ab
4a BFIrrigated	28.4	3a Sudan	32.6	ab
4b BFIrrigated	33.5	5b BF	32.5	ab
5a BF	31.1	1a FescueBF	31.2	bc
5b BF	32.5	5a BF	31.1	bc
6a BF	30.1	6a BF	30.1	bc
6b BFDazomet	34.0	4a BFIrrigated	28.4	c

*Means followed by a different letter are significantly different, as determined by Tukey's Multiple Comparison Test (P<0.10).

Ponderosa Pine

2+0 Density

Table 6 gives the mean density of ponderosa pine by treatment. Densities of ponderosa pine were not significantly different between any of the treatments.

Table 6. Mean Density of 2+0 Ponderosa Pine (seedlings per 2 sq ft).			
Treatment	Mean	Treatments Ranked by Mean	
1a FescueBF	41.7	6b BFDazomet	52.3
1b FescueBFDazomet	46.3	1b FescueBFDazomet	46.3
2a Rye	44.7	2b RyeDazomet	45.7
2b RyeDazomet	45.7	6a BF	45.3
3a Sudan	44.3	2a Rye	44.7
3b SudanDazomet	44.7	3b SudanDazomet	44.7
4a BFIrrigated	38.7	3a Sudan	44.3
5a BF	37.7	1a FescueBF	41.7
6a BF	45.3	4a BFIrrigated	38.7
6b BFDazomet	52.3	5a BF	37.7

2+0 Diameter

Table 7 gives the mean diameters of ponderosa pine by treatment. The only significant difference was between treatments 1a (fescue/bare fallow) and 2b (rye with dazomet). However, treatment 1a (greater diameter) had lower density while treatment 2b (smaller diameter) had higher density. The range in diameters differed by less than 0.8 mm.

Table 7. Mean Diameter of 2+0 Ponderosa Pine by Treatment (mm).				
Treatment	Mean	Treatments Ranked by Mean*		
1a FescueBF	7.4	1a FescueBF	7.4	a
1b FescueBFDazomet	6.7	3a Sudan	7.3	ab
2a Rye	6.8	4a BFIrrigated	7.3	ab
2b RyeDazomet	6.6	5a BF	7.1	ab
3a Sudan	7.3	6b BFDazomet	7.0	ab
3b SudanDazomet	6.7	6a BF	6.9	ab
4a BFIrrigated	7.3	5b BF	6.8	ab
4b BFIrrigated	6.7	2a Rye	6.8	ab
5a BF	7.1	3b SudanDazomet	6.7	ab
5b BF	6.8	1b FescueBFDazomet	6.7	ab
6a BF	6.9	4b BFIrrigated	6.7	ab
6b BFDazomet	7.0	2b RyeDazomet	6.6	b

*Means followed by a different letter are significantly different as determined by Tukey's Multiple Comparison Test ($P<0.10$).

In Table 8, diameters of ponderosa pine are ranked against a reverse ranking of density. If all other factors were equal then treatment means for both density and diameter should fall in the same half of the tabulation (above or below the middle line), because lower densities yield larger seedlings. Table 8 indicates that treatment 6b may have had larger diameter not due to lower density (because it had relatively greater density as well as moderately greater diameter), but differences were not significant.

Table 8. Ponderosa Pine Density Ranked in Reverse Order by Diameter.						
Reverse Ranking by Mean Density			Ranking by Mean Diameter			
Low	5a BF	37.7	1a FescueBF	7.4	High	
	4a BFIrrigated	38.7	3a Sudan	7.3		
	1a FescueBF	41.7	4a BFIrrigated	7.3		
	3a Sudan	44.3	5a BF	7.2		
Middle	3b SudanDazomet	44.7	6b BFDazomet	7.0		
	2a Rye	44.7	6a BF	6.9	Middle	
	6a BF	45.3	5b BF	6.8		
	2b RyeDazomet	45.7	2a Rye	6.8		
	1b FescueBFDazomet	46.3	3b SudanDazomet	6.7		
High	6b BFDazomet	52.3	1b FescueBFDazomet	6.7		
			4b BFIrrigated	6.7		
			2b RyeDazomet	6.6	Low	

2+0 Height

Table 9 gives the mean height of ponderosa pine by treatment. The range in mean heights among treatmentsdiffered by 7.6 cm. Treatments 5a (bare fallow), 6b (bare fallow with dazomet), and 1b (fescue/bare fallow with dazomet), had significantly greater height than treatments 2a (rye) and 4a (bare fallow with irrigation). However, Treatment 4a is the same cultural treatment as 4b (bare fallow with irrigation), and these two treatments together have heights similar to all other treatments. Treatment 5a is the same cultural treatment as 5b and 6a (bare fallow without irrigation), and these three treatments together have heights similar to all other treatments except 2a. This indicates high variability within treatments, and that differences between treatments may have been due to factors other than treatment effects.

Table 9. Mean Height of 2+0 Ponderosa Pine by Treatment (cm).				
Treatment	Mean	Treatments Ranked by Mean*		
1a FescueBF	32.2	5a BF	35.6	a
1b FescueBFDazomet	35.2	6b BFDazomet	35.3	ab
2a Rye	28.0	1b FescueBFDazomet	35.2	ab
2b RyeDazomet	31.3	3b SudanDazomet	34.3	abc
3a Sudan	30.4	5b BF	33.6	abc
3b SudanDazomet	34.3	6a BF	33.6	abc
4a BFIrrigated	30.1	1a FescueBF	32.2	abcd
4b BFIrrigated	32.1	4b BFIrrigated	32.1	abcd
5a BF	35.6	2b RyeDazomet	31.3	abcd
5b BF	33.6	3a Sudan	30.4	bcd
6a BF	33.6	4a BFIrrigated	30.1	cd
6b BFDazomet	35.3	2a Rye	28.0	d

*Means followed by a different letter are significantly different as determined by Tukey's Multiple Comparison Test (P<0.10).

Lodgepole pine

2+0 Density

Table 10 gives the mean density of lodgepole pine by treatment. Lodgepole pine densities were not significantly different between treatments.

Table 10. Mean Density of 2+0 Lodgepole Pine (seedlings per 2 sq ft).			
Treatment	Mean	Treatments Ranked by Mean	
3b SudanDazomet	23.5	4b BFIrrigated	28.3
4b BFIrrigated	28.3	6b BFDazomet	27.5
5b BF	22.8	3b SudanDazomet	23.5
6b BFDazomet	27.5	5b BF	22.8

2+0 Diameter

Table 11 gives the mean diameters of lodgepole pine by treatment. Diameters of lodgepole pine were not significantly different between treatments.

Table 11. Mean Diameter of 2+0 Lodgepole Pine by Treatment (mm).			
Treatment	Mean	Treatments Ranked by Mean	
1b FescueBFDazomet	6.1	3b SudanDazomet	6.8
2b RyeDazomet	6.3	5b BF	6.5
3b SudanDazomet	6.8	6b BFDazomet	6.4
4b BFIrrigated	6.2	2b RyeDazomet	6.3
5b BF	6.5	4b BFIrrigated	6.2
6b BFDazomet	6.4	1b FescueBFDazomet	6.1

2+0 Height

Table 12 gives the mean height of lodgepole pine by treatment. Heights of lodgepole pine were not significantly different between treatments.

Table 12. Mean Height of 2+0 Lodgepole Pine by Treatment (cm).			
Treatment	Mean	Treatments Ranked by Mean	
1b FescueBFDazomet	20.8	6b BFDazomet	24.7
2b RyeDazomet	23.0	3b SudanDazomet	23.4
3b SudanDazomet	23.4	2b RyeDazomet	23.0
4b BFIrrigated	20.9	5b BF	22.3
5b BF	22.3	4b BFIrrigated	20.9
6b BFDazomet	24.7	1b FescueBFDazomet	20.8

Shasta red fir

For Shasta red fir, dazomet fumigation, whether after cover crops or bare fallow, tended to result in larger seedlings than bare fallow alone.

2+0 Density

Table 13 gives the mean density of Shasta red fir by treatment. Densities of red fir were not significantly different between treatments.

Table 13. Mean Density of 2+0 Shasta Red Fir (seedlings per 2 sq ft).

Treatment	Mean	Treatments Ranked by Mean	
3b SudanDazomet	26.5	3b SudanDazomet	26.5
4b BFIrrigated	24.5	4b BFIrrigated	24.5
5b BF	21.8	5b BF	23.5
6b BFDazomet	23.5	6b BFDazomet	21.8

2+0 Diameter

Table 14 gives the mean diameters of Shasta red fir by treatment. Treatment 4b (bare fallow with irrigation) had significantly smaller mean diameter than treatments 2b (rye with dazomet) and 3b (sudan with dazomet). The range in mean diameters among treatments differed by approximately 0.8 mm.

Table 14. Mean Diameter of 2+0 Shasta Red Fir by Treatment (cm).

Treatment	Mean	Treatments Ranked by Mean*		
1b FescueBFDazomet	6.1	2b RyeDazomet	6.4	a
2b RyeDazomet	6.4	3b SudanDazomet	6.3	a
3b SudanDazomet	6.3	1b FescueBFDazomet	6.1	ab
4b BFIrrigated	5.5	6b BFDazomet	5.9	ab
5b BF	5.8	5b BF	5.8	ab
6b BFDazomet	5.9	4b BFIrrigated	5.5	b

*Means followed by a different letter are significantly different as determined by Tukey's Multiple Comparison Test (P<0.05).

2+0 Height

Table 15 gives the mean height of Shasta red fir by treatment. Rye cover crop with dazomet (2b) had significantly greater height than treatments 4b (bare fallow with irrigation) and 5b (bare fallow). The range in mean height among treatments differed by over 6.5 cm.

Table 15. Mean Height of 2+0 Shasta Red Fir by Treatment (cm).

Treatment	Mean	Treatments Ranked by Mean*		
1b FescueBFDazomet	18.5	2b RyeDazomet	20.0	a
2b RyeDazomet	20.0	1b FescueBFDazomet	18.5	ab
3b SudanDazomet	18.0	3b SudanDazomet	18.0	ab
4b BFIrrigated	13.4	6b BFDazomet	17.3	ab
5b BF	15.8	5b BF	15.8	bc
6b BFDazomet	17.3	4b BFIrrigated	13.4	c

*Means followed by a different letter are significantly different as determined by Tukey's Multiple Comparison Test (P<0.10).

Larch

1+0 Density

Average density of larch (seedlings per 2 sq ft) in the bare fallow (5b) was 29, and in the bare fallow with dazomet (6b) was 31.5. The difference in density between treatments was not significant.

DISCUSSION AND CONCLUSIONS

The treatment layout, with the treatments extending across the entire field and many species and seedlots sown across the treatments, provided abundant opportunity to observe treatment effects. Unfortunately, this design allowed for no replication (even duplicated treatments were not analyzed as replicates), resulting in a weak statistical basis for detecting differences between treatments. Effects of the two duplicated treatments, bare fallow with irrigation (4a, 4b) and bare fallow (5a, 5b, 6a), were often inconsistent within species. Significant treatment effects were inconsistent between species.

For the species tested, the target 2+0 density is 20 seedlings per square foot (40 per 2 sq ft). For Douglas-fir, lodgepole pine, and Shasta red fir, none of the treatments resulted in the target density. For ponderosa pine, essentially all treatments met or exceeded target density. The minimum acceptable diameter is 4 mm and height is 15 cm. All treatments for all species resulted in acceptable diameter and height.

From this Demonstration in Field B, few conclusions can be drawn. Trends in the data can suggest which treatments resulted in the best seedling density, diameter, and height for each species. The basis for stratifying treatments effects into high, medium, and low levels might be 4 seedlings per 2 sq ft for density, 0.5 mm for diameter, and 3 cm for height. Values for duplicated treatments can be averaged to determine the effects level for that treatment. On this basis, trends for Douglas-fir indicated the best treatments tended to be **bare fallow with dazomet** and **rye cover crop with dazomet,** with relatively greater density, diameter, and height. For ponderosa pine, the best treatment tended to be **bare fallow with dazomet**, with relatively greater density, diameter, and height. For lodgepole pine, the best treatment tended to be **bare fallow with dazomet** with relatively greater density, diameter, and height. For lodgepole pine, rye cover crop with dazomet also resulted in relatively greater diameter and height, but density was not measured for this treatment. For Shasta red fir, the best treatment tended to be **sudan cover crop with dazomet**, with relatively greater density, diameter, and height. For Shasta red fir, rye cover crop with dazomet and fescue cover crop/bare fallow with dazomet, also had relatively greater diameter and height, but density was not measured for these treatments.

The nursery culturist reported that Douglas-fir growing in the non-fumigated bare-fallow strip in Field B, had noticeably more mycorrhizae than other treatments. However, differences in mycorrhizal development were difficult to quantify, especially because of differences among seedlots. Field B was hand-weeded regularly, and weeds were relatively few over the entire field.

Fusarium species cause several different disease problems in conifers—pre- and post-emergence damping off, root disease, and collar rot. Generally, The highest *Fusarium* levels were found in the cover crop treatments and the lowest levels in the bare fallow. Dazomet fumigation reduced *Fusarium* populations in cover crop treatments but dazomet in addition to bare fallow appeared to result in little further reduction in *Fusarium* populations. However, *Fusarium* populations measured at presow were not consistently correlated with seedling density or size either within or between species. This suggests that factors other than disease affected seedling density and size in these treatments.

Disease pressure in Field B was fairly low, as usual for this field. The next set of trials are in Field K, which usually has more disease pressure; and treatments are in a randomized block design with replication. We expect that treatment effects will be clearly demonstrated in the Field K study.

ACKNOWLEDGEMENT

USDA Forest Service, Forest Health Protection, Washington Office, has contributed Special Technology Development Project funding to these Alternative to Fumigation efforts (STDP R6-93-01 and R2-98-01).

LITERATURE CITED

Hansen, E. M., Myrold, D. D., and Hamm, P. B.. 1990. Effects of soil fumigation and cover crops on potential pathogens, microbial activity, nitrogen availability, and seedling quality in conifer nurseries. Phytopathology 80:698-704.

Komada, H. 1975. Development of a selective medium for quantitative isolation of *Fusarium oxysporum* from natural soil. Review of Plant Protection Research 8:114-125.

Munnecke, D. E., and Van Gundy, S. D.. 1979. Movement of fumigants in soil, dosage responses and differential effects. Annual Review of Phytopathology 17:405-429.

Sabin, T. E., and Stafford, S. G.. 1990. Assessing the need for transformation of response variables. Special publication 20, Forest Research Lab, College of Forestry, Oregon State University, Corvallis, OR.

SAS. 1992. SAS for Windows version 3.10. SAS Institute, Inc., Cary, NC.

Stone, J. K., Hildebrand, D. M., James, R. L., and Frankel, S. J.. 1997. Alternatives to chemical fumigation in bare-root forest nurseries: effects on pathogen levels, and seedling density, mortality and quality. Pages 59-69 in: Proceedings of the third IUFRO working party S7.03-04, Diseases and Insects in Forest Nurseries. R. L. James, ed. USDA Forest Service Northern Region Forest Health Protection Report 97-4, USDA Forest Service, Coeur d'Alene, ID.

Stone, J. K.; Hildebrand, D. M.; James, R.L.; and Frankel, S. M. (in press). Bare fallow: an alternative to chemical fumigation for disease control in bare root forest nurseries. Plant Disease.

Systat. 1998. Systat version 8.0. SPSS Inc. Evanston, IL.

USDA. 2000a. Methyl bromide alternatives newsletter. Volume 6, Number 2, April 2000. [Newsletter available at http://www.ars.usda.gov/is/np/mba/mebrhp.htm]

USDA. 2000b. Methyl bromide alternatives newsletter. Volume 6, Number 3, July 2000.

Vaartaja, O. 1967. Re-infestation of sterilized nursery seedbeds by fungi. Canadian Journal of Microbiology. 13:771-776.

Wildman, H. 1991. Lithium chloride as a selective inhibitor of *Trichoderma* species on soil isolation plates. Mycol. Res. 95:1364-1368.

APPENDIX

Soil Sampling (procedure from Stone, et al., in press)

Soil samples were collected in polyethylene bags, transported to the laboratory in insulated boxes, stored at 4^{o}C, and processed within 48 hours of collection. Soil samples were passed through a 0.6 cm screen, and 10 g (fresh wt) added to flasks containing 90 mL of 0.1 % water agar. These samples were mixed and serially diluted (1:10, 1:100) in 0.1% water agar for plating. A portion of each soil sample was weighed and oven-dried for determination of water content for conversion of propagule counts to a soil dry weight basis.

Four plates of each sample, with 0.5 mL diluted soil on each plate, were prepared on two selective media. Komada's medium (1975), modified with the amendment of 1 g/L of LiCl for suppression of *Trichoderma* spp. (Wildman 1991) was used for enumeration of *Fusarium* species, primarily *F. oxysporum*. Dilution plates of Komada's medium were incubated under fluorescent light and read after six days. For determination of *Pythium* spp., a modified V-8 medium was used, containing 200 mL clarified V-8 juice, 10 mg rifampicin, 20 mg rose bengal, 250 mg ampicillin, 10 mg pimaricin, 20 g agar per liter. Plates were inoculated with soil dilutions as above, incubated in the dark at room temperature, and read after two days. The average number of colonies on four plates multiplied by the dilution factor and corrected for water content yielded colony forming units per gram of oven-dried soil (CFU).