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Effects of Bifenox, DCPA, and Napropamide on Ectomycorrhizal Development of Conifer Seedlings in Central and Northern Rocky Mountain Nurseries

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RESEARCH SUMMARY

Postseeding and postgermination treatments with three weed control herbicides (Bifenox, DCPA, Napropamide) at two rates of application caused little reduction of ectomycorrhizal development on 1- and 2-year-old conifer seedlings in Central or Northern Rocky Mountain nurseries. In many cases, herbicide treatment increased ectomycorrhizal development, particularly with DCPA. In general, herbicide treatment effects on ectomycorrhizal development were species and nursery specific.

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INTRODUCTION

Herbaceous weeds are a major problem in Central and Northern Rocky Mountain forest tree nurseries. Weed competition, when uncontrolled, seriously reduces survival and growth of tree seedlings. Weed control practices most often used are fumigation and costly hand or mechanical removal. Hand or mechanical weeding is slow, often unsatisfactory, and increasingly expensive. Soil fumigation is highly effective in reducing the number of viable seeds in the soil but does not prevent reinvasion from nearby areas. Thus, herbicides are attractive as an economical means of reducing weed competition.

Several years of testing pregermination and early postgermination herbicides have shown that several may be useful for weed control in Central and Northern Rocky Mountain nurseries (Ryker 1981). Among these, the herbicides Bifenox (Mobil trade name Modown) [methyl 5-(2,4-dichlorophenoxy)-2-nitrobenzoate], DCPA (Diamond Shamrock trade name Dacthal) [dimethyltetrachloroterepthalate], and Napropamide (Stauffer trade name Devrinol) [2-(α-naphthoxyl)-N, N-diethylpropionamide] have the potential to reduce hand weeding time by 75 to 95 percent, depending on weed density (Ryker 1981).

Good ectomycorrhizal development is closely related to the ability of conifer seedlings to grow in nursery soils (Trappe and Strand 1969), to survive on harsh sites (Marx 1976), and to successfully afforest or reforest soils lacking in ectomycorrhizal inoculum (Meyer 1973). Some herbicides are reported to reduce growth or development of ectomycorrhizal fungi (Iloba 1974, 1976; Dasilva and others 1977) and to reduce populations of other soil microorganisms (Greaves and others 1976; Ogawa and Yambe 1980). It is possible that herbicides may reduce ectomycorrhizal development on seedlings in treated nurseries, thereby reducing seedling quality. Information on the effects of the above-named three herbicides on ectomycorrhizal development of seedlings in nurseries is lacking and is needed before the herbicides can be approved. This report documents these effects in major forest nurseries of the Central and Northern Rocky Mountains.

MATERIALS AND METHODS

Nursery Locations

The nursery locations represented major conifer-producing nurseries in the Central and Northern Rocky Mountains. These included the U.S. Forest Service nurseries at Coeur d'Alene, ID; Boise, ID (Lucky Peak); Albuquerque, NM; Carbondale, CO (Mt. Sopris); the Montana State Nursery at Missoula, MT; and the privately owned Mountain Home Nursery at DeBorgia, MT.

Experimental Design

The basic experimental design was a randomized block that included the herbicide treatments listed in table 1, and the following seedling species: Austrian pine (*Pinus nigra* Arnold) (AP), blue spruce (*Picea pungens* Engelm.) (BS), Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) (DF), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.) (ES), grand fir (*Abies grandis* [Dougl. ex D. Don] Lindl.) (GF), lodgepole pine (*Pinus contorta* Dougl. ex Loud.) (LPP), ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) (PP), and western larch (*Larix occidentalis* Nutt.) (WL). Not all species were tested in all locations, but only those normally produced at the respective nursery. The herbicide treatment/species combinations tested at the respective nurseries are shown in tables 3, 4, and 5 in the results section. Each combination, including the untreated control, was represented by three replicate plots. Statistical analysis included ANOVA and Duncan's Multiple Range tests, considering treatment effects and interactions only.

Table 1.—Description of herbicide treatments tested for effects on ectomycorrhizal development of conifer seedlings at major forest nurseries in the Central and Northern Rocky Mountains

Herbicide	Formulation (trade name)	Rate of active ingredient	Timing
		Lb/acre (kg/ha)	
Bifenox	Modown 80% WP[1]	3 and 6 (3.4 and 6.7)	Postseeding
		3 and 6 (3.4 and 6.7)	Postgermination
		3 + 3 (3.4 + 3.4)	Postseeding plus postgermination
DCPA	Dacthal, 75% WP	10.5 and 21 (11.8 and 23.5)	Postseeding
		10.5 and 21 (11.8 and 23.5)	Postgermination
		10.5 + 10.5 (11.8 + 11.8)	Postseeding plus postgermination
Napropamide	Devrinol, 50% WP	3 and 6 (3.4 and 6.7)	Postseeding
		3 and 6 (3.4 and 6.7)	Postgermination
		3 + 3 (3.4 + 3.4)	Postseeding plus postgermination
Control	No treatment	0	—

[1]WP is wettable powder formulation; total active ingredient is based on the manufacturer's recommendation.

Field Procedures

Each plot was bed-wide 4 ft by 3 ft (1.2 m by 0.9 m) along the bed. Each herbicide was applied at two rates (1×, at recommended rate and 2×, at twice the recommended rate), and at two times (postseeding, postgermination of tree seed). In addition, we tested the multiple applications of a 1× postseeding spray followed by a 1× postgermination spray. Herbicides were applied with a pressurized sprayer in a water carrier at a volume equivalent to 85 gal/acre (100 mL/plot). Postsowing treatments were applied within 2 days after sowing; postgermination sprays were applied 28 to 35 days after seedling emergence. Emergence is defined as the time when most seedlings had shed their seed coats. Five herbicide treatments plus a control were represented for each herbicide. A total of 155 treatment combinations (465 plots) were evaluated for ectomycorrhizal development. Other details on the herbicide treatments are available in Ryker (1981).

Sampling Procedures

Thirteen to 15 adjacent seedlings representing each plot were lifted in June 1979 (planted April-May 1978, except at Montana where beds were sown in fall 1977). Seedlings were lifted carefully with a digging fork to avoid root loss and damage. In all cases sample seedlings were adjacent, located two rows from the edge, and well away from the end of the plot. Use of adjacent seedlings (seedling groups) minimized damage to the plots, which were also used for phytotoxicity and weed-control evaluations and standardized general sample location to avoid border effects. Within these confines, the exact positioning of the seedling group was random. Seedling rows were uniform except for occasional missing individuals. All seedlings were placed directly into a plastic bag, with no attempt to separate or clean roots on the site. Plastic bags were put on ice or refrigerated at 34 °F (1 °C) for transport to and storage at the laboratory location. All evaluations were completed within 90 days.

Ectomycorrhizal evaluation procedures.—All ectomycorrhizal evaluations were done with no foreknowledge of plot treatments by three examiners working at least two at a time. Root systems from each of 10 seedlings randomly selected from each plot sample were carefully separated and washed in running water prior to examination. Spot checks on loss of small roots caused by washing indicated such losses were small. Three types of root evaluations were made for each seedling: (1) The total root system was scanned and percentage of ectomycorrhizal roots was estimated to the nearest 10 percent. (2) Excised from each seedling were 10-cm segments of major lateral roots (accumulative if necessary) from the uppermost root system and from the lowermost part of the root system. In each case, the 10-cm segments were cut to include just the first short root nearest the originating major root and to just exclude the last short root. Total number of ectomycorrhizal short roots were counted and recorded separately for the upper and lower 10-cm lengths. (3) Each ectomycorrhizal short root was categorized into an arbitrary morphological type based on external appearance (color, branching habit, etc.). In cases of doubt, thin sections of short roots were examined microscopically to determine if a Hartig net and mantle were present.

Soil Properties

Because of the wide variation in the soils at some of the nurseries, basic properties (soil type, physical makeup, pH, CEC, and organic matter content) were determined for the study site at each nursery (Ryker 1981).

RESULTS

Initial results comparing numbers of ectomycorrhizal short roots on shallow, as opposed to deep, lateral roots indicated no significant differences between treatments. Significantly more short roots occurred on the shallow laterals than on the deep. We therefore discontinued use of deep lateral roots in the evaluation process and present only results using surface lateral roots.

Differences between treatments were small, usually sporadic, and nearly balanced—there were almost as many cases where ectomycorrhizal short roots were more numerous on treated seedlings than on untreated seedlings as there were cases where they were fewer (tables 2, 3, 4). Across the various nurseries no consistent patterns of effects emerged between specific herbicides, species, or treatments. Considering all nurseries, cases of significant interactions within a nursery occurred between all three variables at one location or another (table 5).

Although differences were small, the most consistent related changes were slight reductions in numbers of ectomycorrhizal short roots on Douglas-fir seedlings treated with all three herbicides at the Montana State Nursery, Douglas-fir seedlings treated with Bifenox at the Forest Service nursery at Coeur d'Alene, and slight increases in ectomycorrhizal short roots on lodgepole pine seedlings treated with Bifenox and DCPA at the Forest Service, Lucky Peak nursery (tables 3, 4, 5). Statistical comparisons based on differences in percentage of ectomycorrhizal short roots were almost identical to those based on actual numbers as seen in tables 2, 3, and 4. Therefore, these data have not been presented.

Table 2.—Comparisons of herbicide treatments by mean numbers of ectomycorrhizal short roots (cm) on 10-cm segments of main lateral seedling root, based on 30 samples for each treatment

	Nursery											
	Coeur d'Alene										Albuquerque	
	Ponderosa pine		Engelmann spruce		Douglas-fir		Grand fir		Western larch		Ponderosa pine	
Treatment	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
Control (no herbicide)	38.0	9.0	40.6	12.6	30.9	7.4	24.2	11.3	22.0	4.5	42.6	14.6
Bifenox												
Bif. 1×[1], PS[2] + PG[3]	37.3a[4]	9.8	—[5]	—	23.9a**[6]	5.8	28.4a	8.2	—	—	38.1a	13.7
Bif. 1×, PS	46.8b**	11.6	—	—	24.6a**	6.6	26.5a	7.5	—	—	45.2a	10.7
Bif. 1×, PG	40.7a	11.6	—	—	26.6b**	6.4	29.3a	9.9	—	—	46.9b	16.1
Bif. 2×, PS	42.9a	11.4	—	—	22.6a**	4.9	32.1a	8.5	—	—	43.5a	8.8
Bif. 2×, PG	45.5b**	9.6	—	—	30.0b	6.4	27.7a	7.1	—	—	40.6a	13.6
DCPA												
DCPA 1×, PS + PG	—	—	36.2a	9.8	—	—	—	—	23.6a	12.8	45.1a	10.0
DCPA 1×, PS	—	—	47.6b**	8.9	—	—	—	—	21.4a	12.1	44.6a	15.1
DCPA 1×, PG	—	—	37.4a	11.0	—	—	—	—	24.1a	13.1	47.1a	8.9
DCPA 2×, PS	—	—	44.8b	11.6	—	—	—	—	18.5a	5.3	49.6b**	12.1
DCPA 2×, PG	—	—	41.9a	8.4	—	—	—	—	21.1a	3.8	41.8a	13.8
Napropamide												
Nap. 1×, PS + PG	31.2a**	8.9	37.8a	9.5	25.0a**	6.7	27.2a	9.9	—	—	47.9a	9.1
Nap. 1×, PS	36.0a	11.7	38.8a	15.4	26.9a	7.8	25.1a	7.6	—	—	42.8a	15.7
Nap. 1×, PG	42.0b	9.1	36.3a	12.9	27.9a	8.7	26.6a	14.1	—	—	34.1b**	11.1
Nap. 2×, PS	32.9a	9.6	32.3a**	12.1	27.9a	7.3	32.2a	16.7	—	—	38.6b	15.1
Nap. 2×, PG	32.5a	7.1	34.1a	9.8	30.4b	5.1	27.0a	8.9	—	—	45.3a	10.4

[1] 1× = applied concentration according to manufacturer's recommendation, 2× = double concentration, for actual concentration of active ingredient (see table 1).

[2] PS = immediately postseeding.

[3] PG = postgermination, usually 4 to 5 weeks after seedling emergence.

[4] Treatments within a single herbicide group and species (down column) that do not share a common subscript letter are significantly different to at least α = 0.05 level, Duncan's multiple range test.

[5] Dash indicates this combination not tested.

[6] ** = treatment differs from appropriate control (head of column) to at least α = 0.01 level, Duncan's multiple range test.

Table 3.—Comparisons of herbicide treatments by mean numbers of ectomycorrhizal short roots (cm) on 10-cm segments of main lateral seedling root, based on 30 samples for each treatment

	Nursery									
	Mount Sopris						Lucky Peak			
	Ponderosa pine		Lodgepole pine		Engelmann spruce		Ponderosa pine		Lodgepole pine	
Treatment	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
Control (no herbicide)	37.6	7.1	35.7	6.5	48.7	8.9	35.5	6.3	36.1	7.1
Bifenox										
Bif. 1×[1], PS[2] + PG[3]	37.0a[4]	9.8	34.9a	6.5	—[5]	—	38.6a	5.8	43.1a**[6]	8.4
Bif. 1×, PS	31.4a	7.3	33.0a	6.8	—	—	38.6a	8.6	39.6a	7.0
Bif. 1×, PG	35.2a	9.9	36.3a	5.9	—	—	39.0a	4.8	41.6a**	8.9
Bif. 2×, PS	38.0a	7.7	35.1a	7.0	—	—	33.5a	6.7	41.2a**	7.4
Bif. 2×, PG	33.9a	9.9	31.2b*[7]	5.5	—	—	37.6a	6.9	45.9a**	9.1
DCPA										
DCPA 1×, PS + PG	—	—	—	—	—	—	35.6a	6.3	43.8a**	7.2
DCPA 1×, PS	—	—	—	—	—	—	37.7a	6.5	38.2b	5.8
DCPA 1×, PG	—	—	—	—	—	—	38.2a	6.1	38.3b	7.8
DCPA 2×, PS	—	—	—	—	—	—	38.8a	9.1	41.0b**	9.7
DCPA 2×, PG	—	—	—	—	—	—	37.6a	8.1	44.8a**	8.5
Napropamide										
Nap. 1×, PS + PG	35.2a	9.9	35.4a	7.5	43.3a	6.9	—	—		—
Nap. 1×, PS	33.7a	8.1	37.4a	9.3	43.6a	9.0	—	—	—	—
Nap. 1×, PG	37.0a	7.6	35.7a	7.2	45.6a	11.4	—	—	—	—
Nap. 2×, PS	37.5a	12.4	33.1b	7.3	45.2a	8.2	—	—	—	—
Nap. 2×, PG	34.2a	6.5	34.3a	6.4	46.1a	9.4	—	—	—	—

[1]1× = applied concentration according to manufacturer's recommendation, 2× = double concentration, for actual concentration of active ingredient (see table 1).
[2]PS = immediately postseeding.
[3]PG = postgermination, usually 4 to 5 weeks after seedling emergence.
[4]Treatments within a single herbicide group and species (down column) that do not share a common subscript letter are significantly different to at least α = 0.05 level, Duncan's multiple range test.
[5]Dash indicates this combination not tested.
[6]** = treatment differs from appropriate control (head of column) to at least α = 0.01 level, Duncan's multiple range test.
[7]* = treatment differs from appropriate control (head of column) to at least α = 0.05 level, Duncan's multiple range test.

Table 4.—Comparison of herbicide treatments by mean numbers of ectomycorrhizal short roots (cm) on 10-cm segments of main lateral roots, based on 30 samples for each treatment

	Nursery									
	Mountain Home						Montana State			
	Lodgepole pine		Blue spruce		Austrian pine		Ponderosa pine		Douglas-fir	
Treatment	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ	$\bar{x}$	σ
Control (no herbicide)	45.1	8.5	55.1	11.4	59.9	7.7	34.3	6.8	28.3	7.7
Bifenox										
Bif. 1×[1], PS[2] + PG[3]	41.6a[4]	7.9	57.9a	11.0	58.1a	7.9	37.1a	10.1	19.0a**[6]	3.6
Bif. 1×, PS	40.3a	6.4	58.0a	11.7	61.5a	8.1	38.4a	8.8	18.8a**	3.7
Bif. 1×, PG	42.3a	7.7	58.9a	14.5	61.9a	9.0	38.9a	10.0	21.4a**	3.8
Bif. 2×, PS	35.8b**	11.6	55.9a	11.8	61.0a	9.8	33.6a	7.1	23.8b**	5.4
Bif. 2×, PG	41.2a	6.5	64.4b**	11.6	60.8a	9.7	36.0a	8.1	16.3c**	8.5
DCPA										
DCPA 1×, PS + PG	47.5a	7.3	52.2a	11.3	56.5a	7.6	33.0a	13.6	21.8a**	6.2
DCPA 1×, PS	42.1b	8.3	57.3a	10.9	62.9a	9.3	35.2b	7.8	21.9a**	6.4
DCPA 1×, PG	36.6c**	12.4	52.1a	12.9	59.4a	9.9	35.2b	6.9	21.0a**	5.3
DCPA 2×, PS	46.0a	8.3	57.6a	12.2	60.5a	8.1	41.3c*[7]	12.5	19.1b**	4.7
DCPA 2×, PG	43.6b	8.7	55.7a	11.6	63.3a	12.1	38.6b	7.8	19.5b**	3.2
Napropamide										
Nap. 1×, PS + PG	—[5]	—	—	—	—	—	37.8a	9.0	20.5a**	3.6
Nap. 1×, PS	—	—	—	—	—	—	38.3a	8.9	24.1b**	4.5
Nap. 1×, PG	—	—	—	—	—	—	34.1a	7.1	23.4a**	7.0
Nap. 2×, PS	—	—	—	—	—	—	36.4a	7.7	20.7a**	5.3
Nap. 2×, PG	—	—	—	—	—	—	35.1a	8.0	20.6a**	4.4

[1]1× = applied concentration according to manufacturer's recommendation, 2× = double concentration, for actual concentration of active ingredient (see table 1).
[2]PS = immediately postseeding.
[3]PG = postgermination, usually 4 to 5 weeks after seedling emergence.
[4]Treatments within a single herbicide group and species (down column) that do not share a common subscript letter are significantly different to at least α = 0.05 level, Duncan's multiple range test.
[5]Dash indicates this combination not tested.
[6]** = treatment differs from appropriate control (head of column) to at least α = 0.01 level, Duncan's multiple range test.
[7]* = treatment differs from appropriate control (head of column) to at least α = 0.05 level, Duncan's multiple range test.

Table 5.—Overall interactions between sources of variation and numbers of ectomycorrhizal short roots (cm)

	Nursery					
Source of variation	Coeur d'Alene	Albuquerque	Mount Sopris	Lucky Peak	Mountain Home	Montana State
Within individual source						
Species	**[1]	—[2]	*[3]	**	**	**
Herbicide	**	*	NS[4]	NS	NS	NS
Rate	*	NS	NS	*	NS	NS
Two-way interactions						
Species × herbicide	—	—	—	NS	**	NS
Species × rate	—	*	—	*	*	NS
Herbicide × rate	—	**	—	NS	**	NS
Three-way interactions						
Species × herbicide × rate	—	—	—	NS	NS	**

[1]**Interaction significant, α = 0.01, ANOVA.
[2]Dash indicates combination not tested in experimental design.
[3]*Interaction significant, α = 0.05, ANOVA.
[4]NS interaction not significant.

Table 6.—Properties of soils at respective nurseries

Nursery	Soil Type	Particle size distribution Sand	Silt	Clay	ph	Cation exchange capacity	Organic matter
		-------	*Percent*	-------		*meq/100g*	*Percent*
Montana State	Sandy loam	57	30	13	6.9	11.76	2.7
Mountain Home	Loam	40	50	10	5.6	13.67	4.5
Coeur d'Alene	Sandy loam	71	21	8	6.1	6.17	3.1
Lucky Peak	Sandy loam	61	26	13	5.8	7.44	1.7
Mt. Sopris	Sandy loam	55	29	16	6.0	9.87	3.3
Albuquerque	Sandy loam	73	20	7	7.4	5.98	.4

Color and morphology of ectomycorrhizal short roots and other aspects of root structure were similar on the species examined at the respective locations within the limits of variation of sample seedlings. As would be expected, differences occurred in root structure and numbers of ectomycorrhizal short roots on seedlings from different nurseries. Since these differences were not related to the treatments of interest, they were not considered in the analysis. Table 6 documents general soil characteristics at each nursery.

DISCUSSION AND CONCLUSIONS

The lack of strong, consistent relationships between herbicide treatment and numbers of ectomycorrhizal short roots indicate a relatively unpredictable risk factor associated with these herbicides and ectomycorrhizal development. The strong relationships within nurseries, both positive and negative, between herbicide-treated seedlings of particular species and numbers of ectomycorrhizal short roots clearly demonstrate highly individualistic responses. Soil differences between nurseries may contribute to individualistic responses and were likely responsible, at least in part, for between-nursery differences in mycorrhization. However, with regard to mycorrhizae and herbicides, the soil characteristics we measured showed no unusual differences at nurseries where stronger relationships were observed. Accordingly, each combination of herbicide, seedling species, and nursery should be evaluated for possible negative effects.

With the three herbicides investigated here, the most dramatic reductions were from herbicide treatments on Douglas-fir at the Montana State Nursery, which averaged 32 percent. This reduction is probably not enough to cause substantial losses in seedling quality. It does suggest that Douglas-fir may be a sensitive species. The bases for such individualistic responses at a particular nursery are not clear. Because of the lack of explanation, due caution should be exercised with all herbicides.

The lack of strong herbicide-induced reductions and frequent increases in ectomycorrhizal development agree with other experiences (Trappe 1979, 1983; South and Kelley 1972; Ogawa and Yambe 1980; Palmer and others 1980; Greaves and others 1976; Iloba 1974, 1976, 1977; Uhlig 1966). Thus, use of these herbicides for nursery weed control in Central and Northern Rocky Mountain nurseries does not appear to pose high risks to ectomycorrhizal development. The combinations and timing of application tested here could be used in all cases, but with reservations on Douglas-fir. All herbicides and application procedures should be used on this species only with great caution, particularly at the Montana State and Coeur d'Alene nurseries. Even in relatively risky combinations, herbicide use should not be precluded if growth or outplanting performance of seedlings do not suffer.

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Harvey, Alan E.; Ryker, Russell A.; Jurgensen, Martin F. Effects of Bifenox, DCPA, and Napropamide on ectomycorrhizal development of conifer seedlings in Central and Northern Rocky Mountain Nurseries. Research Paper INT-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station; 1985. 7 p.

Postseeding and postgermination treatments with three weed control herbicides (Bifenox, DCPA, Napropamide) at two rates of application caused little reduction of ectomycorrhizal development on 1- and 2-year-old conifer seedlings in Central or Northern Rocky Mountain nurseries. In many cases, herbicide treatment increased ectomycorrhizal development, particularly with DCPA. In general, herbicide treatment effects on ectomycorrhizal development were species and nursery specific.

KEYWORDS: weed control, herbicide, ectomycorrhizae, Modown, Dacthal, Devrinol, toxicity, nursery practice

PESTICIDE PRECAUTIONARY STATEMENT

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

PROTECT

Use Pesticides Safely

FOLLOW THE LABEL

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