Filmforming Antitranspirants: Their Effects on Root Growth Capacity, Storability, Moisture Stress Avoidance, and Field Performance of Containerized Conifer Seedlings

by

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Abstract

The antitranspirants, XEF-4-3561-A, Wilt Pruf, Plantgard, Folicote, Clear Spray, and Vapor Gard, were sprayed on container-grown lodgepole pine, white spruce, western hemlock, and Douglas-fir seedlings before or after a 12-week cold (+2° C) storage period. The effects of the six antitranspirants on root growth capacity, storability, and field performance varied between species. XEF-4-3561-A, Wilt Pruf, Folicote, and Vapor Gard increased moisture stress avoidance of all species, while Plantgard and Clear Spray had no effect. None of the six antitranspirants are recommended for use on white spruce, western hemlock, or Douglas-fir planting stock because of the risk of reducing field performance. Further trials of XEF-4-3561-A and Wilt Pruf on lodgepole pine seedlings seem warranted.

Résumé

Les antitranspirants XEF-4-3561-A, Wilt Pruf, Plantgard, Folicote, Clear Spray et Vapor Gard ont été pulvérisés sur des plants cultivés et réceptifs de pin tordu, d'épinette blanche, de pruche occidentale et de douglas taxifolié avant ou après une période de conservation au froid (+2° C) de 12 semaines. Les effets des six antitranspirants sur la capacité d'accroissement des racines, la capacité de conservation et la performance sur le terrain ont varié selon les espèces. XEF-4-3561-A, Wilt Pruf, Folicote et Vapor Gard ont accru la résistance au stress hydrique chez toutes les espèces, mais Plantgard et Clear Spray ont été sans effet. Aucun des six antitranspirants n'est à recommander sur les plants d'épinette blanche, de pruche occidentale et de douglas taxifolié en raison du risque de diminution de la performance sur le terrain. D'autres essais de XEF-4-3561-A et de Wilt Pruf sur des plants de pin tordu paraissent justifiés.

Introduction

Loss of water by conifer seedlings, either in cold storage or after field planting, may result in growth-limiting or even lethal levels of plant moisture stress. During overwinter cold or frozen storage, seedling water loss is usually minimized by packaging the seedlings in cartons or bags with polyethylene or wax vapor barriers. Once planted on a forest site, water loss must be controlled by stomatal action. Frequently, seedlings are planted in environments that are conducive to foliage water loss, but at the same time, restrict water uptake. The net result is to subject the planted seedlings to growth- and survival-limiting levels of internal plant moisture stress.

Filmforming antitranspirants have been used on herbaceous plants (Anderson and Kreith 1978, Martin and Link 1978, McDaniel and Bresenham 1978), on deciduous fruit trees (Albrigo 1977, Weller and Ferree 1978), and also on forest tree species (Davies and Kozlowski 1974, 1975). This literature suggests that available products have varying effects on transpiration and may reduce photosynthesis or possibly cause mortality. A screening process is, therefore, necessary before filmforming antitranspirants should be considered for use on conifer planting stock.

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This paper reports effects of six filmforming antitranspirants on root growth capacity, storability, moisture stress avoidance, and field performance; and assesses their suitability for use on lodgepole pine (*Pinus contorta* Doug.), white spruce (*Picea glauca* (Moench) Voss), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) planting stock.

Materials and Methods

In February 1981, 11 200 container-grown lodgepole pine, white spruce, western hemlock, and Douglas-fir seedlings from British Columbia Ministry of Forests nurseries were removed from cold (0° to 2° C) storage. Seedlings of each species were randomly divided into 56 lots of 50 trees each, to provide four replicates of 14 treatments.

Six commercially available filmforming antitranspirants were applied in aqueous solution to the seedlings' foliage using a low pressure sprayer (Table 1). The antitranspirant sprays were applied to the lots of 50 seedlings such that all the shoots were well-coated. Two operationally feasible application times were evaluated. Treatment before, or during, winter cold storage was represented by seedlings returned to storage for 12 weeks after treatment. Treatment shortly before planting was represented by seedlings treated at the end of

storage and stored seven days or less between treatment and planting. An untreated control was provided for each group to maintain a balanced experiment, and minimize possible differences in mid-storage warming effects on post-storage physiology and field performance. The antitranspirant treatment of seedlings required that seedlings were removed from cold storage for no more than 6 hours and not subject to air temperatures exceeding approximately 15°C.

Table 1. Formulation and supplier of antitranspirants.

	Product dilution	Type of compound	Supplier
XEF-4-3561-A	1:10	Silicone emulsion	Dow Corning Corp. Midland, Mich. 48640
Wilt Pruf	1:10	Pinolene	Nursery Specialty Products Greenwich, CT 06830
Plantgard	1:5	Polyethylene emulsion	Polymetrics International Inc. New York, NY 10022
Folicote	1:20	Wax emulsion	Crystal Soap and Chemical Corp. Lansdale, PA 19446
Clear Spray	1:10	Acrylic polymer	W.A. Cleary Corp. Somerset, NJ 08873
Vapor Gard	1:20	Pinolene	Miller Chemical and Fertilizer Corp. Hammer, PA 17331

A 7-day root growth capacity (RGC) test (Burdett 1979), commonly used for operational testing in British Columbia nurseries, was conducted on 16 randomly selected seedlings from each antitranspirant treatment applied before the 12-week storage period. The RGC test was conducted by growing the seedlings potted in an unfertilized pH 5.5 peat: vermiculite soil medium in controlled environment chambers (Conviron E15, Conviron Systems Co., Winnipeg, Manitoba) providing the following conditions: 30°C day and 25°C night temperature; 16-hour daily photoperiod ($400 \mu \text{E m}^{-2} \text{s}^{-1}$); 75% relative humidity. After 7 days, the seedlings were scored for the number of roots elongated during the test as follows: 0 = no newly elongated roots; 1 = some newly elongated roots, none more than 10 mm; 2 = 1 to 3 roots elongated by more than 10 mm; 3 = 4 to 10 roots elongated by more than 10 mm; 4 = 11 to 30 roots elongated by more than 10 mm; 5 = 31 to 100 roots elongated by more than 10 mm. Testing occurred immediately after treatment (pre-storage RGC), and after the 12-week cold storage period (post-storage RGC). A storability rating was calculated from the pre- and post-storage measurements.

$$\text{Storability} = \frac{\text{post-storage RGC of treatment "x"}}{\text{pre-storage RGC of untreated seedlings}}$$

Storability values equal to, or greater than 1.0, suggest that seedling quality, or performance potential has been maintained or increased during cold storage. Conversely, storability values less than 1.0 suggest that seedling quality has diminished during cold storage.

Water potential measurements, using the pressure chamber method (Waring and Cleary 1967), were made on shoots of 16 seedlings per antitranspirant treatment after the

7-day RGC test. Measurements were made within two minutes of removal from the dark period, 25°C, 75% RH, RGC test environment.

A moisture stress avoidance test, involving measurement of pre-dawn water potential, was conducted on the white spruce seedlings in a warm glasshouse between July 3 and 22, 1981. In this test, seedlings were planted in coarse sand, well watered for 7 days, then not watered. Ten pre-dawn water potential measurements were made at appropriate (1- to 3-day) intervals until water potential levels reached -6.0 MPa (-60 bars) or the seedlings were dead. To minimize the effects of uneven soil water depletion, seedlings were planted into 40 sand-filled compartments 12 cm (D) x 6 cm (W) x 50 cm (L). Each compartment contained one randomly planted and evenly spaced seedling from each treatment, plus two extra seedlings at the ends of each compartment to reduce edge effects on soil water competition between seedlings. On each of the 10 measurement dates during the drought period, four compartments were selected randomly, and pre-dawn water potential measurements made on the seven treated seedlings in each of those compartments.

The influence of antitranspirants and application time on field performance was evaluated as first growing season survival and growth by outplanting the remaining seedlings at two sites. Lodgepole pine and white spruce seedlings were planted near Prince George, BC as 20-seedling row plots in a randomized complete block design with four blocks. Western hemlock and Douglas-fir were planted in a similar randomized complete block design in the transplant beds of BC Ministry of Forests' Surrey Nursery near Vancouver, BC. The Prince George and Surrey nursery plantings occurred on May 12 and April 10, 1981, respectively. First season survival and shoot growth were assessed in late September, 1981 at both sites.

Pre- and post-storage RGC, water potential, field survival, and growth data were subjected to analysis of variance. Treatment effects were tested for significance using the Student Newman-Keuls test (Zar 1974). Water potential differences between specific treatment and untreated samples on each sample date of the moisture stress avoidance test were tested for significance using the Student's t-test.

Results and Discussion

Both pre- and post-storage root growth capacity of white spruce and western hemlock seedlings were unaffected by the six antitranspirant treatments (Table 2). There were slight, but statistically significant reductions of both pre- and post-storage RGC for lodgepole pine seedlings treated with Folicote and Vapor Gard. Douglas-fir seedlings treated with XEF-4-3561-A showed significant reductions in pre- and post-storage RGC, but only post-storage RGC of Douglas-fir seedlings was adversely affected by Wilt Pruf and Vapor Gard.

Storability was adversely affected by Folicote and Vapor Gard in lodgepole pine; XEF-4-3561-A, Wilt Pruf, Folicote, and Vapor Gard in white spruce; Wilt Pruf and Folicote in western hemlock; and XEF-4-3561-A, Vapor Gard, and Wilt Pruf in Douglas-fir (Table 2).

Water potential measurements made on the seedlings grown for the 7-day RGC test (Table 3) suggest that XEF-4-3561-A, Wilt Pruf, Folicote, and Vapor Gard were effective in significantly increasing pre-dawn plant water potential in lodgepole pine, white spruce, western hemlock, and Douglas-fir seedlings grown under favourable temperature, light, and moisture conditions. Seedlings sprayed with Plantgard and Clear Spray did not have higher pre-dawn water potential levels than untreated seedlings. This suggests that Plantgard and Clear Spray had no effect on transpiration and are thus likely to be less effective in controlling water loss by seedlings

of the four conifers tested.

In the moisture stress avoidance test, white spruce seedlings treated with XEF-4-3561-A maintained significantly ($p < 0.05$) higher water potential levels than untreated seedlings for 9 days of drought (Figure 1). Wilt Pruf and Vapor Gard treated seedlings had significantly higher water potential levels than untreated seedlings for 5 days (Figure 1). Folicote, Plantgard, and Clear Spray were ineffective in promoting moisture stress avoidance of white spruce seedlings.

In the irrigated, but unfertilized, nursery planting of western hemlock and Douglas-fir, survival was high and unaffected by treatment (Table 4). Growth of western hemlock and Douglas-fir was significantly reduced by XEF-4-3561-A, Wilt Pruf, and Vapor Gard. Douglas-fir seedlings treated with Plantgard and Clear Spray had significantly greater growth than the untreated control: 16 and 22 mm more growth, respectively. The reason for the observed growth promotion is not clear;

however, it is unlikely to be a result of reduced transpiration because Plantgard and Clear Spray were ineffective in increasing plant water potential (Table 3).

At the forest planting near Prince George, lodgepole pine seedling survival was unaffected by treatment; however, XEF-4-3561-A, Wilt Pruf, and Vapor Gard all decreased survival of white spruce seedlings (Table 4). First season shoot growth was slightly, but significantly, greater in Wilt Pruf treated lodgepole pine seedlings. Growth of white spruce seedlings was slightly, but significantly, reduced by XEF-4-3561-A and Wilt Pruf treatments. Field performance improvements of seedlings receiving antitranspirant treatments may have been greater had the treated seedlings been planted on more drought prone planting sites rather than in the irrigated nursery beds (Douglas-fir and western hemlock) and the moist forest site at which survival was greater than 90% for both lodgepole pine and white spruce. It is a matter for speculation that

Table 2. Antitranspirant effects on root growth capacity before and after cold storage.

Species	Antitranspirant	Root growth capacity ¹		Storability ³
		Pre-storage	Post-storage ²	
Lodgepole pine	XEF-4-3561-A	4.6 a ⁴	3.5 a	.73
	Wilt Pruf	4.6 a	3.4 a	.72
	Plantgard	4.8 a	3.8 a	.79
	Folicote	3.6 b	2.2 b	.46
	Clear Spray	4.8 a	3.8 a	.79
	Vapor Gard	3.7 b	1.9 b	.40
	Untreated	4.8 a	3.4 a	.72
White spruce	XEF-4-3561-A	2.5	1.8	.56
	Wilt Pruf	2.8	1.9	.60
	Plantgard	3.1	2.7	.86
	Folicote	3.3	2.1	.68
	Clear Spray	3.4	3.2	1.02
	Vapor Gard	3.1	2.3	.72
	Untreated	3.1	2.8	.90
		ns	ns	
Western hemlock	XEF-4-3561-A	3.1	2.7	.76
	Wilt Pruf	3.1	2.2	.62
	Plantgard	3.8	2.8	.79
	Folicote	3.6	2.5	.70
	Clear Spray	3.7	3.1	.88
	Vapor Gard	3.8	2.9	.81
	Untreated	3.6	3.1	.88
		ns	ns	
Douglas-fir	XEF-4-3561-A	3.0 b	2.6 b	.62
	Wilt Pruf	3.6 ab	3.0 b	.73
	Plantgard	4.1 a	4.0 a	.97
	Folicote	4.1 a	3.4 ab	.83
	Clear Spray	3.9 a	4.1 a	.98
	Vapor Gard	3.6 ab	2.8 b	.67
	Untreated	4.1 a	3.8 a	.92

¹Root Growth Capacity assessed using Burdett's (1979) method.

²Storage period was for 12 weeks at +2°C.

³Storability = Post-storage RGC of treatment "x" / Pre-storage RGC of Untreated.

⁴Means followed by same letter do not significantly differ at $P \leq 0.05$; ns - not significantly different.

Table 3. Predawn¹ plant water potential (-MPa) of four container-grown conifer species treated with antitranspirants.

Antitranspirant	Lodgepole pine		White spruce		Western hemlock		Douglas-fir	
XEF-4-3561-A	.45	c ²	.35	b	.30	b	.40	c
Wilt Pruf	.50	bcd	.40	b	.30	b	.45	c
Plant Gard	.55	ab	.60	a	.35	b	.85	a
Folicote	.35	d	.50	b	.30	b	.65	b
Clear Spray	.55	ab	.65	a	.35	b	.95	a
Vapor Gard	.40	cd	.35	b	.30	b	.45	c
Untreated	.60	a	.70	a	.40	a	.95	a

¹Measurements were made on seedlings after they had been grown for seven days in the pre-storage root growth capacity test conditions.

²Means within a column followed by the same letter do not differ significantly at $P \leq 0.05$.

Figure 1. Decrease in plant water potential during a drought period in white spruce seedlings treated with film-forming antitranspirants. That portion of the water potential/days of drought curve for the treated seedlings that is significantly ($p < 0.05$) different from the untreated curve is shown as a broken line. Each point is the mean water potential of four seedlings.

warrants further investigation whether maintenance of higher levels of plant water potential at the expense of reduced CO_2 exchange as demonstrated by Davies and Kozlowski (1974, 1975) will in fact result in better survival and growth of conifer seedlings.

Time of treatment application was only an important consideration in hemlock seedlings, which grew significantly faster when treated shortly before field planting.

In general, the antitranspirants that effectively increased moisture stress avoidance also had the most negative effects on seedling RGC, storability, and field survival/growth. An important exception to this trend occurred in lodgepole pine seedlings treated with XEF-4-3561-A and Wilt Pruf, where xylem water potential was increased without adversely affecting RGC, storability, or field performance.

Summary

Of the six antitranspirants tested, Plantgard and Clear Spray had no effect on conifer seedling water relations. A slight growth stimulus, due to unknown causes, was observed when these products were applied to Douglas-fir seedlings. The most effective antitranspirants, in order, were: XEF-4-3561-A, Wilt Pruf, Vapor Gard, and Folicote. These also were generally the most effective compounds in reducing seedling RGC, storability, and field performance.

Antitranspirants should not be considered for operational use on white spruce, western hemlock, or Douglas-fir planting stock at the rates considered in this experiment because of the adverse effects on RGC and field performance.

The possibility of using Wilt Pruf and XEF-4-3561-A on lodgepole pine seedlings should be explored further in operational trials because these two products appear to reduce moisture stress development (Table 3) without significantly reducing RGC or storability (Table 2) and may actually result in first season field growth improvements (Table 4). Application of the antitranspirants may occur at any operationally convenient time possibly before packaging or in the field before planting.

Table 4. Survival and first season growth of container-grown conifer seedlings treated with several antitranspirants before and after cold storage.

Species	Antitranspirants	Survival ¹ (%)	Growth (mm)
Lodgepole pine	XEF-4-3561-A	99	102 ab ²
	Wilt Pruf	100	107 a
	Plant Gard	99	99 ab
	Folicote	100	99 ab
	Clear Spray	99	96 b
	Vapor Gard	99	91 b
	Untreated	99	96 b
		ns	
	Pre-storage application	99	100
	Post-storage application	99	97
		ns	ns
White spruce	XEF-4-3561-A	91 b	44 b
	Wilt Pruf	91 b	45 b
	Plant Gard	98 a	51 a
	Folicote	95 ab	50 ab
	Clear Spray	98 a	52 a
	Vapor Gard	91 b	48 ab
	Untreated	99 a	51 a
	Pre-storage application	95	49
	Post-storage application	95	48
		ns	ns
Western hemlock	XEF-4-3561-A	98	91 b
	Wilt Pruf	98	96 b
	Plant Gard	96	151 a
	Folicote	98	122 ab
	Clear Spray	98	150 a
	Vapor Gard	96	87 b
	Untreated	98	148 a
		ns	
	Pre-storage application	97	109 a
	post-storage application	97	132 b
		ns	
Douglas-fir	XEF-4-3561-A	100	87 de
	Wilt Pruf	100	89 de
	Plant Gard	100	116 ab
	Folicote	100	100 cd
	Clear Spray	100	122 a
	Vapor Gard	100	82 e
	Untreated	100	106 bc
		ns	
	Pre-storage application		
	Post-storage application	100	97
		ns	ns

¹Lodgepole pine and white spruce were outplanted on a forest site near Prince George, BC., while Western hemlock and Douglas fir were outplanted in the transplant beds of Surrey Nursery near Vancouver, BC.

²Means followed by same letter do not significantly differ at $p \leq 0.05$.

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