Cone Stimulation of *Abies procera*—Evaluating Variable Rates of $GA_{4/7}$, Timing, and Girdling

Chal G. Landgren, Sara R. Lipow, James Reno, and Robert Ohrn

Oregon State University Extension Forester, Beaverton, OR; Forest Geneticist, Oregon Department of Forestry, Salem, OR; Seed Orchard Manager, Weyerhaeuser Company, Federal Way, WA; District Silviculturist, Bureau of Land Management, Salem, OR

Abstract

This study investigated cone stimulation options having operational relevance to seed orchard managers. Replicated trials with five treatments were established at three orchard sites. Treatments included three variable rates of gibberellic acid $GA_{4/7}$ with girdling, one rate without girdling, and one treatment with girdling and $GA_{4/7}$ at a later treatment date. Cone and pollen production were inventoried. Results varied by orchard site. One orchard showed no relationship to treatment for either cone or pollen production. Another orchard showed treatment effect for cones but not pollen. At the third site, treatment influenced both pollen and cone production.

Introduction

Noble fir [*Abies procera* (Rehd.)], like many true firs, produces neither abundant nor frequent cone crops. Cone crops in the wild are reported at intervals averaging around 6 yr (Franklin 1983), yet pickable crops in specific desirable areas may be decades apart (J. Heater, personal communication; owner, Silver Mountain Nursery, and seed collector, Silverton, OR) with little seed available for planting. Cone stimulation trials using $GA_{4/7}$ on small Pacific silver fir (*Abies amabilis*) trees (Owens and others 2001) were encouraging, yet results relevant to larger fir in general and to noble fir in particular are unknown.

Noble fir has developed into the predominate Christmas tree species in the Pacific Northwest, replacing Douglas-fir. Currently, annual Christmas tree plantings of noble fir in Oregon alone exceed 5.3 million seedlings (Godwin 2004). Noble fir is also receiving increased attention from forest landowners. The acreage of noble fir reforestation plantings above 1,500 ft (457.2 m) elevation in Oregon and Washington is increasing, in part to replicate natural species diversity.

Noble fir seed orchards have been established at many sites in Oregon and Washington to help fill the seed needs for both Christmas trees and reforestation. These grafted orchards contain clones selected in tree improvement programs. Yet seed crop production has remained unpredictable, resulting in seed shortages and preventing capture of the full benefits from tree improvement efforts.

The objective of this research was to examine the effectiveness of $GA_{4/7}$ applications, with and without girdling, on cone production of noble fir.

Methods

This experiment evaluated the effect of five stimulation treatments on cone and pollen production in noble fir seed orchards and compared these to production in untreated trees. The treatments included three rates of $GA_{4/7}$ applied at vegetative budbreak, with girdling; one treatment at a medium $GA_{4/7}$ rate applied 2 wk after budbreak, with girdling; one treatment of $GA_{4/7}$ without girdling, and one control (table 1). This range of rates was derived from small-scale plot observations over the last decade. Rates beyond those selected caused severe yellowing and deformation of new growth (William Schlesinger and Jim Reno, Weyerhaeuser Company, personal communications). The number of cones present from the season before treatment (2003) and following treatment (2004) were counted for each tree. Pollen levels were also assessed following treatment and scored as high, medium, and low.

Experimental treatments were replicated on three noble fir seed orchard sites. Trees selected for treatment were all >5.08 cm (2 in) in diameter at breast height (DBH) and did not show evidence of heavy cone crops the previous year. Each treatment was applied to 24 selected candidate trees at each site. Where possible, all treatments were applied to ramets of the same clone. Treatments were randomly assigned to clones at each orchard position while attempting to maintain a within-clone distribution of treatments. The status of each orchard and treatment dates are summarized in table 2.

For the double-overlapping girdling, a pruning saw was used to sever the cambium layer with overlapping half-circumferential cuts on opposite sides of the stem. The cuts were spaced 1.5 × stem diameter apart and overlapped 2.54 cm (1 in) on both sides of the cut. The $GA_{4/7}$ treatment used ProCone® containing 42 µg of $GA_{4/7}$ ml^{-1}. The ProCone® was injected into holes drilled at a 30° angle 20 cm (7.8 in) above the upper girdling cut and distributed evenly around the circumference. Hole depth was sufficient to hold the volume of ProCone® in the xylem.

The operational methodology with respect to dose, volume, and application of $GA_{4/7}$ is summarized in table 3. As an example, consider the 2(E) treatment, where 20 µg of $GA_{4/7}$ is applied per inch DBH to a tree 10 in DBH. This tree received 250 mg of $GA_{4/7}$ at a rate of 20 mg. The $GA_{4/7}$ was delivered as 4.8 ml of ProCone® distributed in four drilled holes evenly spaced around the tree circumference above double-overlapping girdles.

Cone and pollen production (recorded to 1, 2, and 3) were analyzed with ANOVA for each orchard individually by a GLM procedure (SAS Institute, Inc., Cary, NC, 1998). The model included treatment (a categorical variable) and DBH as a covariate. A second model examined the relative increase in cone production by adding cone production in 2003 as a covariate. Because pollen production was a categorical variable, we also analyzed the data with a chi-square test that examined the contingency table of treatment by pollen category.

Table 1. Treatment overview.

Treatment	Girdling	µg $GA_{4/7}$ inch DBH^{-1}	Timing
C	None	0	NA
1E	Double overlap	10	At vegetative budbreak
2(E)	Double overlap	20	At vegetative budbreak
2(L)	Double overlap	20	2 wk after budbreak
3	Double overlap	40	At vegetative budbreak
2N	None	20	At vegetative budbreak

Table 2. Summary of orchard site information.

Owner, location	Approximate acreage	Year established	Mean DBH (in)	Number of clones	Germplasm origin	Treatment dates
Bureau of Land Management, Colton, OR	10	1973	12	117	Oregon Cascade seed zones 451,452, and 462. Cone production since 1993.	6/2/2003 & 6/18/2003
Weyerhaeuser Company, Sequim, WA	2	1974	11.4	53	Clone selections from seed zones 041, 430, and 440. Cone production since 1999. Good pollen yields.	5/8/2003 & 5/22/2003
Dixie PNW Christmas Tree Association, North Plains, OR	2	1995	4.3	30	Coastal Oregon sources. No prior cone crops.	5/15/2003 & 5/29/2003

Table 3. Operational summary of ProCone® dose, volume, and hole numbers by DBH class at various GA rates (10, 20, 40 a.i. in^{-1} of DBH).

DBH		Dose of $GA_{4/7}$/tree (mg) for various DBH midpoints			Volume of ProCone/tree (ml)[1]			Number of holes/tree[2]		
Average	Class	10	20	40	10	20	40	10	20	40 (2.4 ml)
4	3–5	40	80	160	1.0	1.9	3.8	1 (0.6ml)	2	2
6	5–7	60	120	240	1.4	2.9	5.7	1	2	2
8	7–9	80	160	320	1.9	3.8	7.6	2	3	3
10	9–11	100	200	400	2.4	4.8	9.5	2	4	4
12	11–13	120	240	480	2.9	5.7	11.4	2	5	5
14	13–15	140	280	560	3.3	6.7	13.3	3	6	6
16	15–17	160	320	640	3.8	7.6	15.2	3	6	6
18	17–19	180	360	720	4.3	8.6	17.1	4	7	7
20	19–21	200	400	800	4.8	9.5	19.0	4	8	8

[1] Concentration was 42 mg a.i./ml.

[2] Application was 1.2 ml of ProCone/hole (except where as noted).

Results

The results differed between seed orchard sites (tables 4 and 5). Chi-square tests on pollen production produced similar results to the ANOVA: significance levels were 0.24, 0.06, and 0.26 for the Bureau of Land Management (BLM), Dixie, and Weyerhaeuser orchards respectively. There were no statistically significant differences in DBH among the treatments at any orchard (*p* ranged from 0.23 to 0.81).

Stimulation method did not affect either cone or pollen production in the BLM orchard. The experimental trees in this block were large (table 4), and larger trees produced more pollen and cones (table 5). By design, all experimental trees had few cones in 2003. Most of the 144 experimental trees in this orchard, regardless of treatment, produced cones in 2004, with 100 trees producing 10 or more and 38 producing over 100.

In the Weyerhaeuser orchard, stimulation treatment did not affect pollen production but did affect cone production (table 5). The significance of the treatment effect for relative cone production was only p=0.112, but the significance of cone production in 2003 (the covariate) was p=0.226; indicating that it should not be in the model. A series of orthogonal contrasts designed to detect differences among treatments revealed that stimulated trees produced significantly more cones than controls (F=8.50, p=0.0045, dof=1). None of the differences among individual stimulation treatments, however, including girdled versus not-girdled, early versus late application of $GA_{4/7}$, and rate of $GA_{4/7}$, proved to be statistically significant (p>>0.05) in all cases. As with the BLM orchard, the larger trees in this orchard produced more pollen and cones.

Trees in the Dixie seed orchard were much smaller (Table 4) and not yet producing natural cone crops. Stimulation did significantly affect cone and pollen production in 2004. At the higher rates, trees showed significant yellowing, and the new growth exhibited twisting. Again, a series of orthogonal contrasts revealed that stimulated trees had significantly more cones than control trees (F=8.33, p=0.0045, df=1), but no statistically significant differences among stimulation methods were evident (p>>0.05 in all cases).

Table 4. Mean DBH and number of cones in 2003 and 2004 for each treatment and overall at each orchard site.

Orchard	Trait	Stimulation treatment						Overall mean
		C	1E	2E	2L	3	2N	
BLM	DBH (in)	13.9	13.3	14.5	13.3	14.2	14.3	13.9
	Cones, 2003	1.3	0.7	1.5	0.8	3.1	0.1	1.3
	Cones, 2004	52.0	49.0	61.8	46.0	79.1	70.7	59.8
Dixie	DBH (in)	4.5	4.5	4.4	4.2	4.2	4.3	4.3
	Cones, 2003	0.4	0.0	0.4	0.3	0.6	0.0	0.3
	Cones, 2004	1.4	6.1	8.8	13.2	6.4	4.0	6.6
Weyerhaeuser	DBH (in)	11.8	11.4	11.4	12.4	9.1	11.2	11.4
	Cones, 2003	22.3	8.9	8.3	6.4	19.6	10.8	12.0
	Cones, 2004	48.4	87.3	101.6	86.8	51.0	77.5	80.6

Table 5. The effect of stimulation treatment and DBH on cone and pollen production in 2004.

Orchard	Source of variation	df	Cone production, 2004		Relative cone production, 2004[1]		Pollen production, 2004	
			F	P	F	P	F	P
BLM	Treatment	5	0.45	0.8112	0.41	0.8387	0.93	0.4608
	DBH	1	10.59	0.0014	9.49	0.0025	12.98	0.0004
Dixie	Treatment	5	3.78	0.0031	3.77	0.0032	3.46	0.0057
	DBH	1	7.22	0.0081	6.48	0.012	1.81	0.1806
Weyerhaeuser	Treatment	5	2.36	0.0467	3.17	0.112	1.14	0.3444
	DBH	1	12.26	0.0007	7.3	0.0083	3.05	0.0841

[1] Relative production is the effect of stimulation treatment and DBH on the increase in cone production in 2004 relative to 2003.

Summary

Stimulation significantly increased cone production in two of the orchards but had no effect on the larger trees in the more mature BLM orchard. One possible explanation might be the fact that there was a “natural crop” in 2004 and for the past several years in that area. The other two orchards were located in areas outside the natural noble fir production region. Likewise, it was not possible to detect significant differences among the individual treatments on those sites where stimulation was effective.

Address correspondence to: Chal Landgren, OSU Extension Forestry, Washington County, 18640 NW Walker Rd. #1400, Beaverton, OR 97006; e-mail: chal.landgren@oregonstate.edu; phone: 503–725–2102.

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