Evaluating the Effect of Slow Release Fertilizers Incorporated into Containerized Seedlings in Mediterranean Climates

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Objectives:

1. To evaluate the partial contributions of fertilizer type and rate to seedling survival and growth in the field for Douglas fir and ponderosa pine.

2. To determine the influence of site quality and precipitation on seedling response to incorporated slow release fertilization.

Introduction:

Over the last several years, the use of slow release fertilizers incorporated into container seedling media has become increasingly popular. Early results from studies done by the Nursery Technology Cooperative (Oregon State University) and others on Douglas fir response to slow release fertilizers were encouraging and showed strong potential for volume increases at the early stages of seedling growth.

These early results prompted timber companies to experiment with this process in other regions, specifically northern California and southwestern Oregon. The majority of the work done extrapolated the fertilizer data from Oregon to a more Mediterranean climate. Initial results were promising, however, as time went on significant problems with survival and growth were encountered with the fertilizer type and rates used from the Oregon data.

The purpose of this study is to determine appropriate fertilizer ratios and rates for typical conifer species grown in Mediterranean climates and to evaluate survival and growth responses over a range of site qualities and moisture regimes.

Methods:

The experimental design within sites will be a completely randomized 2x2x4 factorial treatment structure split across sites. The treatments will be as follows:

3 sites (20-30" ann. Precip., 30-50" ann. Precip., >50" ann. Precip.)
2 species (Douglas-fir & ponderosa pine, sugar pine on Soper Wheeler Site)
1 stock size per species (ST-8, pine & ST-10, doug-fir)
1 fertilizer blend (Nutra-cote), ratio to be determined
4 rates per species (ST-8 pine = 0, 0.8, 1.6 & 3.2 grams per cell),
(ST-10 doug-fir = 0, 1, 2 & 4 grams per cell)
2 plant timings (fall and spring)

16 total treatments per site x 5 replications = 80 plots per site.

Plots will contain 25 trees per plot spaced 5' x 5'. This will require 2000 total trees per site (1000 p. pine & 1000 d. fir).

Total land area needed will be approximately three acres. Buffer rows of trees should not be necessary since the experiment will be of short duration.

The low precipitation site will be on land managed by W.M. Beaty & Associates, the moderate precipitation site will be on land managed by Silver Butte Timber Co. and the high precipitation site will be on land managed by Soper-Wheeler Company.

Site Prep: All sites will be doubled ripped and site prepped with 4 lbs a.i./ac of atrazine. Follow up foliar treatments will be applied as necessary.
Soil Temperature: Since the release rate of the fertilizer is temperature dependent, soil temperatures will be monitored at two points on each site at a depth of six inches using Hobo data recorders over the entire first growing season. The Co-op will also look into installing a local weather station as an alternative option.

Status: The seed for this study was sent to PRT in Campbell River, B.C. in the fall of 2002 for sowing.

The site located on Silver Butte Timber Co. lands was site prepped and double ripped in the summer of 2002. The site on Soper-Wheeler lands was logged and the slash was piled in the summer of 2003. This site was not double ripped. The site on W.M. Beaty & Associates land was part of the Devil Fire which burned in May of 2001. The site was logged and double ripping was done in the summer of 2002.

Plot layout was done on all three sites in the summer of 2003. The Silver Butte and Beaty sites have 80 plots each; the Soper site has 120.

Weather stations was installed at the Silver Butte and Beaty sites in August. The Soper site received a station in September. The continuous-recording stations measure soil and air temperature, soil moisture, and precipitation. They will be left in place over the winter.

After some rains in the early part of the month, the planting of the fall treatments started on the sites in October. The Silver Butte site was planted on October 24, the Soper site on November 4, and the Beaty site on November 5. The soil was moist at about the six inch depth on the Silver Butte site at the time of planting and the temperature was cool. The soil was dry at the other two sites and it was hot and windy on these sites. The planting was done by early afternoon at all three locations. The seedlings were auger planted on the Soper site to compensate for the lack of ripping. The other two sites were shovel planted. Within a week after planting, all sites had received rain.

There were some changes to the specifications as set forth in the original proposal. All seedlings were grown in Styro-10 containers, the fertilizer was Nutra-Cote 16-10-10, and the fertilization rates were 0, 1, 2, and 3 grams per cell. All the seedlings looked very healthy and each treatment was properly packed and labeled.

At the time of planting, sample seedlings representing all species by land owner were taken back to Redding where measurements of caliper and length were taken on 100 trees per species per land

owner (**Table 1**). At the time of measurement, the seedlings were visually examined for fertilizer. None of the seedlings that were treated at the "0" rate (no fertilizer) showed any signs of having been fertilized regardless of species. The ponderosa pines that were supposed to have received one of the three rates of fertilizer (1, 2, or 3 grams/cell) all showed evidence of fertilizer. It was impossible to estimate the rate, but all the seedlings had received some fertilizer. The Doug-fir showed a 13% error in fertilizer application – thirteen percent of the trees that should have been fertilized at one of the 3 rates were in fact not fertilized. The error for the sugar pine was 16%. Trees with as few as one prill per cell were considered fertilized.

The spring planting treatment will be applied in the spring of 2004. Similar measurements/observations like those taken on the fall planted seedlings will be made on seedlings from this planting. Caliper and height will be measured for all seedlings in each treatment at the end of the growing season. Seedling volume will be derived from these measurements. Survival will be noted at the time of measurement. First year results will be reported in the 2004 Annual Report.

2004: The spring-planting treatments for all three sites were installed by early April, 2004. Planting conditions were ideal on all sites at the time of planting. All sites received rain shortly after planting. The seedlings on Silver Butte lands were shovel planted, those on W.M. Beaty lands hodad planted, and the seedlings for Soper-Wheeler were auger planted. All seedlings arrived from the nursery in good condition.

All seedlings for the Silver Butte and Soper-Wheeler sites were labeled properly. The Douglas-fir seedlings for the W.M. Beaty site were labeled properly, but the ponderosa pine seedlings had no indication at all on the label as to how much, if any, fertilizer had been applied. Of the four boxes of pine seedlings designated for this site, only one had been fertilized. We assigned the fertilized box to the 3 gram treatment and planted these seedlings in the plots designated for that treatment. We assigned a treatment to the other three boxes and planted those seedlings just as if they had been labeled correctly. Of course, one of the boxes went into the 0 gram plots, so this treatment was correct as planted.

As had been done with seedlings from the fall-planting treatment, sample seedlings representing all species by land owner/treatment were taken back to Redding where measurements of caliper and length were taken on 100 trees per species per land owner (**Table 2**). At the time of measurement seedlings were visually examined for fertilizer. If a seedling had at least one prill, they were considered fertilized. It was impossible to check for amount of fertilizer ie. 1 gram, 2 grams, etc. There was much variation within a treatment; for example seedlings that were to receive 3 grams of fertilizer might have anywhere from 2 to 30 prills in them.

Consistent with results from the fall planting, many seedlings within a certain fertilizer treatment rate (1 gram, 2 grams, 3 grams) did not have any fertilizer at all. For all three sites between 12-44 percent of the Douglas-fir that were to be fertilized in fact had no fertilizer at all. The ponderosa pine

that were incorrectly fertilized ranged from 4 percent to 36 percent. Figures for the sugar pine ranged from 8 to 28 percent. Generally those seedlings that were not to receive any fertilizer (0 gram treatment) were not fertilized. Variations in number of seedlings actually fertilized by species/land owner/fertilization rate are available if interested.

First year growth measurements were taken on all three sites during the fall of 2004. Measurements taken included caliper (at one inch above ground line) and height (ground line to tip of bud). Seedling volume will be calculated from these measurements. Survival was noted at this time as well as pest problems.

Survival for Douglas-fir was greater with the spring planting than with the fall planting on all three sites (**Table 3**). Fertilization had no effect on Douglas-fir survival.

For ponderosa pine, neither planting time nor fertilization affected survival at the Silver Butte site. At the other two sites, survival was greater for spring planting, overall, but this effect varied based on fertilization. At the Soper-Wheeler site, the higher rates of fertilizer resulted in slightly lower survival with the fall-planted seedlings. Fertilization rates did not affect the survival of the spring-planted seedlings. At the Beaty site, survival was greater than 99% for all rates of fertilization with the spring planting. For the fall-planting, the 1 and 2 gram rates had lower survival than the 0 and 3 gram rates.

For the sugar pine on the Soper-Wheeler site, spring planting resulted in significantly greater survival, but survival was greater than 90% for both planting times. There was no fertilization effect.

For all three of the sites, Douglas-fir spring-planted seedlings were significantly taller than fall-planted seedlings (**Tables 4** and **5**). At the Soper-Wheeler and Beaty sites, spring-planted seedlings were also significantly larger in caliper. Only at the Beaty site were the spring-planted seedlings also larger in volume, but only about 3% of the fall-planted seedlings survived.

For Douglas-fir, fertilization effect varied by site. At the Soper-Wheeler site fertilization did not significantly affect seedling size. At the Silver Butte site, seedlings that received the 1 and 2 gram rates of fertilization were significantly larger in caliper and volume than those seedlings that received no fertilization. Although seedlings receiving 3 grams of fertilizer averaged larger caliper and volume than those receiving no fertilizer, the difference was not significant. At the Beaty site, the results varied based upon planting time. Because of the low survival of the fall-planted seedlings, those results are questionable. For the spring-planted seedlings, the only fertilizer effect was a slight but significant decrease in height at the highest rate of fertilization.

For ponderosa pine, there were no significant differences in seedling size resulting from planting time or fertilization at the Beaty site (**Tables 6** and **7**). At the Silver Butte site, spring-planted seedlings were slightly taller than those planted in the fall and there were no significant effects of fertilization. At the Soper-Wheeler site,

caliper and volume did not differ significantly with planting time or fertilization, but the unfertilized, spring-planted seedlings were significantly taller than the other seedlings.

For sugar pine, the only significant effect was that fall-planted seedlings were slightly taller than those planted in the spring (**Table 8**).

Second year growth measurements will be taken in the fall of 2005. Survival will be noted at this time. Low survival of the fall-planted Douglas-fir seedlings at the Beaty and possibly the Soper-Wheeler sites may drop these treatments from the study.

Total funded: $27,365; Total Spent as of 12/31/04: $15,060.57.

Table 1—Values for caliper, height and volume for seedlings of Slow Release Proposal at time of lifting (fall treatment) fall, 2003.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Soper Wheeler	0.47	22.24	5.17
Silver Butte	0.46	20.21	4.38
Beaty	0.42	17.39	3.18
Douglas-fir			
Soper Wheeler	0.37	27.73	4.00
Silver Butte	0.37	28.69	3.99
Beaty	0.36	23.66	3.12
Sugar Pine			
Soper Wheeler	0.30	16.68	1.55

Table 2—Values for caliper, height and volume for seedlings of Slow Release Proposal at time of lifting (spring treatment) spring, 2004.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Soper Wheeler	0.44	22.25	4.31
Silver Butte	0.45	20.76	4.20
Beaty	0.42	16.72	2.95
Douglas-fir			
Soper Wheeler	0.37	23.16	3.17
Silver Butte	0.38	27.28	3.94
Beaty	0.34	20.24	2.34
Sugar Pine			
Soper Wheeler	0.30	16.42	1.48

Table 3 - Survival for all sites and species

	Fertilizer	**Beaty**		**Silver Butte**		**Soper-Wheeler**		
Timing	Grams	PP	DF	PP	DF	PP	SP	DF
Fall	0	91.2	5.6	91.2	54.4	89.6	89.6	39.2
	1	76.0	2.4	78.4	62.4	93.6	92.0	37.6
	2	75.2	2.4	88.0	48.0	70.4	90.4	40.8
	3	84.0	1.6	86.4	50.4	74.4	95.2	26.4
Spring	0	100	98.4	86.4	91.2	99.2	100	96.0
	1	100	97.6	83.2	89.6	98.4	100	92.8
	2	99.2	95.2	94.4	89.6	96.8	96.8	99.2
	3	99.2	96.8	90.4	84.8	95.2	99.2	93.6

Table 4a - Raw data means and standard errors for Soper-Wheeler Douglas-fir

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	20.7	1.29	4.6	0.15	1.3	0.14
	1	21.3	0.69	4.4	0.27	1.3	0.19
	2	22.5	1.38	4.6	0.40	1.6	0.29
	3	24.2	1.97	4.7	0.88	2.1	0.78
Spring	0	24.6	0.64	4.6	0.47	1.5	0.35
	1	24.4	0.61	4.9	0.39	1.8	0.30
	2	24.6	1.08	5.3	0.41	2.1	0.37
	3	24.4	0.32	5.9	0.37	2.5	0.30

Table 4b - Raw data means and standard errors for Beaty Douglas-fir

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	11.3	2.90	3.7	0.81	0.51	0.30
	1	18.8	4.25	5.2	0.92	1.5	0.69
	2	7.6	0.38	3.1	0.32	0.23	0.01
	3	6.8	0.25	2.6	1.2	0.14	0.10
Spring	0	23.2	0.39	5.4	0.15	1.9	0.13
	1	24.4	0.19	5.6	0.12	2.1	0.10
	2	22.5	0.58	5.4	0.12	1.8	0.12
	3	21.2	0.48	5.4	0.11	1.8	0.11

Table 4c - Raw data means and standard errors for Silver Butte Douglas-fir

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	24.4	2.52	4.8	0.22	1.7	0.20
	1	26.7	1.11	5.8	0.26	2.9	0.41
	2	29.2	1.12	6.2	0.26	3.3	0.36
	3	28.3	2.76	5.8	0.36	2.7	0.30
Spring	0	32.4	1.02	5.3	0.16	2.7	0.21
	1	33.6	0.86	5.4	0.26	2.8	0.34
	2	32.8	0.86	5.7	0.30	3.1	0.36
	3	32.2	1.36	5.4	0.15	2.8	0.22

Table 5a – Soper-Wheeler Douglas-fir: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	183.39	<.0001	15.33	.0004	4.62	.0392	4.10	.0514
Rate	3,32	0.95	.4281	0.26	.8567	0.74	.5347	1.60	.2080
Time*Rate	3,32	0.37	.7726	0.29	.8290	1.11	.3584	0.30	.8228
Least-Square Means									
	Fall	36.0	b	21.8	b	4.44	b		
	Spring	95.4	a	24.5	a	5.06	a		

Table 5b – Beaty Douglas-fir: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,20[1]	2852.02	<.0001	126.58	<.0001	30.47	<.0001	59.03	<.0001
Rate	3,20	0.75	.5314	8.46	.0008	2.52	.0867	4:84	.0108
Time*Rate	3,20	0.34	.7962	5.14	.0085	2.10	.1319	3.66	.0299
linear	1,20			13.68	.0014			8.68	.0080
quadratic	1,20			5.22	.0333			5.40	.0309
cubic	1,20			9.86	.0051			3.39	.0805
Least-Square Means									
	Fall	3.0	b	9.7	b	3.3	b	.31	b
	Spring	94.7	a	22.8	a	5.4	a	1.88	a
	0			15.6	ab			.84	ab
	1			20.3	a			1.56	a
	2			13.0	b			.64	ab
	3			12.0	b			.41	b
Fall	0			10.5	cd			.37	bc
	1			16.9	bc			1.18	b
	2			7.5	d			.23	bc
	3			6.7	d			.09	c
Spring	0			23.2	ab			1.87	a
	1			24.4	a			2.08	a
	2			22.6	ab			1.82	a
	3			21.2	b			1.75	a

[1]Survival DDF is 32.

Treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 5c – Beaty Doug-fir(spring): F and p values from ANOVAs.

		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p
Rate	3,16	8.75	.0011	0.45	.7178	1.49	.2550
linear	1,16	15.83	.0011				
quadratic	1,16	7.87	.0127				
cubic	1,16	2.58	.1280				
Least-Square Means							
	0	23.2	a				
	1	24.4	a				
	2	22.6	ab				
	3	21.2	b				

Table 5d – Silver Butte Douglas-fir: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	63.54	<.0001	25.45	<.0001	0.40	.5306	0.96	.3355
Rate	3,32	0.77	.5218	1.47	.2410	4.38	.0109	4.02	.0156
Time*Rate	3,32	0.47	.7075	1.34	.2794	2.14	.1148	1.78	.1703
linear	1,32					5.29	.0281	5.21	.0293
quadratic	1,32					7.46	.0102	6.51	.0157
cubic	1,32					0.47	.4969	0.33	.5675
Least-Square Means									
	Fall	53.8	b	27.4	b				
	Spring	90.2	a	32.7	a				
	0					5.05	b	2.15	b
	1					5.58	ab	2.77	a
	2					5.93	a	3.17	a
	3					5.51	ab	2.72	ab

Treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 6a - Raw data means and standard errors for Soper-Wheeler Ponderosa Pine

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	27.2	0.55	6.8	0.23	3.8	0.27
	1	25.6	0.63	6.6	0.15	3.1	0.21
	2	27.8	0.70	7.6	0.57	4.8	0.77
	3	26.1	0.54	7.2	0.63	4.2	0.66
Spring	0	31.4	0.56	6.6	0.27	3.9	0.31
	1	24.8	0.61	7.8	0.55	4.6	0.89
	2	27.2	0.96	8.0	0.69	5.1	0.99
	3	26.9	0.77	8.0	0.39	4.9	0.41

Table 6b - Raw data means and standard errors for Beaty Ponderosa Pine

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	22.0	0.42	8.0	0.11	3.9	0.11
	1	21.5	0.30	7.4	0.41	3.3	0.38
	2	20.4	0.38	7.8	0.29	3.6	0.32
	3	20.7	0.58	8.5	0.30	4.1	0.27
Spring	0	21.5	0.78	8.2	0.31	4.1	0.42
	1	20.6	0.39	7.6	0.13	3.3	0.07
	2	20.3	0.81	7.7	0.18	3.4	0.23
	3	20.7	0.51	7.6	0.33	3.3	0.34

Table 6c - Raw data means and standard errors for Silver Butte Ponderosa Pine

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	23.7	0.76	7.1	0.50	3.5	0.59
	1	24.7	0.90	7.9	0.28	4.4	0.31
	2	24.9	0.45	7.3	0.37	3.8	0.40
	3	24.8	0.74	7.3	0.15	3.8	0.23
Spring	0	26.4	0.76	7.4	0.33	4.2	0.32
	1	27.1	1.07	7.4	0.30	4.2	0.49
	2	28.6	0.39	7.2	0.36	4.3	0.55
	3	26.1	0.54	7.0	0.31	3.6	0.37

Table 7a – Soper-Wheeler ponderosa pine: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	41.46	<.0001	3.00	.0927	3.01	.0925	2.53	.1218
Rate	3,32	7.17	.0008	12.85	<.0001	1.99	.1350	1.54	.2232
Time*Rate	3,32	4.31	.0116	5.46	.0038	1.22	.3167	0.66	.5852
linear	1,32	14.84	.0005	6.80	.0137				
quadratic	1,32	0.01	.9339	9.98	.0034				
cubic	1,32	6.66	.0147	20.26	<.0001				
Least-Square Means									
	Fall	82.0	b						
	Spring	97.4	a						
	0	94.4	a	29.2	a				
	1	96.0	a	25.1	c				
	2	83.6	b	27.4	ab				
	3	84.8	b	26.4	bc				
Fall	0	89.6	a	27.1	b				
	1	93.6	a	25.5	b				
	2	70.4	b	27.7	b				
	3	74.4	b	26.1	b				
Spring	0	99.2	a	31.4	a				
	1	98.4	a	24.7	b				
	2	96.8	a	27.2	b				
	3	95.2	a	26.8	b				

Treatment means in the each column followed by the same letter do not differ significantly at the 0.05 level.

Table 7b – Beaty ponderosa pine: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	81.82	<.0001	1.14	.2936	0.35	.5584	0.99	.3262
Rate	3,32	3.73	.0209	2.54	.0742	2.24	.1029	2.53	.0746
Time*Rate	3,32	3.46	.0276	0.25	.8586	2.07	.1235	1.14	.3479
linear	1,32	2.07	.1601						
quadratic	1,32	9.09	.0050						
cubic	1,32	0.03	.8585						
Least-Square Means									
	Fall	81.6	b						
	Spring	99.6	a						
	0	95.6	a						
	1	88.0	ab						
	2	87.2	b						
	3	91.6	ab						
Fall	0	91.2	ab						
	1	76.0	c						
	2	75.2	c						
	3	84.0	a						
Spring	0	100	a						
	1	100	a						
	2	99.2	a						
	3	99.2	a						

Table 7c – Silver Butte ponderosa pine: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	0.83	.3701	22.80	<.0001	0.46	.5037	0.28	.6016
Rate	3,32	2.48	.0787	1.74	.1795	0.68	.5732	0.54	.6603
Time*Rate	3,32	0.77	.5170	0.83	.4858	0.47	.7070	0.68	.5731
Least-Square Means									
	Fall			24.5	b				
	Spring			27.0	a				

Treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 8a - Raw data means and standard errors for Soper-Wheeler Sugar Pine

		Height (cm)		Caliper (mm)		Volume (cm^3)	
Timing	**Fertilizer**	Mean	SE	Mean	SE	Mean	SE
Fall	0	19.0	1.20	4.3	0.18	1.1	0.17
	1	20.2	0.50	4.3	0.15	1.2	0.13
	2	20.8	1.57	4.9	0.29	1.5	0.24
	3	20.1	1.00	4.6	0.21	1.3	0.16
Spring	0	15.5	0.82	4.6	0.22	1.1	0.16
	1	19.3	2.15	4.7	0.33	1.3	0.32
	2	17.4	0.65	4.4	0.14	1.0	0.09
	3	18.6	1.39	5.1	0.28	1.4	0.10

Table 8b –Soper-Wheeler sugar pine: F and p values from ANOVAs.

		Survival		Height		Caliper		Volume	
Effect	**DF**	F	p	F	p	F	p	F	p
Time	1,32	18.92	.0001	7.63	.0094	0.85	.3645	0.37	.5469
Rate	3,32	0.88	.4638	1.54	.2230	1.06	.3802	1.11	.3605
Time*Rate	3,32	0.66	.5816	0.46	.7112	1.62	.2039	1.27	.3005
Least-Square Means									
	Fall	91.8	b	19.9	a				
	Spring	99.0	a	17.4	b				

Treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.