

Fertilization Studies Summary:

Statistical Approach:

Both sets of data were analyzed as factorial designs using SAS® PROC MIXED with plot as a random variable. Sites and species were analyzed separately. All analyses were weighted based on the number of surviving seedlings within each plot. Comparisons among the least-squared means were made using Bonferroni's adjusted probabilities for multiple comparisons. For the slow release study, linear, quadratic, and cubic contrasts were tested when rate was significant. Data were transformed prior to analyses if first runs indicated a lack of homogeneity of variance. Analyses were run on survival, height, caliper, and stem volume index. For the stock type study, three analyses were performed. Bareroot and plugs were analyzed separately for fertilizer effect, and then nonfertilized seedlings were analyzed for stock type effect. For the slow release study, the Beatty site had different analyses than the other sites. Survival for Douglas-fir planted in the fall was too low to include the time effect in the ANOVA analysis. Also at Beatty, because of a fertilizer problem, the fall planting for ponderosa pine was analyzed separately from the spring planting, and only the no fertilizer and highest fertilizer rates were included in the spring-planted analysis.

Slow Release Study:

Survival for Douglas-fir was greater with the spring planting than with the fall planting for all three sites, but fertilization had no effect on survival.

For ponderosa pine, at the Beatty site, fertilization did not affect survival for the spring planting comparisons, but there was a trend for greater survival for nonfertilized seedlings. At Silver Butte and Soper-Wheeler, spring planting survival was greater than fall planting survival. Survival for the 0 and 0.8 fertilizer rates was greater than the 1.6 and 3.2 rates at Soper-Wheeler.

For sugar pine, spring planting also resulted in significantly greater survival, and survival was greater than 90% for both planting times. There was no fertilization effect.

For Douglas-fir at the Silver Butte and Soper-Wheeler sites, spring-planted seedlings were significantly taller than fall-planted seedlings. At the Soper-Wheeler site, spring-planted seedlings were also larger in caliper and volume. Survival for the fall-planted seedlings at the Beatty site was too low for comparisons to be made between the planting dates. Fertilization did not significantly affect seedling size at Silver Butte and Soper-Wheeler. For the Beatty spring-planted Douglas-fir, the 1 gram rate had taller seedlings than the 4 gram rate, but difference was slight.

For ponderosa pine, differences in planting time and fertilization did not result in significant differences in seedling size at the Silver Butte site. For the fall-planted seedlings at the Beatty site, the 3.2 gram fertilization rate resulted in taller seedlings than the 0 and 0.8 gram rates. There was a similar nonsignificant trend for volume. There were no trends for fertilization for the spring-planted seedlings at Beatty. At Soper-Wheeler, the spring-planted seedlings were larger in both caliper and volume than the fall-planted seedlings, and there were no significant trends with fertilization.

Fertilization and planting time resulted in no significant differences in size of sugar pine seedlings.

Percent survival for Slow Release Study, all sites and species (n=5)

Timing	Fertilizer Grams	Beatty		Silver Butte		Soper-Wheeler		
		PP	DF	PP	DF	PP	SP	DF
Fall	0	91.2	2.4	73.6	40.8	90.4	87.1	38.4
	0.8,1	74.4	1.6	69.6	46.4	92.8	91.2	40.0
	1.6,2	73.4	0.8	82.4	44.0	70.4	90.4	39.2
	3.2,4	83.2	0.8	72.8	45.6	74.4	94.4	28.8
Spring	0	100	95.2	83.2	80.8	99.2	100	95.1
	0.8,1	100	96.0	80.0	80.8	98.4	99.2	92.0

	1,6,2	99.2	89.6	90.4	84.0	96.8	96.0	98.4
	3,2,4	99.2	92.0	84.0	76.0	95.2	100	93.6

Raw data means and standard errors for Beatty Douglas-fir (n=5)

Timing	Fertilizer	Height (cm)		Caliper (cm)		Volume (cm ³)	
		Mean	SE	Mean	SE	Mean	SE
Fall	0 ¹	11.7	--	0.43	--	2	--
	1 ²	24.0	1.5	0.65	0.15	11	4
	2 ¹	13.5	--	0.40	--	2	--
	4 ¹	7.5	--	0.30	--	1	--
Spring	0	26.7	0.6	0.74	0.05	16	2
	1	28.6	1.0	0.76	0.05	18	3
	2	26.1	1.2	0.73	0.06	16	3
	4	24.7	0.5	0.75	0.04	16	2

¹n=1 ²n=2

Raw data means and standard errors for Silver Butte Douglas-fir (n=5)

Timing	Fertilizer	Height (cm)		Caliper (cm)		Volume (cm ³)	
		Mean	SE	Mean	SE	Mean	SE
Fall	0	40.1	2.3	0.80	0.08	32	7
	1	43.8	3.4	1.00	0.08	57	12
	2	42.1	2.9	0.92	0.06	42	6
	4	42.8	3.8	0.90	0.06	42	8
Spring	0	44.6	1.2	0.85	0.04	38	3
	1	46.1	1.4	0.88	0.04	42	5
	2	47.2	1.8	0.96	0.08	54	10
	4	44.8	1.2	0.90	0.03	45	3

Raw data means and standard errors for Soper-Wheeler Douglas-fir (n=5)

Timing	Fertilizer	Height (cm)		Caliper (cm)		Volume (cm ³)	
		Mean	SE	Mean	SE	Mean	SE
Fall	0	31.6	1.9	0.92	0.07	34	7
	1	33.5	2.2	0.96	0.06	40	5
	2	38.6	1.9	1.04	0.05	48	4
	4	36.0	3.0	1.03	0.10	54	12
Spring	0	41.2	3.0	1.17	0.13	68	17
	1	42.5	3.0	1.28	0.09	86	15
	2	42.7	2.7	1.28	0.10	81	15
	4	44.5	2.3	1.36	0.11	99	19

Raw data means and standard errors for Beatty ponderosa pine (n=5)

Timing	Fertilizer	Height (cm)		Caliper (cm)		Volume (cm ³)	
--------	------------	-------------	--	--------------	--	---------------------------	--

Timing	Fertilizer	Mean	SE	Mean	SE	Mean	SE
Fall	0	36.6	0.8	1.37	0.08	76	9
	0.8	36.1	0.5	1.38	0.04	75	4
	1.6	37.7	1.2	1.47	0.03	90	6
	3.2	40.2	0.5	1.50	0.03	96	4
Spring	0	38.8	1.2	1.45	0.06	90	9
	0.8	37.4	1.4	1.38	0.07	77	9
	1.6	37.4	0.8	1.48	0.05	87	6
	3.2	38.1	2.0	1.44	0.08	87	12

Raw data means and standard errors for Silver Butte ponderosa pine (n=5)

Timing	Fertilizer	Height (cm)		Caliper (cm)		Volume (cm ³)	
		Mean	SE	Mean	SE	Mean	SE
Fall	0	42.8	3.6	1.28	0.10	84	18
	0.8	45.1	1.3	1.36	0.08	104	17
	1.6	43.2	3.1	1.23	0.15	86	24
	3.2	42.9	2.3	1.31	0.06	90	14
Spring	0	45.4	1.8	1.27	0.10	93	18
	0.8	47.9	2.0	1.37	0.06	107	13
	1.6	46.5	2.0	1.38	0.07	107	17
	3.2	43.4	2.9	1.21	0.11	81	17

Raw data means and standard errors for Soper-Wheeler ponderosa pine (n=5)

Timing	Fertilizer	Height (cm)		Caliper (cm)		Volume (cm ³)	
		Mean	SE	Mean	SE	Mean	SE
Fall	0	47.6	1.5	1.87	0.04	177	13
	0.8	45.1	1.1	1.85	0.03	166	11
	1.6	50.4	1.5	1.93	0.13	214	30
	3.2	46.3	1.8	1.88	0.07	187	16
Spring	0	45.8	1.3	1.87	0.04	171	9
	0.8	47.2	1.3	2.02	0.05	205	13
	1.6	49.6	1.9	2.09	0.08	233	25
	3.2	52.3	1.6	2.04	0.06	239	19

Raw data means and standard errors for Soper-Wheeler sugar pine (n=5)

Timing	Fertilizer	Height (cm)		Caliper (cm)		Volume (cm ³)	
		Mean	SE	Mean	SE	Mean	SE
Fall	0	28.5	0.9	0.95	0.02	28	3
	0.8	30.4	0.3	0.93	0.03	29	2
	1.6	31.0	1.5	1.05	0.03	38	4
	3.2	29.9	0.7	0.98	0.03	33	2
Spring	0	30.2	1.2	1.11	0.12	63	20
	0.8	32.3	2.3	1.09	0.06	45	8
	1.6	30.5	0.8	0.98	0.04	33	4

	3.2	30.7	0.6	1.04	0.03	37	2
--	-----	------	-----	------	------	----	---

F and p values from ANOVAs for Beatty Douglas-fir

Effect	DF	Survival		Height ¹		Caliper ¹		Volume ¹	
		F	P	F	p	F	p	F	p
Time	1,32	2809	<.0001						
Rate	3,32	1.08	.3715	3.62	.0361	0.07	.973 3	0.23	.870 7
Time*Rate	3,32	0.48	.7015						
linear	1,16			5.40	.0336				
quadratic	1,16			3.44	.0823				
cubic	1,16			2.03	.1733				
Least-Square Means									
Fall		1	b						
Spring		93	a						
0				26.7	ab				
1				28.6	a				
2				26.0	ab				
4				24.7	b				

¹Spring only, df=3,16 and 1,16 for contrasts

F and p values from ANOVAs for Silver Butte Douglas-fir

Effect	DF	Survival		Height		Caliper		Volume	
		F	p	F	p	F	p	F	p
Time	1,32	55.00	<.0001	8.42	.0067	0.40	.530 8	1.94	.172 8
Rate	3,32	0.19	.9004	0.87	.4653	2.29	.096 7	2.68	.063 5
Time*Rate	3,32	0.22	.8819	0.29	.8340	1.27	.302 5	1.51	.231 9
Least-Square Means									
Fall		44	b	41.0	b				
Spring		82	a	45.7	a				

F and p values from ANOVAs for Soper-Wheeler Douglas-fir

Effect	DF	Survival		Height		Caliper		Volume	
		F	P	F	p	F	p	F	P
Time	1,32	173.7	<.0001	18.81	.0001	19.3 6	.000 1	19.9 5	<.0001
Rate	3,32	0.77	.5195	1.26	.3056	0.88	.459 8	1.94	.1435
Time*Rate	3,32	0.66	.5822	0.63	.6029	0.18	.907 7	0.18	.9075

Least-Square Means									
Fall		36	b	34.5	b	0.97	b	41	b
Spring		97	a	42.3	a	1.25	a	76	a

F and p values from ANOVAs for Beatty ponderosa pine (fall planting)

Effect	DF	Survival		Height		Caliper		Volume	
		F	P	F	p	F	p	F	p
Rate	3,16	3.71	.0337	5.06	.0118	1.72	.2031	3.11	.0560
linear	1,16	1.66	.2162	11.09	.0042				
quadratic	1,16	9.39	.0074	4.38	.0526				
cubic	1,16	0.08	.7834	0	.9739				
Least-Square Means									
0		91.2	a ¹	36.7	b				
0.8		74.4	a	36.1	b				
1.6		73.5	a	37.3	ab				
3.2		83.2	a	40.2	a				

¹Once adjusted for multiple comparisons, p values > 0.05. Lowest value was p=0.0636 for 0 and 1.6 comparison

F and p values from ANOVAs for Beatty ponderosa pine (spring planting)

Effect	DF	Survival		Height		Caliper		Volume	
		F	p	F	p	F	p	F	p
Rate	1,8	1.00	.3466	0.15	.7054	0.03	.8634	0.11	.7445

F and p values from ANOVAs for Silver Butte ponderosa pine

Effect	DF	Survival		Height		Caliper		Volume	
		F	p	F	p	F	p	F	p
Time	1,32	4.67	.0383	0.95	.3367	0.01	.9414	0.04	.8367
Rate	3,32	1.52	.2281	0.59	.6277	0.40	.7541	0.44	.7257
Time*Rate	3,32	0.03	.9915	0.20	.8929	0.94	.4312	0.62	.6087
Least-Square Means									
Fall		76	b						
Spring		86	a						

F and p values from ANOVAs for Soper-Wheeler ponderosa pine

Effect	DF	Survival		Height		Caliper		Volume	
		F	P	F	p	F	p	F	p
Time	1,32	43.32	<.0001	1.85	.1832	7.91	.0083	5.09	.0310
Rate	3,32	7.46	.0006	2.82	.0546	1.12	.3548	2.83	.0537
Time*Rate	3,32	1.90	.1493	2.73	.0600	0.82	.4900	1.11	.3592
linear	1,32	17.46	.0002						
quadratic	1,32	0.08	.7795						
cubic	1,32	4.85	.0350						
Least-Square Means									
Fall		85	a			1.87	b	180	b
Spring		99	b			2.00	a	208	a
0		98	a						
0.8		98	a						
1.6		87	b						
3.2		88	b						

F and p values from ANOVAs for Soper-Wheeler sugar pine

Effect	DF	Survival		Height		Caliper		Volume	
		F	P	F	p	F	p	F	p
Time	1,32	27.72	<.0001	1.26	.2692	3.26	.0803	3.77	.0610
Rate	3,32	1.49	.2364	0.92	.4408	0.02	.9945	0.06	.9802
Time*Rate	3,32	0.98	.4126	0.34	.7934	1.88	.1526	1.75	.1765
Least-Square Means									
Fall		93.0	b						
Spring		99.8	a						