Improving Seedling Nutrition in the Nursery to Increase Seedling Performance in the Field

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Objectives: Determine optimal nutrition for planting stock of Douglas-fir, white fir, and ponderosa pine to ensure high field survival and rapid early growth. Secondly, identify nursery nutritional practices to accomplish the first objective.

Seedlings grown with constant and sufficient internal nutrient concentrations achieved through exponential fertilization are free of nutrient stress. Seedlings can be produced with balanced, high reserves of nutrients superior to those possible through late-season heavy fertilization. Presumably, balanced, surplus reserves of nutrients at planting affords growth that is rapid enough to offset weed competition and soil drought. Questions to be answered are: (1) what techniques are best for western species? (2) how does nutrition favoring rapid growth affect seedling resistance /susceptibility to drought, pests, and temperature extremes?

At one or more forest nurseries, seedlings will be raised according to various nutrient regimes including conventional fertilization and exponential fertilization. Growth and nutrient status of the seedlings will be assessed at 2-week intervals during the culture period to chart the progress and adjust nutrient supply schedules. At lifting, seedlings will have nutrient contents that vary incrementally from conventional to very high values, and should identify a treatment optimal for out-planting success. Survival and growth of these seedlings will be followed for at least 5 years, at which time a firm decision can be reached on the best treatment(s) to apply to operational planting.

Status: A trial run using the fertilization rates specified in the proposal was made during 2001 at Cal Forest Nursery in Etna, CA. Three Co-op members supplied seedlings for the test, Boise Cascade, Fruit Growers Supply Co., and Soper-Wheeler. Three species were grown, Douglas-fir, pondersoa pine, and white fir

Problems with pH complicated the study while the seedlings were in the nursery. Over all, the constant rate fertilized seedlings outgrew the exponentially fertilized ones. Mortality was excessive with the latter application technique.

Vic Timmer visited Cal Forest Nursery in January of 2002.

The foliar analysis done at Davis showed a range of nitrogen levels in the seedlings, but only in the constant feed application. Timmer believed that nutrient concentrations were too low in the early stages for the exponential treatments, and that seedlings were stunted and not able to catch up to those in the constant feed treatment. A later foliar sample from Scott's Lab showed minor but consistent differences in nitrogen levels among the constant feed treatments. Whole seedling nitrogen concentrations generally increased in

proportion to nitrogen concentrations in the constant feed solution.

It was decided to out-plant only the two extreme treatments in the constant feed technique: 50 ppm and 300 ppm.

The seedlings were lifted in February. Seedling height and caliper were recorded for each treatment and needles were collected and sent to Scott's Laboratory for analysis. This data will serve as baseline data.

In order to make this and other studies under Working Group I more compatible with the needs from Working Group II, the original design for this study was changed (see meeting notes for February 19 –20). Six replications of each treatment were to be out-planted if there were sufficient seedlings available. Spacing was to be increased to 10' X 10'. Plot size was to be 70' X 70' with 25 measure trees surrounded by a row of buffer trees in each plot. Seedling protection was to be applied at time of planting. The sites on Boise Cascade and Fruit Growers had been ripped; the site on Soper-Wheeler had not. To overcome this difference, the seedlings for the Soper-Wheeler site were to be auger planted. Vegetation control would be applied chemically to all plots and the plots will be kept weed-free during the life of the study.

All plots were established by the last week in March, 2002. Plot corners were marked by metal conduit and planting spots were designated with wire stake flags. All three sites had been planted as of the first week in April. Only ponderosa pine had sufficient numbers of seedlings to be out-planted on the Boise Cascade site. Six replications of the 50 ppm and 300 ppm treatments were out-planted there. Fruit Growers had enough seedlings for 5 replications of each treatment for ponderosa pine and white fir; four replications of Douglas-fir were out-planted. Six replications of each treatment for ponderosa pine and white fir and five replications of Douglas-fir were out-planted on the Soper-Wheeler site.

Measurements for seedling height and caliper were taken at all three sites in October, 2002. Needle samples were taken at this time for foliar analysis. This foliar analysis is currently being done. Survival was noted at the time the measurements were being taken.

First year data were analyzed in December, 2002. The experimental design was completely randomized with one-way treatment structure. Two treatments were each replicated 4 to 6 times. To test for treatment effects and significant differences among treatments, one-way analysis of variance of treatment means and Tukey tests were applied. Statistical significance in all tests was at the 0.05 level.

Results: Survival at the end of the first growing season was uniformly high for both treatments with all species on the three sites. Survival was always higher for the 50 ppm treatment when compared to the 300 ppm treatment but not statistically higher. For the study as a whole (all three sites), ponderosa pine survival ranged from 97-100 percent; white fir from 91-100 percent; and Douglas-fir from 94-100 percent.

Caliper, height, and volume values for the seedlings are presented in Table 1 and Table 2. The first table shows

values at the time of lifting at Cal Forest Nursery in February of 2002. The second table shows the values at the end of the first growing season after out-planting. These measurements were taken in October, 2002. Volume is derived by multiplying squared caliper by the height.

For ponderosa pine, the only significant differences at time of lifting were for caliper of the Boise Cascade seedlings, where the 50 ppm treatment seedlings were larger than those in the 300 ppm treatment (a 19% increase), and height of the Fruit Growers seedlings, where the 300 ppm treatment seedlings were taller than those in the 50 ppm treatment (17% taller)

White fir seedlings showed no significant differences in caliper at time of lifting. Seedling height and volume for the 300 ppm treatment were always significantly larger than their counterparts in the 50 ppm treatment, however. The height of the seedlings receiving the 300 ppm treatment was about 45% greater than the height of those that received the 50 ppm treatment. The volume of the 300 ppm seedlings was about 50% more than volume of the 50 ppm seedlings.

For Douglas-fir, there were significant differences in height and volume at time of lifting for both Fruit Growers and Soper-Wheeler seedlings. The seedlings from the Fruit Grower's 300 ppm treatment also had significantly larger caliper than those seedlings in the 50 ppm treatment. Seedlings that were fertilized at the 300 ppm rate showed about a 30% increase in height over those fertilized at the 50 ppm rate. Volume was about 60% larger for the 300 ppm seedlings when compared to the 50 ppm seedlings.

It is obvious from the data presented in Table 1 that the seedlings are responding early on to the different levels of fertilization. For the most part, the seedlings that received the largest fertilizer rate (300 ppm) were bigger than those seedlings that received the smaller rate (50 ppm). At the time of their lifting in the nursery, white fir and Douglas-fir showed significant differences in height and volume for all seed lots. Those seedlings receiving the 300 ppm treatment were always larger than those receiving 50 ppm. Generally speaking, ponderosa pine seedlings did not show these differences.

The values shown in Table 2 represent the seedlings at the end of their first growing season after out-planting.

Even after one growing season in a plantation, ponderosa pine caliper does not differ significantly between the two fertilizer treatments. This is true for all three sites. The caliper for those seedlings receiving the 300 ppm treatment is always larger than that for the seedlings receiving 50 ppm, but not significantly so. Height and volume are a different story. Unlike at the time of lifting, these two values show significant differences between the two treatments after one growing season in a plantation. The values for the 300 ppm treatment are always significantly larger than those for the 50 ppm treatment. Height for the 300 ppm treatment shows about a 20% increase (average for the three sites) over the 50 ppm treatment. Volume shows about a 30% increase.

White fir seedlings showed significant differences in caliper, height, and volume between the treatments at the end of the first growing season on both sites. The 300 ppm treatment always had significantly larger seedlings than did the 50 ppm treatment. Caliper was about 17% larger, height about 43% larger, and volume about 97% larger for the seedling in the 300 ppm treatment when compared to those in the 50 ppm treatment.

Douglas-fir followed the pattern shown by white fir. In all instances except for the caliper of the Fruit Grower's seedlings, the values for the seedlings receiving the 300 ppm treatment were significantly larger than the values of those seedlings receiving the 50 ppm treatment. Height for the 300 ppm treatment was about 30% taller (two site average) than that of the 50 ppm treatment. Volume was about 65% more in the 300 ppm treatment than in the 50 ppm treatment.

In summary, after their first growing season, seedlings that were fertilized at the 300 ppm rate are always significantly taller and have significantly more volume than do their counterpart that received the 50 ppm rate. With the exception of ponderosa pine, this is also true for caliper. The percentage differences in height and volume that showed up at time of lifting are continuing to show after one year. The difference in volume is actually increasing. Survival is high regardless of treatment.

The seedlings will be measured at the end of their second growing season (fall 2003) to determine if these differences will continue to show. The higher level of fertilization does produce a larger seedling at least through the first growing season

2003: The seedlings were remeasured for caliper and height at all three sites in the fall of 2003 at the end of their second growing season. Survival was noted at the time the measurements were being taken.

Survival at the end of the second growing season was still uniformly high for both treatments with all species on the three sites. Unlike at the end of the first growing season, survival was not always higher for the 50 ppm as compared to the 300 ppm. For the study as a whole (all three sites), ponderosa pine survival ranged from 95-99 percent; white fir from 83-99 percent; and Douglas-fir from 85-91 percent. These percentages are lower than those reported at the end of the first growing season, but not significantly so.

Caliper, height, and volume values for the seedlings are presented in Table 3. Volume is derived by multiplying squared caliper by the height. These values represent the seedlings at the end of their second growing season after out-planting.

At the end of two growing seasons in a plantation, ponderosa pine caliper does not differ significantly between the two fertilizer treatments. This is true on all three sites. The caliper for those seedlings receiving the 300 ppm treatment is always larger than that for the seedlings receiving 50 ppm, but not significantly so. Ponderosa pine height is significantly taller for the seedlings receiving 300 ppm when compared to those seedlings receiving 50 ppm. This

is true for all three sites. Height for the 300 ppm treatment showed about a 13% increase (average for the three sites) over the 50 ppm treatment. The ponderosa pines on the Fruit Growers site were the only ones to show significant differences for volume between the treatments. This is different than in 2002 when all three sites showed significantly more volume in the 300 ppm treatment as compared to the 50 ppm treatment. The 2003 volume for the seedlings receiving 300 ppm was about 35% more than the volume of the seedlings receiving 50 ppm.

Unlike at the end of the first growing season at which time both sites showed significant differences in white fir caliper, only the Soper-Wheeler site shows significant difference between the treatments in 2003. The caliper of the seedlings receiving 300 ppm was about 18% larger than the caliper of the seedlings receiving 50 ppm. As they were in 2002, height and volume for white fir is significantly larger on the 300 ppm treatment as compared to the 50 ppm treatment on both sites, although the differences are getting smaller. Height is about 27% larger and volume about 63% larger.

Douglas-fir showed no significant differences between treatments in caliper or volume on either of the sites. The values for the 300 ppm treatment were always larger than for the 50 ppm treatment but not significantly so. This is different than in 2002 at which time there were significant differences in volume on both sites and significant differences in caliper on one of the sites. Douglas-fir height was significantly different between the two treatments on both sites. For the study as a whole, height was about 24% larger in the 300 ppm treatment than in the 50 ppm treatment. This percentage difference is less than that found at the end of the 2002 growing season.

In summary, after their second growing season, seedlings that were fertilized at the 300 ppm rate are always significantly taller than are their counterparts that received 50 ppm. But the differences are less than at the end of the first growing season. Many of the significant differences among treatments in caliper and volume that showed up at the end of the first growing season are no longer there. The 300 ppm treatment always gives the higher values for these two variables but many of the differences among the two treatments are no longer statistically different. Survival continues to be high for all treatments.

2004: Seedlings were remeasured for caliper and height at all three sites in the fall of 2004 at the end of their third growing season. Survival was noted at the time the measurements were being taken.

Survival continues to be high for both treatments with all species on the three sites. Survival for the 50 ppm treatment is slightly higher than that in the 300 ppm treatment in 5 of the 7 comparisons. For the study (all three sites), ponderosa pine survival ranged from 96-99 percent, exactly the same as at the end of the second growing season; white fir from 79-89 percent, down slightly from the end of the second growing season; and Douglas-fir from 80-90 percent, also down slightly from the second growing season numbers.

Caliper, height, and volume values for the seedlings are presented in Table 4.

Volume is derived by multiplying squared caliper by height. These values represent the seedlings at the end of their third growing season after out-planting.

Caliper: At the end of three growing seasons in a plantation, ponderosa pine caliper does not differ significantly between the two fertilizer treatments. This is true on all three sites. The caliper for those seedlings receiving the 300 ppm treatment is always larger than for those seedlings receiving 50 ppm, but not significantly so. As was the case at the end of the second growing season, only the Soper-Wheeler white fir showed significant difference between the treatments in 2004. Douglas-fir showed no significant differences between treatments in 2004 on either site.

Height: Ponderosa pine height is significantly taller for the seedlings receiving 300 ppm when compared to those receiving 50 ppm on the Soper-Wheeler site only. Although there is a difference, it is not significant on the other two sites. This is a change from the 2003 results in which height was significantly taller with the 300 ppm treatment on all three sites. Only on the Soper-Wheeler site was height difference significant for white fir between the treatments. The seedlings receiving 300 ppm were always larger. In 2003 both sites having white fir showed significant differences in height. The only significant difference in Douglas-fir height was on the Fruit Growers site. In 2003 both sites having Douglas-fir showed significant differences in height.

Volume: There was no significant difference in volume between treatments for ponderosa pine on any of the sites. This differed from 2003 at which time the Fruit Growers site showed significant differences in pine volume. The Soper-Wheeler site was the only site showing significant differences in white fir volume between the treatments. Last year the Fruit Growers and the Soper-Wheeler sites showed significance differences. As was the case in 2003, Douglas-fir showed no significant differences in volume due to treatment on any of the sites.

In summary, after three years in a plantation, seedlings that were treated at the 300 ppm rate are always taller, have larger caliper, and have more volume than seedlings treated at the 50 ppm rate. But the majority of these differences are no longer significant. Of the 21 comparisons possible (fertilizer rates/species), only 5 show significant differences. In 2003 that number was 11. There seems to be an influence of site quality (most influence on higher sites) but even this generalization has problems. As far as tree species, white fir is the most influenced by fertilization rate. The most influenced dependent variable is tree height. Survival continues to be high on all sites for all treatments.

Total Funded: $30,000; Total Spent as of 12/31/04: $15,002.31.

Table 1-- Values for caliper, height, and volume for seedlings for the Timmer/Jopson Proposal at time of lifting, February, 2002.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Boise Cascade			
50 ppm	0.487a	15.000a	3.602a
300 ppm	0.409b	17.000a	2.928a
Fruit Growers Supply			
50 ppm	0.495a	16.200b	4.040a
300 ppm	0.457a	19.000a	3.909a
Soper-Wheeler			
50 ppm	0.476a	14.450a	3.295a
300 ppm	0.436a	16.850a	3.267a
White Fir			
Fruit Growers Supply			
50 ppm	0.347a	15.056b	1.842b
300 ppm	0.347a	23.889a	2.915a
Soper-Wheeler			
50 ppm	0.371a	16.600b	2.298b
300 ppm	0.384a	22.300a	3.313a
Douglas-fir			
Fruit Growers Supply			
50 ppm	0.383b	21.553b	3.229b
300 ppm	0.429a	30.580a	5.727a
Soper-Wheeler			
50 ppm	0.406a	26.000b	4.404b
300 ppm	0.440a	32.100a	6.252a

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 2-- Values for caliper, height, and volume for seedlings for the Timmer/Jopson Proposal at end of first growing season, October, 2002.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Boise Cascade			
50 ppm	0.756a	26.818b	16.948a
300 ppm	0.803a	29.170a	20.435a
Fruit Growers Supply			
50 ppm	0.896a	24.360b	21.178b
300 ppm	0.940a	29.976a	28.244a
Soper-Wheeler			
50 ppm	0.879a	19.977b	16.582b
300 ppm	0.921a	26.186a	24.009a
White Fir			
Fruit Growers Supply			
50 ppm	0.416b	20.628b	3.791b
300 ppm	0.484a	29.217a	7.282a
Soper-Wheeler			
50 ppm	0.490b	19.653b	5.045b
300 ppm	0.579a	28.399a	10.259a
Douglas-fir			
Fruit Growers Supply			
50 ppm	0.584a	28.475b	10.757b
300 ppm	0.659a	36.941a	17.544a
Soper-Wheeler			
50 ppm	0.592b	25.319b	9.663b
300 ppm	0.669a	33.945a	16.136a

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 3-- Values for caliper, height, and volume for seedlings for the Timmer/Jopson Proposal at end of second growing season, October, 2003.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Boise Cascade			
50 ppm	1.81a	43.79b	176.23a
300 ppm	2.02a	48.11a	219.36a
Fruit Growers Supply			
50 ppm	1.52a	38.89b	102.12b
300 ppm	1.65a	45.82a	137.57a
Soper-Wheeler			
50 ppm	1.97a	40.52b	176.53a
300 ppm	2.08a	45.83a	218.40a
White Fir			
Fruit Growers Supply			
50 ppm	0.77a	28.60b	18.74b
300 ppm	0.84a	36.69a	29.65a
Soper-Wheeler			
50 ppm	0.80b	27.31b	20.31b
300 ppm	0.94a	34.11a	33.88a
Douglas-fir			
Fruit Growers Supply			
50 ppm	0.83a	31.72b	27.52a
300 ppm	0.93a	40.40a	43.16a
Soper-Wheeler			
50 ppm	0.90a	33.46b	33.69a
300 ppm	1.00a	40.55a	45.42a

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.

Table 4-- Values for caliper, height, and volume for seedlings for the Timmer/Jopson Proposal at end of third growing season, October, 2004.

	Caliper (cm)	Height (cm)	Volume (cm^3)
Ponderosa Pine			
Boise Cascade			
50 ppm	3.64a	87.44a	1397.64a
300 ppm	4.04a	97.14a	1738.00a
Fruit Growers Supply			
50 ppm	3.06a	62.03a	690.63a
300 ppm	3.26a	67.88a	816.00a
Soper-Wheeler			
50 ppm	2.96a	78.89a	797.10a
300 ppm	3.18a	85.06b	969.53a
White Fir			
Fruit Growers Supply			
50 ppm	1.41a	43.01a	100.07a
300 ppm	1.55a	49.19a	140.48a
Soper-Wheeler			
50 ppm	1.21a	44.07a	74.62a
300 ppm	1.51b	52.16b	132.71b
Douglas-fir			
Fruit Growers Supply			
50 ppm	1.51a	47.83a	143.25a
300 ppm	1.70a	56.82b	201.02a
Soper-Wheeler			
50 ppm	1.30a	50.15a	107.38a
300 ppm	1.37a	53.07a	116.66a

For land-owner and species, treatment means in each column followed by the same letter do not differ significantly at the 0.05 level.