Fertilization of Douglas-fir and Noble Fir Christmas Trees

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Abstract

This study evaluated the impacts of nitrogen (N) and sulfur (S) applications through a rotation of noble and Douglas-fir Christmas trees. A wide spectrum of both increasing and constant N/S rates were used. Color was the only tree variable positively correlated to N/S rate on both species. On Douglas-fir, value was improved on the shallow hill soils with the increasing rates.

Soil acidity values in the upper 8 inches of soil was also reduced by .7 pH units for Douglas-fir at the highest N/S application rates.

The ^{15}N study found that prior N/S fertilization had no impact on N uptake. Approximately 20% of the fertilizer was used by the trees, 30% was stored in the soil, an estimated 40% was lost by leaching, and an estimated 10% lost by denitrification.

Introduction

Included in this brief summary are the results from three related fertilizer experiments on Christmas trees. Two of these were similar in design but used different species- noble fir and Douglas-fir. These two studies are evaluations of various nitrogen (N) and sulfur (S) application rates. In addition, on the noble fir plots applications of sul-po-mag were evaluated.

The third study, ^{15}N, evaluated movement of nitrogen into the tree and through the soil profile.

Procedures-Fertilizer Plots

Noble Fir Plot Locations

Nine plots were established in the spring of 1988. Plot locations extended from Rochester, Washington to Oakland, Oregon. Plots were located on either well-drained valley soils or on well-drained hill soils.

Douglas-fir Plot Locations

Nine plots were established in the spring of 1987. Plot locations extended from Springfield, Oregon to Chehalis, Washington. Plots were estabfished on three different groups of soils with three plots on each grouping. The soil groups were well-drained valley soils, deep hill soils, and shallow hill soils.

Douglas-fir and Noble Fir Plot Layout

A randomized split-plot experimental design was used in the fertilizer rate studies with a block on soil group (i.e., valley and hill soils). All plots were located in well-managed plantations, cared for by experienced growers. The seedlings on these plots had been planted the year previous to the beginning of the study. Most seedlings were 2-0s when planted and initially measured 12 to 15 inches tall. Planting spacing was either 5 X 5 feet or 5.5 X 5.5 feet. Four fertilizer treatment areas (control, low, medium and high) were randomly established at each plot location. These blocks were then split, so that each split plot or experimental unit was approximately 45 X 35 feet (or 7 by 9 tree spaces). The inner 15 trees constituted the measurement trees on each split plot.

Fertilizer Materials

A blended granular fertilizer of urea and ammonium sulfate (urea-sul, 33-0-0-12) was used for all N/S applications.

One split-plot in the noble fir study received annual applications of "sul-po-mag" (also commonly called "K-Mag"). The analysis of this material is 0-0-22-22-11 (N-P-$K_2$0-S-MgO).

The fertilizer was uniformly applied, by hand, in a two-foot diameter around each seedling during the first year of the study. In all following years, fertilizers were broadcast. Fertilization was done in March of each year.

Treatments

Tables 1-3 outline the application rates used in the study.

Table 1. Noble fir- Annual lb/acre N, S, K_2O and MgO applied for each treatment.

Treatments	Fertilizer	1988	1989	1990	1991	1992	1993	1994
Control-A (1-1)	none	0	0	0	0	0	0	0
Control-B (1-2)	sul-po-mag ($S/K_2O/MgO$)	0	0	92/92/46	92/92/46	92/92/46	92/92/46	92/92/46
Low-A (2-1)	urea-sul (N/S)	15/5	15/5	15/5	15/5	15/5	15/5	15/5
Low-B (2-2)	urea-sul (N/S)	15/5	15/5	15/5	25/9	25/9	25/9	50/18
Medium-A (3-1)	urea-sul (N/S)	45/16	45/16	45/16	45/16	45/16	45/16	45/16
Medium-B (3-2)	urea-sul (N/S)	45/16	45/16	45/16	75/27	75/27	75/27	150/54
High-A (4-1)	urea-sul (N/S)	135/49	135/49	135/49	135/49	135/49	135/49	135/49
High-B (4-2)	urea-sul (N/S)	135/49	135/49	135/49	225/82	225/82	225/82	450/164

Table 2 . Noble fir- Total N,S, K_2O and MgO applied during study, 1988-1994.

Treatment	Fertilizer	lb N/ac	lb S/ac	lb K_2O/ac	lb MgO/ac
Control A	none	0	0	0	0
Control B	sul-po-mag	0	460	460	230
Low A	urea-sul	105	35	0	0
Low B	urea-sul	170	60	0	0
Medium A	urea-sul	315	112	0	0
Medium B	urea-sul	510	183	0	0
High A	urea-sul	945	343	0	0
High B	urea-sul	1530	557	0	0

Table 3. Douglas-fir- Annual and total pounds/acre of N and S applied for each treatment.

Treatments	Fertilizer	1987	1988	1989	1990	1991	Total lb N/S/Ac.
Control-A (1-1)	none	0	0	0	0	0	0
Control-B (1-2)	urea-sul (N/S)	0	0	0	195/70	195/70	390/140
Low-A (2-1)	urea-sul (N/S)	15/5	15/5	15/5	15/5	15/5	75/25
Low-B (2-2)	urea-sul (N/S)	15/5	15/5	25/9	50/18	50/18	155/55
Medium-A (3-1)	urea-sul (N/S)	45/16	45/16	45/16	45/16	45/16	225/80
Medium-B (3-2)	urea-sul (N/S)	45/16	45/16	75/27	150/54	150/54	465/167
High-A (4-1)	urea-sul (N/S)	135/49	135/49	135/49	135/49	135/49	675/245
High-B (4-2)	urea-sul (N/S)	135/49	135/49	225/82	450/164	450/164	1395/508

Soil Measurements

Baseline soil chemical analyses were made prior to the initial fertilizations. Macro and micro nutrient concentrations, pH and organic matter were determined at two depths: 0-8 and 8-16 inches. Also, pH was monitored as the study progressed. Following the final year of fertilization, all soil variables were reevaluated. These data provide an indication of how soil chemistry changes over time in a fertilized Christmas tree field.

Foliar Analyses

Tissue nutrient analyses were conducted each year in September. Sampling was done by removing a pinch of 3 to 6 needles from current season foliage at approximately 10 to 20 locations throughout the upper one-half to two-thirds of the tree crown. A range of macro and micro nutrients (N, P. K, S, Ca, Mg, Mn, Fe, Cu, B, Zn) were analyzed at various points during both studies.

On noble fir, foliar analyses were conducted to determine nutrient variations associated with whorl position.

Growth and Quality Parameters

Measurements were conducted throughout both studies to determine effects of fertilizer treatments on tree growth, quality and value.

Procedures- ^{15}N Study

Research plots were established in a third rotation Douglas-fir Christmas tree plantation eight miles east of Salem, Oregon. This site was chosen because it was also the location of one of the nine test sites. This allowed comparing N movement with and without previous fertilization. Soil was a 35-inch deep silty clay loam. In late March, a water table was encountered at a depth of 30 inches.

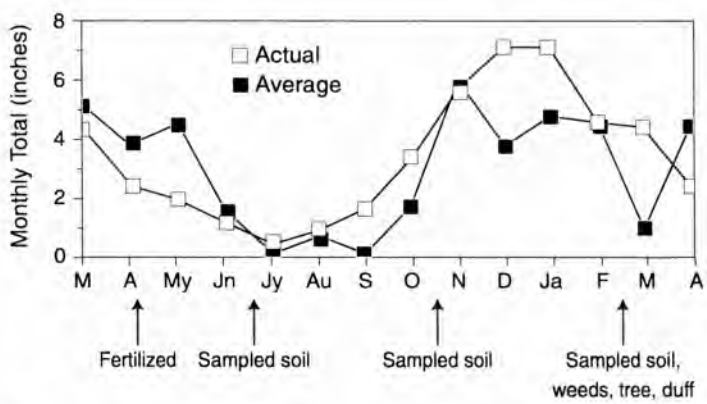

Figure 1. Comparison of actual rainfall during the study period with historical average.

Rainfall during the 385-day study period is shown in Figure 1.

The experimental design consisted of two blocks of six trees each. Each block was 5 by 30 feet to a depth of 30 inches. One block received 390 pounds of N in the last two years (Table 3). This plot is referred to as 390+N. The other bloc received no N fertilization prior to this study. Thi plot is referred to as 0+N.

Perimeters of the treatment blocks were trenched to a depth of 30 inches, lined with black plastic and backfilled. A liquid solution of ammonium sulfate (21-0-0-24), providing 150 lb Nacre was applied on both blocks on March 26, 1991. The fertilizer N solution contained about 5% ^{15}N.

At the conclusion of the study, dynamite was used to extract the roots, following a technique perfected by Mike Newton, Oregon State University Professor.

Results-Fertilizer Plots

On both the noble and Douglas-fir experiments, the only tree measurement variable related to N rate was tree color. Figures 2 and 3 illustrate the color change associated with increasing N application rates for each species.

Figure 4 illustrates changes in soil pH at two soil levels resulting from N and S fertilization through one rotation of Douglas-fir Christmas trees. The

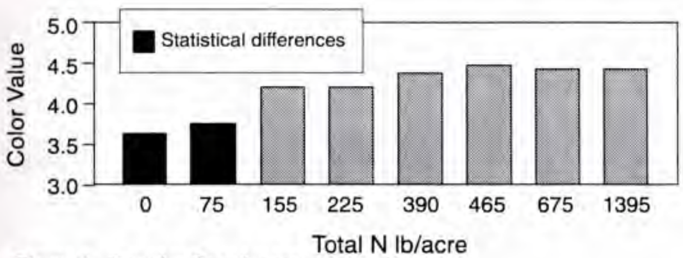

Figure 2. Douglas-fir color response to N rate.

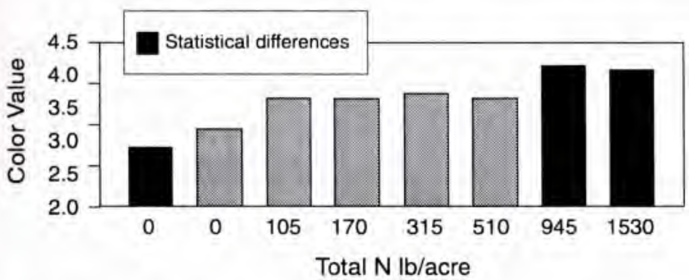

Figure 3. Noble fir color response to N rate.

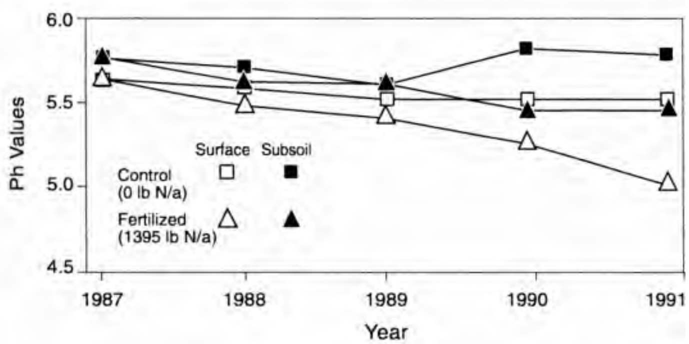

Figure 4. pH values at two soil levels by treatment in Douglas-fir (0, 1385 lb/ac N).

pH changes are illustrated for the control plots and the highest N application (1395 lb. N) at two different depths- surface (0-8 inches) and for the subsoil (8-16 inches). Important to note here is the steep drop in pH in the upper 0-8 inch soil on the heavily fertilized plots.

The table below summarizes the research results for Douglas-fir. It is interesting to note that soil grouping had an important interaction with the N and S applications. When all plots were analyzed together, no relationship was found with N and S rate and final tree value (a derived value based on tree height and grade). When soil grouping and value were separated N and S rate was important in the shallow hill soils.

Douglas-fir Summary	Results
All trees on all plots	No relationship between fertilizer rate and value
By soil grouping:	
Deep hill soils	No relationship between fertilizer rate and value
Valley soils	No relationship between fertilizer rate and value
Shallow hill soils	The data suggests that the increasing fertilizer rates (treatments 155, 465, 1395) improved average tree value.

For Noble fir, no relationship between N/S rates and value were found.

On noble fir, foliar analyses were conducted to determine nutrient variations associated with whorl position.

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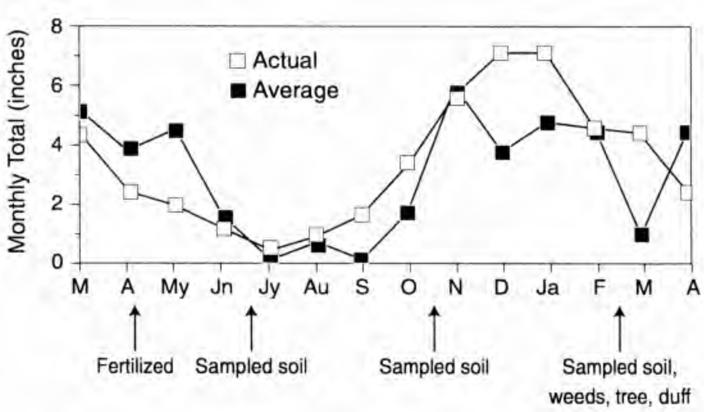

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Results- ^{15}N Study

Distribution and Loss of N Fertilizer

The uptake and loss of N fertilizer was similar for trees with previous fertilization (390+N) and those without (0+N). The expectation was that previous fertilization of the 390+N plots would have enriched the soil and trees with available N. Consequently, the trees would have been expected to use less of the applied fertilizer N. The finding of no difference between the two treatments is interpreted to mean that N from previous applications was not present or available in the soil. Further, the demand for N from previously fertilized trees was no less than for trees not previously fertilized.

At the end of this study, 21% of the N fertilizer was found in the trees, 30% remained in the soil, and the balance, 49%, was lost from the site. The amount of N lost was considerably higher than expected. In a similar study (Heilman et. al. 1982) in young forest plantations approximately 32% of the applied N fertilizer was not taken up by the trees or found in the soil and was presumably lost from the site. In another study under forest conditions, Cole and Gessel (1965) found very little N was lost from fertilizer they applied to a fully vegetated forest site.

Possible mechanisms for the N loss are volatilization, denitrification, and leaching. Volatilization can occur when urea-based fertilizers are applied in the late winter and early spring. Warm soil and air conditions can cause gaseous ammonia to be released from the fertilizer directly into the atmosphere. Applying liquid ammonium sulfate, as done in this study, should have minimized any volatilization loss.

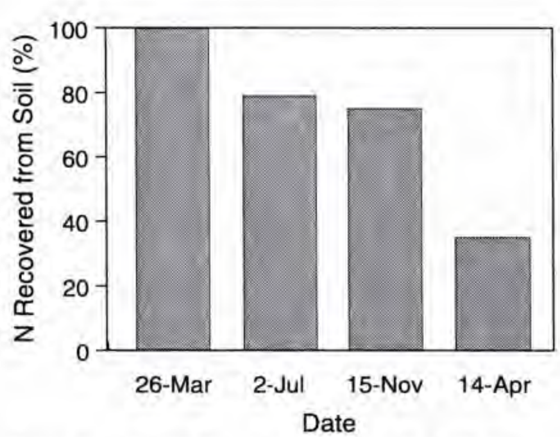

Figure 5. Fertilizer N remaining in the soil at different sampling times.

Denitrification is a natural process that occurs when soil microorganisms convert nitrate forms of N into nitrogen gas which escapes into the air. This process occurs most commonly in saturated soil conditions, especially near the water table in the soil profile. Based on current knowledge about denitrification in well-drained soils, it is believed unlikely that more than 10% of the fertilizer N loss was caused by denitrification.

Leaching, then, is believed to be the main cause of N loss. This conclusion is supported by two important observations. First, the abnormally high rainfall shortly after application (52% above normal) likely pushed the fertilizer N lower in the soil profile than would be expected in a normal year. At this lower location, the nitrogen was more likely to be leached below the root zone the following winter or denitrified in the saturated soil zone near the water table.

Secondly, a 40% decrease in recoverable nitrogen in the soil was observed between the sample dates of November, 1991 and April, 1992 (Figure 5). This loss came at a time when plant uptake is very slow and rainfall amounts for the year are very high leading to the belief that N was lost to leaching.

Tree Nitrogen Distribution and Removal at Harvest

Table 4. Total N by tree part.

Tree Part	Total N lb/acre
Branches and Needles	164
Stems	14
Roots	11
Duff	21
Total	210

Table 5. Total N in the soil at the study site by soil depth.

Soil depth (inches)	Total N (lb N/ac.)
0-8	4626
8-16	3400
16-24	3000
Total	11026

Total N in the trees and soil is shown in Tables 4 and 5, respectively. At harvest, branches, needles and stems would be removed from the site, which would remove 178 lb N/ac. Because the soil contains over 11,000 lb N/ac, depletion of total N from the site is not a serious concern. However, probably only a tiny fraction of the total soil N becomes available to the trees during the growing season, and this amount may, in fact, be less than the trees annual requirements, meaning that the trees may benefit from readily available fertilizer N.

Conclusions

Fertilizer N/S significantly improved tree color for both species. Other tree variables showed no response to N/S, except on shallow hill soils, where value was improved with the increasing fertilizer rates.

Heavy N/S fertilization during a rotation increased soil acidity in the upper soil levels by .7 pH units.

The ^{15}N study determined that about 20% of the fertilizer N was used by the trees, 30% was stored in the soil, up to 40% was lost by leaching, and 10% or more was suspected to have been lost by denitrification. Because of heavier than normal rainfall in the four months following fertilizer application, and because of root pruning incurred during plot installation, leaching losses may have been greater than typical. In spite of these reservations, growers should be aware that significant leaching losses are a real possibility.

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