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Christmas Tree Nutrient Management Guide

for

Western Oregon and Washington

Oregon State University
Extension Service

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During the past 50 years, plantation Christmas tree production has grown in acreage and sophistication. Nitrogen applications with a tuna can have been replaced by precise, mechanized application of a wide array of nutrients and lime.

Current nutrient management programs must focus on three concepts for success.

- Is the management practice biologically sensible? Is it likely that fertilizing these trees at this time and with this product will produce a significant improvement in tree color or growth?
- Is the management practice economically efficient? Can I afford it based on expected results?
- Is the management practice environmentally responsible? Does it produce little or no potential negative impact on soil, water, or air quality?

When the answer to all three questions is "yes," nutrient management practices should be used to increase Christmas tree quality and profitability.

To understand and influence plant nutritional health and performance, you need a broad knowledge of several important topics, including:

- How conifers grow
- The nutrients necessary for optimal growth
- How to assess the nutrient status of soil and plant foliage
- How to formulate a strategy for nutrient management during the rotation

These topics form the basis for this publication. This guide provides more than fertilizer and lime recommendations; you also will learn to assess a plantation's nutritional needs based on soil and foliar analyses and rotational timing. These tools will help you design strategies for effective nutrient applications and produce high-quality trees with minimal negative environmental impact.

Figure 1. Christmas trees growing on Bellpine soil in Oregon.

The recommendations included here are appropriate for Christmas tree growers in the foothills of the coastal and Cascade ranges of western Oregon and Washington. In these regions, Christmas trees typically are grown on well-drained clay loam soils at 500 to 1,500 feet elevation. Common soil series include Salkum, Prather, Cinnebar, Olympic, and Melbourne in Washington, and Lauralwood, Aloha, Bellpine, Goble, Cornelius, Chehalem, Cazadero, Bornstedt, Alspaugh, Honeygrove, and Jory in Oregon (Figure 1). Many of these soils are forest-derived soils that were cleared for agricultural production. Most are reasonably productive for Christmas tree plantations.

The region's widely planted tree species, Douglas-fir and noble fir, are our primary focus. We assume that trees are sheared and that planted seedlings are suitable for Christmas tree production. Fertilization will not compensate for other growth-limiting problems such as soil compaction, poor drainage, pest infestations, weather-related stress, or poor tree selection (Figure 2).

Field research from Oregon and Washington (1987–2003), research from other areas and other crops, and grower observations are the basis for guidelines presented here (Figure 3). This publication is a guide, not a prescription. Use it to formulate recommendations that make sense based on your management style, economics, and site conditions. Consultation with a nutrient management professional may aid in decision-making.

Figure 2. Christmas trees growing in a rocky Briedwell soil. Planting in these or similar situations is not recommended, as the droughty nature of the site can be difficult to manage.

Conifer growth

Christmas trees are part of a complex biological system made up of the tree, soil, water, and air. Trees take moisture and nutrients from the soil and air and move them to the foliage, which converts energy from the sun and produces compounds necessary for survival and growth.

Plants require 16 elements for growth. Carbon, hydrogen, and oxygen are obtained from air and water. The remaining 13 elements—nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, copper, chlorine, manganese, molybdenum, iron, and zinc—are supplied by the soil. All soil-supplied nutrients are available in fertilizer form. The key to economical Christmas tree production is to apply only the nutrients not adequately supplied by soil.

Christmas tree growers need to consider when to apply nutrients each year (annual timing) as well as when to apply nutrients during the life of a stand (rotational timing).

Figure 3. More than a decade of research was performed to establish relationships between Christmas tree growth, color, and nutrient level.

Seasonal and developmental changes influencing nutrient management

Christmas tree growth follows an annual cycle. Understanding this growth pattern helps ensure that fertilizer applications are timed properly. Proper timing of nutrient application promotes growth and improved color, while minimizing environmental risk. Figure 4 shows a typical pattern of Christmas tree root and shoot growth in western Oregon and western Washington.

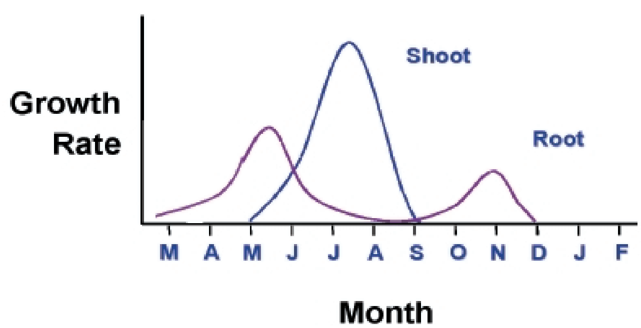

Figure 4. Annual growth rate of roots and shoots. Note that peak root and shoot growth occur at different times of the year.

When root growth begins in February or March, trees benefit from fertilization with mobile elements, such as nitrogen, sulfur, and boron. These nutrients move easily in the soil to Christmas tree roots, which take them into the plant.

Spring bud break occurs during April or May, depending on the tree species and weather conditions. Appearance of new foliage is the most prominent feature of bud break. This event marks the beginning of the trees' annual maximum nutrient need. Shoots and roots are growing simultaneously. The trees must be able to draw from a full complement of nutrients in the soil as growth progresses.

Be especially careful when applying any material shortly after bud break. New needles lack the waxy cuticle layer that protects older needles. Thus, they are susceptible to damage from corrosive or salty materials such as fertilizers and oil-based surfactants applied directly to the needles.

During late summer, conifers stop producing new foliage and set buds for the next growing season. Although food storage and wood production continue into the fall, few nutrients move through the aboveground part of the tree during this time. Therefore, late summer is the time to collect needle samples for nutrient analysis.

A minor root growth spurt accompanies fall rains. Soil and air temperatures continue to drop as the rainy season progresses. Trees reach maximum dormancy in the winter.

Tree growth removes nutrients from the soil. As conifers grow, the amount of nutrients stored above ground in wood and foliage doubles each year. Approximately 50 to 60 percent of the nutrients are in the needles, 25 percent in branches, and 15 percent in roots and trunk. Figure 5 shows the nutrient content of a typical conifer needle.

Tree harvest removes nutrients permanently from the field. Table 1 shows approximate amounts of nutrients removed by harvest.

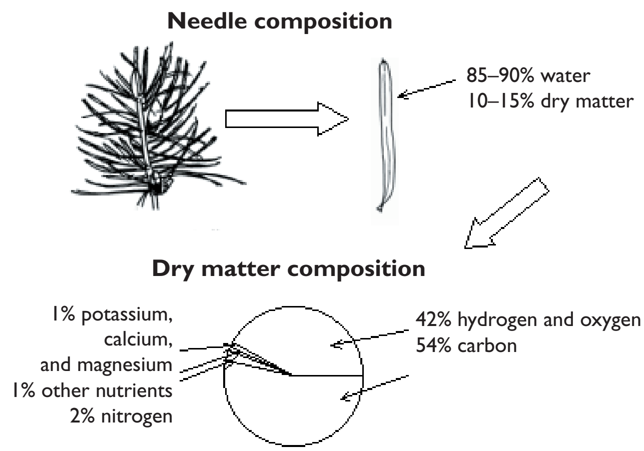

Figure 5. Conifer needle composition. Elements other than hydrogen, oxygen, and carbon are supplied from the soil.

Table 1.—Approximate nutrient removal with harvest

Nutrient	Amount removed (lb/acre)
Nitrogen (N)	125–175
Phosphorus (P)	15–25
Potassium (K)	75–150
Calcium (Ca)	75–125
Magnesium (Mg)	7–15
Sulfur (S)	5–15

Table 2.—Outline of nutrient monitoring and management strategies for Christmas tree plantations.

Plantation age or tree height	Monitoring activity	Season	Field operation
Site preparation	Soil sampling for Ca, Mg, K, P, pH, and SMP lime requirement	Be consistent	Incorporate Ca, Mg, K, P, and liming materials into soil as needed.
Early rotation or tree height less than 3 feet	None needed unless observation indicates potential problems		Apply fertilizer to individual trees if indicated by soil or foliar testing.
Midrotation or tree height greater than 3 feet	Single baseline foliar sampling for P, K, Ca, Mg, and S. Do not repeat unless results are low enough to cause concern. Annual foliar sampling for N and B	September or October	Broadcast or band needed fertilizers as indicated by test results and recommendations in this guide.

Rotational timing and nutrient assessment

Nutrient management for Christmas trees can be divided into four stages: site preparation (Figure 6), seedling establishment, early rotation (trees generally are less than 3 feet tall), and late rotation (trees are nearing harvest). Table 2 summarizes monitoring and field activities based on plantation age and height. Keep in mind that routine nutrient monitoring with soil and tissue testing is cheaper than purchasing and applying unneeded fertilizer.

Figure 6. The final tillage operation in preparation for planting Christmas trees usually is disking and smoothing.

Site preparation

Soils on which Christmas trees commonly are grown in western Oregon and western Washington can supply most nutrients in sufficient quantities for Christmas tree production. Soil analysis should always be the basis for preplant fertilization decisions (Figure 7). A soil test is an inventory of the soil's capacity to provide nutrients for tree growth. Soil analysis is recommended prior to planting every rotation. Test results can help you provide adequate nutrients for an entire rotation.

Soil tests important during site preparation are pH, phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and SMP buffer test for lime. P, K, Ca, and Mg do not move rapidly in the soil, so application and incorporation during site preparation is the best strategy. Typically, these nutrients move only an inch in the first year after application and even less in subsequent years. Figure 8 illustrates some differences in nutrient concentration with soil depth. Table 3 provides recommendations based on soil and foliar analysis for P, Mg, Ca, and K.

Correcting nonmobile nutrient deficiencies is difficult in perennial crops such as Christmas trees and is not recommended during a rotation because of their slow movement in soil. Amending soils to correct P, K, Ca, or Mg deficiencies will not affect foliar concentrations for at least 1 year after fertilizer is applied.

Soil can be analyzed during site preparation for other nutrients and properties not listed in Table 2, but their application at this time is not recommended. For example, soil organic matter can be measured; however, increasing it in Christmas tree plantations is difficult, expensive, and ineffective over the course of a rotation.

Taking a soil test and interpreting results

OSU Extension publication EC 628, *Soil Sampling for Home Gardens and Small Acreages*, provides information about sampling soils. *A List of Analytical Laboratories Serving Oregon*, EM 8677, is also available. See "For more information," page 26, for instructions on how to obtain these publications.

Soil test results provide the information upon which to base nutrient and lime addition decisions. They also influence the choice of material to supply the nutrients. Nutrient test results are discussed in this section. For information on specific fertilizer and lime materials, see Appendix 2, page 20.

Fertilizer recommendations based on soil tests (Table 3, page 6, and Table 5, page 10) are expected to provide nutrients needed for Christmas tree growth. Nutrient application is designed to produce growth, possibly a darker color, and an economic return. The rates recommended in this guide may not increase soil test values.

Phosphorus (P). Although soils in western Oregon and Washington are naturally low in plant-available P, phosphorus deficiencies severe enough to reduce Christmas tree growth or tree quality have not been well researched or well documented. Occasionally, soil test levels of less than 2 ppm have been observed without producing readily apparent growth limitations, reduced tree quality, or inadequate levels of foliar P.

Figure 7. Obtaining a soil sample with a tube or probe from a field of recently planted Christmas trees.

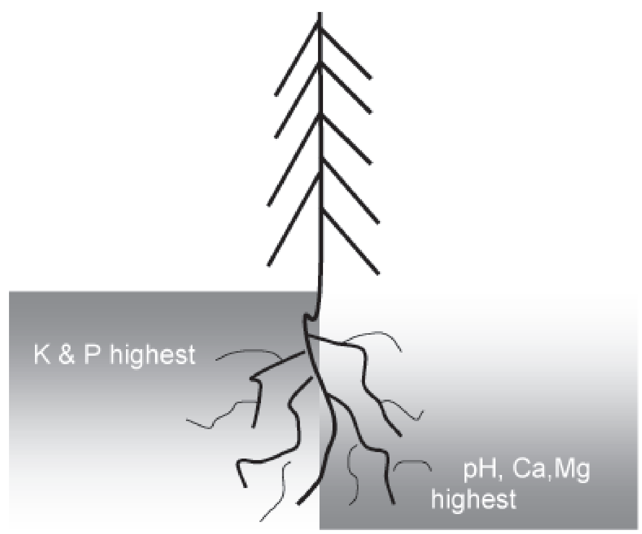

Figure 8. Fertilization influences nutrient distribution. Potassium and phosphorus concentrations decrease with depth in the surface foot of soil; pH, calcium, and magnesium concentrations increase with depth over the course of a rotation. Tillage between rotations reduces this effect.

Table 3.—Preplant fertilizer recommendations for Douglas-fir and noble fir Christmas trees based on pre-site-preparation soil analysis.

Nutrient	Test value	Rate	Comments[1]
Phosphorus (P)	**(ppm)**	**(lb P_2O_5/acre)**	Bray
	0–10	180	
	11–15	90	
	Above 15	Adequate; monitor foliar P.	
Potassium (K)	**(ppm)**	**(lb K_2O/acre)**	Ammonium acetate extractable
	Below 75	100–200	
	Above 75	Adequate; monitor foliar K.	
Soil pH	**(pH)**	**(ton lime/acre)**	
	Below 5	Add lime according to SMP buffer test (Table 4, page 7).	See "Magnesium" to determine whether dolomitic lime is needed.
	5–5.6	Consider adding 1–1.5 ton/acre.	See "Magnesium" to determine whether dolomitic lime is needed.
	Above 5.6	No lime needed.	
Calcium (Ca)	**(meq/100 g soil)**	**(ton lime/acre)**	Ammonium acetate extractable
	Soil Ca below 5 meq/100 g soil and pH below 5.0	Add lime as indicated by SMP buffer test (Table 4, page 7).	See "Magnesium" to determine whether dolomitic lime is needed.
	Soil Ca below 5 meq/100 g soil and soil pH between 5.0 and 5.5	1	See "Magnesium" to determine whether dolomitic lime is needed.
	Soil Ca above 5 meq/100 g soil and soil pH above 5.5	Monitor foliar Ca and Mg.	
Magnesium (Mg)	**(meq/100 g soil)**	**(ton dolomite/acre or lb Mg/acre)**	Ammonium acetate extractable
	Soil Mg below 0.4 meq/100 g soil and pH below 5.5	Add 1 ton dolomitic lime/acre.	
	Soil Mg below 0.4 meq/100 g soil and pH above 5.5	Apply 100–200 lb Mg/acre.	Supply Mg as K-Mag or Epsom salts.

[1]Recommendations are based on the listed lab test methods. Bray and ammonium acetate refer to methods used for soil analysis. Recommendations are designed for a soil sample from the soil surface to a depth of 6 or 8 inches.

Trees, to a greater extent than many plants, rely on mycorrhizal associations to extract P from soil. Mycorrhizae are beneficial fungal root infections. The fungi extend the tree's root area thousands of times and enable the roots to extract phosphorus and water much more efficiently than they would alone. The tree, in turn, provides the fungi with food (sugars). Both the tree and the fungi benefit.

Because P is immobile in soil, root distribution in the soil is important. Correcting P deficiencies after plantation establishment is difficult because P moves less than 0.25 inch per year. Therefore, applying and incorporating P before planting is critically important. As a precaution, growers are advised to apply P when soil tests are below 15 ppm, even though reduced growth or tree quality cannot be confidently predicted for lower soil test levels (see Table 3).

Potassium (K). Potassium-containing minerals are present in parent material of most Pacific Northwest soils. In general, this native K supply is adequate to meet Christmas tree need, making K fertilization unnecessary. However, farming practices or other activities occasionally deplete natural K levels, so check soil levels prior to planting to determine whether K supplies remain adequate. Potassium is removed in substantial amounts from the plantation with harvest, as shown in Table 1.

Table 4.—Lime requirement based on SMP buffer test.

SMP buffer	Ton/acre of 100-score lime* needed to raise pH of surface 6 inches of soil to the following pH	
	5.6	6.0
4.8–5.0	5–6	7–8
5.1–5.3	4–5	6–7
5.4–5.6	3–4	4–6
5.7–5.9	2–3	3–4
6.0–6.2	1–2	2–3
6.3–6.5	0	1–2
6.6	0	1

*Lime recommendation is based on the effectiveness of the liming reaction, regardless of lime source. See Appendix 2 for explanation of lime score and liming materials.

When soil K is below 75 ppm, apply K as recommended in Table 3. Potassium is not extremely mobile, so it should be incorporated prior to planting.

Soil acidity, pH, and liming. Soils in western Oregon and Washington are naturally acidic, with a pH between 5.0 and 6.5. Christmas trees are well suited to these moderately acidic soils. The recommended pH range for conifers is 5.0 to 5.6; therefore, soil management for Christmas tree production should not allow pH to drop below 5.0.

At the start of a rotation, apply lime if you think the soil pH may drop below 5.0 during the rotation. For example, if the soil pH is 5.2 at the beginning of the rotation, it easily could fall below 5.0 during the rotation, particularly if you add acidifying fertilizers such as ammonium or urea. If you till the field only every other rotation, ensure that the soil pH is sufficient for two rotations.

Lime increases soil pH, supplies Ca and/or Mg, and reduces problems associated with soil acidity. Lime moves slowly in soil, so it must be applied and incorporated during site preparation to be effective.

Two primary types of lime are available: agricultural or calcitic lime and dolomitic lime. Calcium carbonate predominates in agricultural lime, while dolomitic lime consists of both Ca and Mg carbonates. Agricultural lime normally is preferred unless soils also are low in magnesium. By-product lime also is available. Appendix 2 details lime sources.

Two soil tests are used to make a lime recommendation—soil pH and SMP buffer-lime requirement (LR). Soil pH determines whether a soil needs lime, but it does not indicate how much lime is needed. Lime recommendations (Table 4) are based on the SMP buffer. In Table 4, lime recommendations to raise soil pH to 6.0 are presented only for contrast. Notice, for example, that for a 6.2 SMP buffer, the lime needed to achieve a final pH of 5.6 is 1 to 2 ton/acre. Raising soil pH to 6.0, only 0.4 unit higher, requires almost twice as much lime.

Calcium (Ca) and magnesium (Mg). Calcium is important for cell structure. Calcium deficiencies are extremely rare when soil pH is above 5.0. Calcium applications in Table 3 are given as lime recommendations.

Magnesium is a component of chlorophyll. Deficiencies cause chlorosis (yellowing) of needles. Mg deficiencies have not been documented for Christmas tree production in western Oregon and Washington. Current research in Douglas-fir shows no relationship between needle color and soil or needle Mg concentration. Magnesium applications in Table 3 are given as dolomite recommendations.

Micronutrients. Site preparation fertilization with micronutrients such as boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), and zinc (Zn) has not produced a growth or color response in Christmas trees in western Oregon and Washington. The lack of tree growth or color response is not surprising for metallic micronutrients (Fe, Zn, Cu, Mn), which are readily available in the region's acidic soils.

Seedling establishment

The first year following planting begins the establishment phase (Figure 9). Growers gain little benefit from applying nutrients as seedlings make the transition from the nutrient-rich nursery condition to the dryland situation. Nutrients are stored in seedlings, and newly planted trees have a nutrient concentration approaching double that needed for adequate field growth. For example, nursery stock commonly has 3 to 4 percent N in the needles, while older field-grown trees have 1.5 to 2 percent N. The high level of tissue N in seedlings supplies growth needs during establishment. Excessive fertilization, improperly calibrated rates, and poor fertilizer placement easily damage first-year seedlings.

If you have not yet performed the soil analyses and treatments discussed previously under site preparation, follow the recommendations for taking a soil sample found on page 4. Nutrient additions, particularly of nonmobile elements such as phosphorus, potassium, calcium, and magnesium, are difficult to apply at this stage; they are most effective if incorporated into the soil. If the trees are in their first growing season, you likely can incorporate these elements into the soil between the rows with minimal root damage. After that time, consult your county office of the OSU or WSU Extension Service regarding possible strategies.

Midrotation

During the second or third year for Douglas-fir and the third or fourth year for noble fir, roots begin to fill the soil as the trees grow rapidly (Figures 10 and 11). Growers want to harness this rapid growth into a "frame" that can support the tree's foliage. Inadequate nutrients at this stage can limit growth, so fertilizer applications can be beneficial.

Foliar analysis is the primary tool for detecting nutrient deficiencies at the midrotation stage. Foliar analysis determines the amount of nutrients present in needles at the time of sampling. Monitoring nutrient levels with foliar samples is an important management tool in a plantation's nutrient management plan. Annual foliar analysis is recommended for trees 3 years of age and older. Detection of declining foliar nutrient levels allows fertilizer to be applied before nutrient deficiencies impair tree growth and/or quality.

Figure 9. A newly planted field of Douglas-fir Christmas trees.

Figure 10. Noble fir Christmas trees in midrotation.

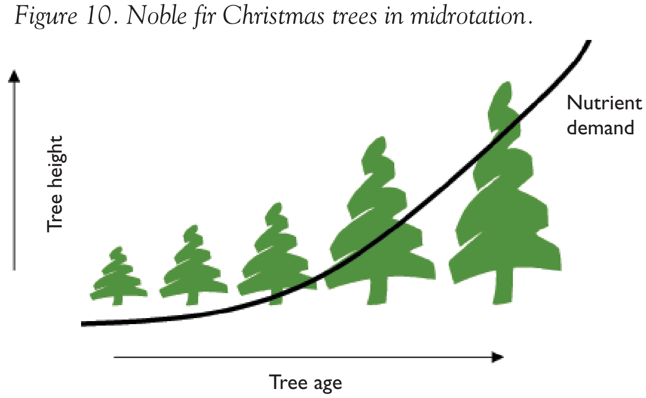

Figure 11. Tree growth during a rotation. Note that growth rate and nutrient demand increase as the plantation reaches midrotation.

Recommendations based on foliar tests are designed to keep trees healthy and, in the case of N, to ensure adequate growth and, later, sufficient color. Additions of nutrients when tissue concentration is sufficient provide no economic return, as nutrients are already present in sufficient quantities.

Taking a foliar sample and interpreting results

Sample Christmas tree foliage in the late summer or early autumn, before the rainy season begins. During this time, roots are dormant, the trees have produced most of their annual woody growth, and nutrient levels are stable. Foliar sampling timing is critical for accurate results, especially for mobile nutrients (N, S, and B). Recommendations in this guide are based on late-summer foliage sampling.

Collect the sample by pinching five to eight needles of new or current-season growth from six to eight locations on the upper one-third of the tree crown (Figures 12 and 13). Never sample the tree leader. Include only needles—no buds, bark, stem wood, or lammas (summer flush) growth. Repeat this procedure on 20 to 30 trees. Sampled trees should be of similar age, color, and growth.

Consult Table 2 for analyses to request from a laboratory. Some foliar analyses commonly performed for other crops are not listed in Table 2. These nutrients rarely limit Christmas tree growth or color, and they are not necessary for routine foliar analysis for Christmas trees. Consult an OSU or WSU Extension office with questions about foliar sampling and analysis.

Foliar test results permit growers to consider nutrient additions and to choose the appropriate material. For information on specific fertilizer materials, see Appendix 2, page 20. Apply all nutrients as indicated in Tables 5–7.

Nitrogen. Foliar N of 1.6 percent is adequate for growth in Douglas-fir; 1.4 percent N is adequate for noble fir growth (Table 5, page 10). Higher foliar N is not necessarily related to increased growth, so nitrogen fertilization to increase rates above these levels is not justified. Although higher nitrogen rates may improve color, color generally is not a concern at this stage.

If tree growth is inadequate, interpret soil and foliar analyses carefully. If foliar nutrient levels are acceptable, but trees are performing poorly, the problem is not nutritional; it may be due to disease, insects, or other causes.

See Table 5 for nitrogen fertilizer rates.

Figure 12. Pinch five to eight needles of new or current-season growth.

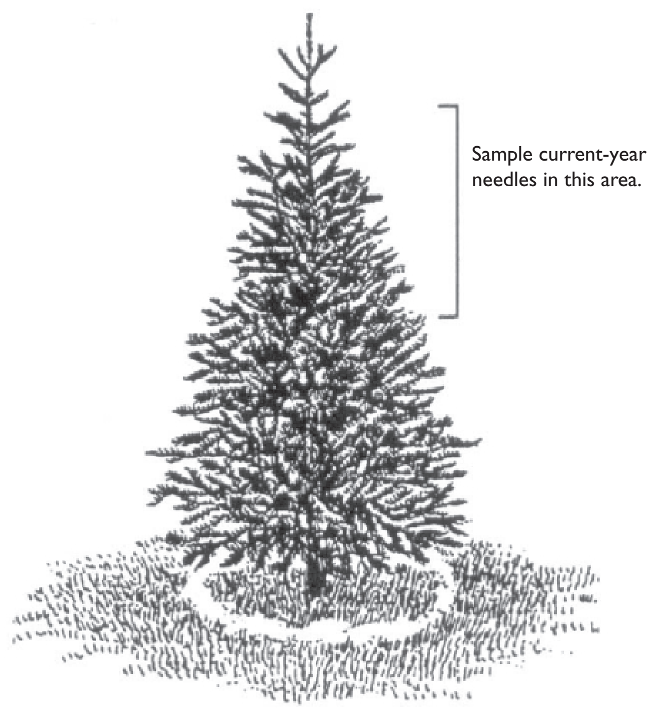

Figure 13. Sample from six to eight locations in the top one-third of the tree.

Table 5.—Nitrogen recommendations for Douglas-fir and noble fir based on foliar testing.

Species	Foliar N concentration (%)	Broadcast (lb N/acre)	Individual tree (oz N/tree)
Douglas-fir	Above 1.6	0	0
	1.2–1.6	100	1–2
	Below 1.2	150	2–3
Noble fir	Above 1.4	0	0
	1.1–1.4	100	1–2
	Below 1.1	150	2–3

Begin foliar analysis in September the third year after planting; continue annually.

Apply fertilizer in February or March of the year following foliar analysis.

Table 6. Macronutrient fertilizer recommendations for Douglas-fir and noble fir based on foliar analysis.

Nutrient	Foliar analysis	Fertilizer
Phosphorus (P)	(%)	(lb P_2O_5/acre)
	Below 0.08	180
	0.08–0.15	90
	Above 0.15	0
Potassium (K)	(%)	(lb K_2O/acre)
	Below 0.4	100
	0.4–0.8	50
	Above 0.8	0
Sulfur (S)	(%)	(lb S/acre)
	Below 0.06	20–30
	Above 0.06	0
Calcium (Ca)	(%)	(lb Ca/acre)
	Below 0.25	1,000 lb gypsum/acre or 1 ton lime/acre
	Above 0.25	0
Magnesium (Mg)	(%)	(lb Mg/acre)
	Below 0.07	20–40
	Above 0.07	0

Begin foliar analysis in September the third growing season after planting.

Reanalyze every other year to determine whether deficiencies have been corrected.

Because macronutrients other than sulfur move into soil slowly, apply these fertilizers as soon as convenient, and preferably before winter rains.

Apply sulfur fertilizers in February or March the year following foliar analysis.

Table 7. Micronutrient fertilizer recommendations for Douglas-fir and noble fir based on September–October foliar analysis.

Nutrient	Foliar nutrient concentration below which nutrients may be needed (ppm)	Comments
Boron (B)	15	Broadcast 3 lb B/acre. Can be toxic if banded or overapplied.
Zinc (Zn)	10	Generally is not deficient in acid soils of western Oregon and Washington.
Manganese (Mn)	25	Generally is not deficient in acid soils of western Oregon and Washington.
Copper (Cu)	Below 3	Generally is not deficient in acid soils of western Oregon and Washington.
Iron (Fe)	Uncertain	Foliar analysis is unreliable and not recommended.

Begin foliar analysis in September the third growing season after planting.

Reanalyze every other year to determine whether deficiencies have been corrected.

Custom blending fertilizers that supply these nutrients with other fertilizers is a common practice by the fertilizer supply industry. Consult a fertilizer dealer or other professional regarding amount and method of applying micronutrients.

Calcium (Ca) and magnesium (Mg). Calcium and magnesium rates based on foliar tests are provided in Table 6. Because of the need to incorporate these materials into the soil, seek professional advice if adding them at this stage of growth. If magnesium is needed during a rotation, choose a soluble source such as magnesium sulfate (Epsom salts) or potassium magnesium sulfate (K-mag).

Sulfur (S). Although growers commonly apply sulfur fertilizer, it has not been shown to be beneficial in Christmas tree production. Fertilization rates based on foliar S concentration are given in Table 6.

Micronutrients. In trees grown on soils listed on page 1, tissue concentrations of metallic micronutrients (Mn, Zn, or Cu) do not fall below those shown in Table 7. If trees were planted as described on pages 4–6 but still show a low tissue concentration of micronutrients, possible causes are overapplication of lime or twice the normal growth rate.

No local research has evaluated metallic micronutrient application. Thus, standard recommendations are not available for situations where foliar nutrient concentrations are at or below values in Table 7.

If a metallic micronutrient deficiency is diagnosed, consult your local Extension office for assistance. Because deficiencies are uncommon, a unique corrective action is necessary for each situation.

Boron (B) deficiency has not been identified in Christmas trees. It has, however, been shown to be limiting in some Douglas-fir timber production, especially on gravelly glacial outwash soil in southwestern Washington. A trial application is recommended if needle B concentration is below the 15 ppm standard in Table 7.

Late rotation

As the plantation approaches harvest, it grows very rapidly, drawing more heavily on soil nutrients (Figure 14). Foliage quality is a critical concern. During this phase of the rotation, trees require more nitrogen than in earlier growth stages, and fertilizer applications must be adequate to support tree growth and color development. Soil deficiencies neglected to this point are difficult to correct.

Foliar analysis is the primary tool for assessing nutrient status. Collect and submit foliar samples as described under "Midrotation," page 9.

Spring applications of mobile nutrients such as N and S are most likely to improve tree color during the final 2 to 3 years of the rotation. Apply nitrogen, if needed, in February or March during the period of active root growth (Figure 4, page 2). Do not exceed 150 lb N/acre in any year.

Harvest-year fall fertilization may not produce adequate color before harvest. The success of this practice is linked to fall rains. Early August or September rains provide a greater chance for color improvement. Fall N applications are most vulnerable to loss by leaching.

Figure 14. Douglas-fir Christmas trees approaching sufficient size for harvest, the end of the rotation.

Where does the fertilizer go?

What is the fate of nitrogen following a fertilizer application? How much of the nitrogen is taken up by the tree? These questions were explored during a year-long study of a Douglas-fir Christmas tree plantation. To answer these questions, researchers monitored nitrogen as it moved through the soil and into the trees. A nonradioactive isotope of nitrogen, ^{15}N, was used to mark the fertilizer applied to the soil. Soil and trees were monitored for 385 days.

After 1 year, the following results were found.

- Twenty-one percent of the N was found in trees, and 30 percent went into storage in the soil. About half (49 percent) was not found in the trees or the surface foot of soil and was presumed lost from the site.
- Nitrogen losses occurred during periods of heavy rainfall.
- Nitrogen also was removed as the trees were harvested. Approximately 178 lb N/acre was removed via harvest, assuming 900 trees/acre.
- The majority of the nitrogen taken up by the tree (68 percent) was supplied from nitrogen stored in the soil rather than directly from the fertilizer application (32 percent).

The above findings have important implications for fertilizer applications.

- Be cautious if applying N fertilizers in the fall. Fall fertilizer applications have greater potential for loss by leaching than spring applications.
- Never overfertilize. The tree will take up only a portion of what is applied; a portion may leach to groundwater. Groundwater nitrate concentrations greater than 10 ppm NO_3-N are considered a human health risk.

Foliar test results can be compared with values in Tables 5, 6, and 7 to estimate amounts of nutrients to apply. Various nutrient test results are discussed in the following paragraphs. Information on specific fertilizer materials is found in Appendix 2, page 20.

Nitrogen (N). Nitrogen fertilizer has been used for decades to enhance color, growth, and value of Christmas trees.

• ***Douglas-fir.*** A nitrogen fertilizer trial on Douglas-fir Christmas trees in western Oregon and Washington (Bondi et al. 1993) established a quantitative relationship between color and foliar nitrogen levels (Figure 15). Although color improved up to 2 percent foliar nitrogen, adequate color was

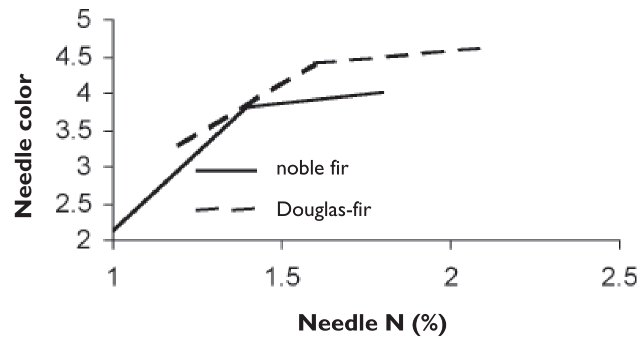

Figure 15. The relationship of Douglas-fir and noble fir needle color to needle nitrogen concentration. Little color increase and marginal gain occur as needle nitrogen increases above 1.4 percent for noble fir and 1.6 percent for Douglas-fir.

Evaluating color in Christmas trees

What is a "good" color, how can it be measured, and how important is it? Tree color is influenced by many factors. Some, such as sun angle, needle wax, and tree density, influence our perception of color. Other factors, such as N levels or disease and insect problems, may influence the color of individual needles, branches, or entire trees.

Because color assessment is complex, we have tested a simple comparative scheme using standardized color chips (Figure 16). Chips cover the range of tree colors from yellow (poor tree color, Figure 17) to dark green or blue/green (excellent tree color, Figure 18). Colors are ranked using a number grade for Douglas-fir and noble-fir: 1=poor, 3=average, 5=excellent. Measurements are standardized by: (1) assessing color with one's back to the sun, (2) evaluating trees at a consistent date and time of day, and (3) evaluating color on multiple parts of the trees, not just a few selected needles.

Most of the trees in our initial assessment fell into the medium green range. Tree color for both species was evaluated against recognized standards (Bondi et al. 1993).

A medium color may be sufficient for most consumers; darker green or blue trees may not command a better price. As color level approaches 1, the trees look yellow. Buyers avoid these fields, fearing disease or other damage.

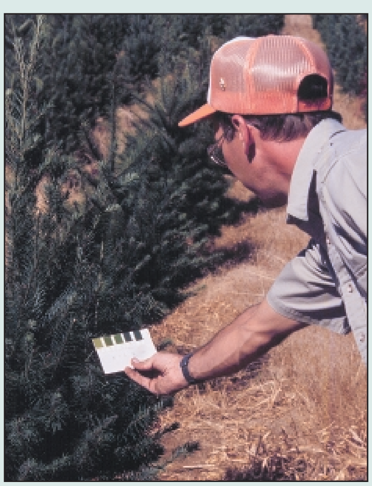

Figure 16. Determining Christmas tree color with a color chart.

Figure 17. A Douglas-fir Christmas tree with poor color when compared to standard colors of the color chart.

Figure 18. A noble fir Christmas tree with excellent color when compared to standard colors of the color chart.

achieved at 1.6 percent N, the level recommended in Table 5 nitrogen applications.

Trees grown in deep soils usually do not need nitrogen fertilizer additions late in the rotation for growth. During the final 2 years, color may improve with nitrogen applications if foliar N levels are approaching 1.6 percent or lower. On shallow hill soils, Douglas-fir Christmas trees may experience both increased growth and improved color from nitrogen applications throughout the rotation, if foliar test results justify applications. Table 5 provides recommendations for N application.

- ***Noble fir.*** A similar study of fertilized noble fir (Fletcher et al. 1998) revealed no improved growth from nitrogen applications. Color improved with increasing needle nitrogen concentration and was darkest at 1.6 percent N (Figure 15). The economic threshold for optimum color was achieved at 1.4 percent N. For the research plots, more than 300 lb N/acre was applied over the rotation to achieve 1.4 percent N tissue concentration. Given the risk of N leaching from high N applications, consider splitting the N into smaller yearly doses. An example might be to start in year 3 with 50 lb N/year, and then increase to 100 lb N/year the final 2 years before harvest. Always base annual N applications on foliar analyses from the previous year.

Micronutrients. Christmas tree growth or color change in response to additions of micronutrients has not been verified by research. Based on research in forestry, boron is the micronutrient most likely to limit Christmas tree growth in the Pacific Northwest (Green et al. 1993).

Table 7 provides recommendations for B applications. A single B application should provide adequate B for the life of the stand. Once B has been applied, wait until the next foliar test before considering another B application. Broadcast B fertilizers; never band. Damage to trees can result from a B misapplication.

The metallic micronutrients Zn, Cu, Mn, and Fe are readily available in the region's acidic soils. Applications have not produced increased growth or improved color in Christmas trees.

Figure 19. A field with Christmas tree stumps remaining following harvest and clearing. The apparent erosion between rows shows this site is a candidate for cover crops.

Postharvest

Postharvest is the time to reflect on the successes and areas for improvement of the previous rotation and to plan for the next rotation (Figure 19). Sample soils, establish a cover crop, evaluate marginal sites, and plan your future soil and nutrient management practices. Evaluate problems such as compaction, lime need, and diseases, and make adjustments to reduce their impact on the next rotation's quality.

Summary

Cost-effective and environmentally responsible nutrient management begins with soil analysis and applications of P, K, Mg, and lime prior to tree planting. During the rotation, monitor nutrients in tree foliage annually, and decide whether additional nutrients will improve tree growth or color for a reasonable cost. Also, consider possible leaching of nitrogen into water sources or other environmental impacts.

Three examples of the decision process described in this guide follow. They serve as a review of how to use this guide with soil and foliar test results.

Examples of nutrient applications using soil and foliar tests

Preplant example

Douglas-fir Christmas trees are to be planted on a third-rotation field. The grower collects a soil sample after trees were harvested. The results are shown in Table 8.

Preplant K or P applications are not needed (see discussion on pages 5–7).

A soil pH of 4.6 shows lime is needed prior to planting. Table 4 (page 7) provides interpretation for the SMP buffer value of 5.6. The lime recommendation is to incorporate 3 to 4 tons of 100-score lime to raise the pH to 5.6.

Soil test results showed 2.4 meq/100 g soil Ca and 0.35 meq/100 g soil Mg. Table 3 (page 6) provides interpretation for calcium and magnesium. The calcium recommendation is found under the condition of soil pH less than 5.0 and soil Ca less than 5 meq/100 g soil. The lime recommendation based on the SMP buffer (3 to 4 tons) will supply sufficient Ca.

Dolomite is recommended when magnesium is below 0.4 meq/100 g soil. Apply a maximum of 1 ton dolomite/acre per application (Table 4). One ton of dolomite provides sufficient Mg; calcitic lime is a more economical choice for the remaining lime. Thus, the lime application should be split between 3 tons agricultural lime/acre and 1 ton dolomitic lime/acre. Work both agricultural lime and dolomite into the soil prior to planting.

Late-rotation example

The plantation is in the fifth year of a noble fir rotation. The preplant soil sample was taken and recommendations followed. The grower began monitoring foliar samples in year 3. The fifth-year results are shown in Table 9.

Based on the information given in Tables 5, 6, and 7 (pages 10–11), the grower notes the following.

- The threshold for adequate N in noble fir is 1.4 percent. The fourth-year sample showed N levels at 1.4 percent, so a downward trend in N levels seems evident. Foliar levels of 1.28 percent are low enough to justify a nitrogen application of up to 100 lb N/acre this year.
- P is acceptable; no fertilization is required.
- K is low, 0.6 percent compared with the recommended level of 0.8 percent. The fourth-year sample had K of 1.1 percent. Such a large drop in K level in a single year is unexpected. Before taking action, the grower might consider the following.
  - — Does the low value fit with other observations and data? For example, was the preplant soil test also low?
  - — Was the season immediately prior to needle sampling unusually dry? K results can fluctuate depending on how dry the year has been. This is the most likely situation since the fourth-year sample was adequate.

Table 8.—Soil test results where Douglas-fir will be planted.

pH	Ca (meq/100 g soil)	Mg (meq/100 g soil)	SMP buffer pH	K (ppm)	P (ppm)
4.6	2.4	0.35	5.6	124	17

Table 9.—Foliar test results for noble fir.

N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	B (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)
1.28 Low	0.16	0.6 Low	0.15	0.4	0.10	15 Marginal	14	150	7	784

The grower has several choices.

— Wait until next year and retest; if K is low because of drought, the level may change.

— Apply a surface band of 50 lb K/acre, as recommended in Table 6. Contact an Extension agent for recommendations on how to make this application between tree rows.

- Foliar S is adequate, so no application is recommended.
- Calcium and Mg are adequate.
- Boron is at the threshold level. Application of B is not essential for current tree growth, but rates below this level will be of concern. Three logical options are as follows.

— Do not apply B now, but reevaluate the situation based on next year's foliar analysis.

— Apply a half rate of 1 to 1.5 lb B/acre.

— Apply the full rate of 2 to 3 lb B/acre.

Foliar applications of B are not recommended due to the possibility of overapplication. Granular or liquid B should be broadcast, not banded.

- Zn and Mn levels are acceptable.
- Cu is adequate.
- Fe testing is not necessary for Christmas trees in western Oregon and Washington. Fe is analyzed routinely at no extra cost. Fe usually is high in our area, but no information exists on test interpretation.

Continuous cropping example

The owner of a U-cut operation (Figure 20) has not worked the soil in 20 years. Most of the trees are Douglas-fir. Trees range from seedlings to 10 years of age and are grown on an 8-year rotation.

To assess nutrient status of unevenly aged trees, the grower collects soil and foliar samples. Foliar samples taken from mixed-aged fields must be from a single species. If a significant portion of the field is another species, submit samples from each species. Collect foliage from trees within 3 years of harvest.

Soil and foliar test results are found in Tables 10 and 11.

Based on the Tables 4, 5, 6, and 7 (pages 5, 10–11), the grower notes the following.

- The soil test results indicate moderately low pH. This pH level is sufficient, but the trend is a concern.

Figure 20. A "choose and cut" Christmas tree farm.

Table 10.—Soil test results.

pH	Ca (meq/100 g soil)	Mg (meq/100 g soil)	SMP buffer pH	K (ppm)	P (ppm)
5.1	5.1	0.4 Marginal	5.6	150	16

Table 11.—Foliar test results.

N (%)	P (%)	K (%)	S (%)	Ca (%)	Mg (%)	B (ppm)	Zn (ppm)	Mn (ppm)	Cu (ppm)	Fe (ppm)
1.45 Low	0.16	0.9	0.15	0.4	0.10	25	14	150	7	784

- Soil Ca is sufficient, but low. The level is consistent with a pH of 5.1.
- Mg is low.
- Foliar test results indicate low N.

According to Table 5, 1 to 2 oz N/tree will remedy the low foliar N level. Apply N to all trees that are within 3 years of harvest.

The grower has two options for addressing soil pH, Ca, and Mg levels.

- Clear a portion of the field and rework it as recommended in the section on "Site preparation" (pages 4–8). Incorporate appropriate amounts of calcitic and dolomitic lime during site preparation (Table 4, page 7). These additions will correct pH and supply Ca and Mg. As time passes, the plantation will develop into smaller areas of evenly aged trees.
- Continue to plant seedlings as mature trees are harvested. Incorporate calcitic and dolomitic lime into backfill from auger holes. The rate per tree is the recommendation per acre, divided by 1,500 (assuming 1,500 trees per acre).

U-cut growers should take soil samples for analysis every 5 years.

Appendix I

Methods of nutrient application

Nutrients can be supplied to Christmas trees by application to soil or to foliage. An explanation of the options follows.

Hand application

Traditionally, fertilizers have been applied to Christmas trees by hand—a handful or more of fertilizer is provided to each tree. Hand fertilization has been used by hundreds of large and small growers on thousands of acres over the past 40 years. The method is easily explained, can be done by anyone, and requires minimal equipment. However, hand fertilization can be slow and labor-intensive on larger farms, and it risks inaccurate or variable application (Figure 21).

By using a measuring device such as a tuna can, a uniform amount of fertilizer can be delivered to each tree. You can use the nitrogen recommendations in Table 5 (page 10) to calibrate a measuring device and apply only the fertilizer needed, as indicated by foliar test results.

Applications for each tree usually are divided into two portions, applied under the drip line on opposite sides of the trunk. This "two-strike" method places half the material under each side of the tree. With concentrated fertilizers, this method is better than the "one-strike" method, which places all of the material under the drip line on one side of the tree.

Nonmotorized broadcast spreaders are preferred over the one- or two-strike methods, as they may be faster and apply material more evenly. Options include shoulder harness-style spreaders or hopper-style wheeled spreaders that are pushed by the operator (Figure 22). These systems lack the capacity of motorized systems, however.

Ground speed and spreader setting dictate application rate; take care not to change application speed. Wheeled spreaders require a relatively debris-free, smooth surface for optimal fertilizer application. Making a second pass 90° to the first application can compensate for an uneven spread pattern.

Figure 21. Needle "burn" is the result of uneven and too high fertilizer application. Note the amount of fertilizer applied was sufficient to kill even the grass next to the tree.

Figure 22. Application of nutrients with a nonmotorized broadcast spreader.

Figure 23. Application of foliar material using ground-based motorized equipment.

Ground-based motorized application

Tractors, four wheelers, and other equipment can be used to apply fertilizer as long as the equipment fits between the trees (Figure 23). These methods are ideal for broadcast and banded fertilizer applications. A well-calibrated ground-based motorized system is fast and even. Throttle or speed control makes a more uniform application possible.

A variety of easily calibrated spreaders is available. Individual growers should assess the economics of motorized versus nonmotorized systems.

Aerial application

When motorized spreaders no longer fit between the trees, the most efficient way to apply nutrients is by aircraft. Because of the cost to move aircraft and loading equipment to a site, 8- to 10-acre fields are considered the minimum size for cost-effective treatment. Proper application depends on flight access clear of tall trees and power lines.

Foliar application

Foliar applications generally are not recommended. In any plant, nutrient uptake through the foliage is inefficient compared to uptake through roots. Foliar nutrient application is especially difficult in coniferous evergreen trees because their needles' "waxy" coating and narrow shape limit nutrient penetration. Foliar applications also risk foliar burn, discoloration, and needle loss.

Timing is critical if foliar-applied materials are to have any effectiveness. The needles' waxy cuticle controls nutrient uptake. Immediately after bud break, needles lack a fully developed cuticle. Foliar-applied nutrients are most likely to enter the tree via the needles at this time, but the risk of foliar damage is also highest. This period also is the time of maximum nutrient uptake through the roots, which always is more efficient than nutrient uptake through foliage.

Appendix 2

Nutrient sources

A variety of fertilizer materials is available. Some, such as urea, supply a single nutrient. Others, either standard or custom blends, supply more than one nutrient. A review follows of materials commonly used on Christmas trees in this region.

Choose materials carefully, taking into account specific site conditions and interpretations of soil and foliar test results. Manufacturers frequently release new fertilizer materials. If you have questions about the suitability of a specific material for your plantation, consult an Extension agent or crop consultant.

Organic versus inorganic fertilizers

Opinions vary concerning the merits of manure or other organic fertilizers compared to inorganic fertilizers. Excellent trees can be grown using either type. Plants do not differentiate between nutrients from organic or inorganic fertilizers; the form absorbed by plant roots from both sources is identical.

Organic nutrient sources generally are of lower analysis than their inorganic counterparts. The lower analysis means more material must be applied to obtain the same amount of nutrient, thus increasing handling and shipping costs. In addition, most purchased organic nutrient sources are more expensive than inorganic nutrient sources. An example of calculating cost on a nutrient basis is found in Appendix 3 (page 24).

Another consideration in the use of organic materials is the release rate or availability of nutrients, especially nitrogen and sulfur. Nitrogen from organic nutrient sources is converted to plant-available forms—ammonium (NH_4^+-N) and nitrate (NO_3^--N)—by microbial activity. Microbial action requires sufficient time, temperature, and moisture. A small amount of early-season inorganic fertilizer may ensure adequate plant nutrition until soils warm enough to produce plant-available nutrients from organic sources.

The conversion of organic N to a plant-available form can take more than a year to complete. The use of organic fertilizers such as manure may require supplemental commercial N application the first year or two to provide immediately available N. In subsequent years, organic sources can be used without supplemental commercial N.

Commercial nitrogen (N) sources

Several commercial fertilizer materials supply N in the ammonium and nitrate forms, which are immediately available to plants. The ammonium and urea forms of N are acidifying to the soil. Nitrate forms are not.

Urea

Urea ($CO\ [NH_2]_2$)is commonly applied as a solid white N fertilizer. Urea contains 45 to 46 percent N, the highest N content of any dry N fertilizer. It usually is the least expensive dry N material. It is easily blended with ammonium phosphates and ammonium sulfate. Never mix it with ammonium nitrate, store it close to ammonium nitrate, or handle it with the same equipment. Urea's solubility allows for use in fertilizer solutions, where appropriate. About 1 lb of urea will dissolve in about 1 quart of water.

Growers commonly express two concerns about urea. The first is that the N will be lost to the atmosphere as ammonia gas. Substantial N loss from urea is not likely in western Oregon or western Washington unless lime has been applied recently or the soil pH is above 7.0. Although it is common for no trace of urea to be visible shortly after application, the N has not volatilized. Urea is extremely soluble in water and dissolves in heavy dew. The material then moves onto the soil surface in the area around the former granule.

A second concern about urea relates to tree damage from high concentrations of N. Small trees may suffer root damage from high application rates of urea. If urea is inadvertently applied to foliage, foliar damage may result.

Ammonium nitrate

Ammonium nitrate is a granular or dry white N material that has an N concentration of 33 to 34.5 percent by weight. All of the N supplied by ammonium nitrate is in forms available to plants (ammonium and nitrate). Ammonium nitrate typically costs approximately 10 percent more per pound of N than urea. Ammonium nitrate is soluble in water and, like urea, may dissolve in heavy dew.

Ammonium sulfate

Ammonium sulfate is a white crystalline solid with a grade of 21-0-0-24(S). It is a primary source of S.

Ammonium sulfate is applied alone or in blends with other granular fertilizers. The sulfur is in a soluble and plant-available sulfate form, SO_4. A common blend used in the Christmas tree industry, called urea-sul, is a mixture of urea and sulfur. It typically contains 38 to 42 percent N and 8 to 10 percent S.

The use of ammonium sulfate as the only source of N is not recommended for Christmas tree production for several reasons. First, the material acidifies soil faster than ammonium nitrate or urea. Second, when used alone, it supplies many times the amount of S required in order to supply enough N. Therefore, if S is needed, use a blend containing ammonium sulfate.

Calcium nitrate

Calcium nitrate is a granular nitrogen carrier with 15.5 percent N and 21 percent Ca. In contrast to other common N-supplying materials, all of the nitrogen is in the nitrate form, which most plants take up preferentially. This material does not acidify soil.

Offsetting these benefits are calcium nitrate's lower N analysis and higher cost compared to other nitrogen materials. The lower N analysis means that three times as much material must be applied compared to urea. Each pound of N from calcium nitrate costs $0.25 to $0.35 more than N as urea ($25 to $35 more per 100 lb).

Some growers say the extra cost is offset by a reduced need for lime. Let's consider the economics. Calcium nitrate contains 21 percent Ca and 15.5 percent N (21 lb calcium and 15.5 lb N per 100 lb material). If the additional cost of the nitrogen (compared to urea) is $0.25/lb, then 21 lb calcium costs $3.87 (0.25 x 15.5 = 3.875) for a cost of about $0.18/lb. If lime costs $60/ton and contains 40 percent Ca (800 lb/ton), the cost of calcium in lime is $0.075/lb of calcium. The calcium in calcium nitrate provides plant-available Ca, but does not neutralize soil acidity.

Biosolids

This material consists of residuals from municipal wastewater treatment. Its use is regulated for metals and pathogen content. Biosolids commonly are land applied in a number of agricultural systems. They contain significant nitrogen and phosphorus and are inexpensive. However, we do not recommend this material for Christmas tree production for the following reasons.

- Phosphorus is best applied between rotations and incorporated into the soil. At that time, soluble nitrogen could travel to surface or groundwater sources.
- Biosolids are pumped onto fields as a thick liquid. Christmas trees most need nitrogen near the end of the rotation, when the trees are quite large and equipment cannot travel between the rows.
- Christmas trees can suffer needle burn from foliar contact with this material. Such damage is difficult to overcome before the end of the rotation.
- Late-rotation application of this material may have aesthetic ramifications that affect marketability.

Phosphorus (P) sources

Ammonium phosphate

Ammonium phosphate, as a granular or liquid material, is the most common phosphorus fertilizer available from commercial fertilizer suppliers. Granular ammonium phosphate is either monoammonium phosphate (11-52-0), diammonium phosphate (18-46-0), or ammonium phosphate-ammonium sulfate (16-20-0-14). The common grade of liquid ammonium phosphate is 10-34-0.

Rock phosphate

Rock phosphate is quite variable in grade, with a P_2O_5 content of 10 to 35 percent. Rock phosphate is unlikely to supply deficient Christmas trees with a usable supplement over the length of a tree rotation.

Potassium (K) sources

Two primary solid crystalline sources of potassium are available: potassium chloride (KCl, 0-0-60) and potassium sulfate (K_2SO_4, 0-0-52-18). One material contains chloride and the other sulfur. Concentration of potassium chloride around a young tree can cause needle burn.

Boron (B) sources

Sodium borate is the most frequently used boron fertilizer. B fertilizers are sold with trade names such as Solubor, Fertibor, Granubor, and Solubor DF, all of which are sodium borate. Most B fertilizers contain 10 to 20 percent B. Solubor is 20.5 percent boron, and Granubor is 15 percent boron.

Boron is fairly mobile in soils and may be applied by several methods. Boron sources may be blended with granular N-P-K fertilizers, but segregation can be a problem if particle sizes differ significantly. You also can apply boron separately to the soil as a liquid or spray it onto trees. Do not band fertilizers containing B. Too much B may interrupt Christmas tree bud formation and growth. Excessive B rates will severely affect tree growth.

Liming materials

Liming materials are used to raise soil pH and supply calcium or magnesium to the soil (Figure 24). The carbonate part of the calcium carbonate molecule neutralizes soil acidity.

The quality of a liming material is related to its chemical composition, particle size (degree of fineness), and moisture content. All liming materials sold in Oregon must have a lime score. Lime score is a numerical expression of lime quality that provides a method for comparing liming materials. It is based on fineness, moisture content, and acid-neutralizing value or calcium carbonate equivalent.

Ground limestone

Ground limestone is either calcitic or dolomitic. Calcitic lime (calcium carbonate, or $CaCO_3$), also called agricultural lime, is the industry standard. It readily changes soil pH and is a source of calcium.

Dolomitic lime is a combination of calcium carbonate and magnesium carbonate, $CaMg(CO_3)_2$. Dolomitic lime supplies both calcium and magnesium, but changes soil pH slowly.

We do not recommend using only dolomitic lime, although this material is appropriate when both pH and Mg are low. Dolomitic lime is more expensive than calcitic lime. Also, because it is slightly less soluble than calcitic lime, it neutralizes soil acidity more slowly and is best applied between rotations. See "Site preparatioin" (pages 4–8) to learn more about using nonmobile nutrients, including magnesium. When magnesium is needed during a rotation, choose a soluble source such as magnesium sulfate (Epsom salts) or potassium magnesium sulfate (K-Mag).

Figure 24. A preplant application of lime.

Most calcitic or dolomitic lime has a lime score of 80 to 110. Finely ground, dry calcitic lime has a score of 100.

By-product materials

By-product or alternative lime materials come from manufacturing operations such as paper manufacturing. During the manufacturing process, lime is not entirely reacted and enters the mill's waste stream, from which it is recovered and spread on land. Another example of by-product lime is ash from wood-burning power-generation facilities. Most by-product material is effective, safe to use, and suitable for application in Christmas tree plantations.

Unfortunately, some by-product lime contains unwanted material, including charcoal, metal contaminants, and/or salts. Materials with ash or high chloride content generally are high in salt content. These contaminants can cause reduced yield, reduced efficacy of some herbicides, and undesirable soil quality changes.

By-product lime typically has a lower lime score than traditional agricultural lime (between 10 and 80) and consequently should cost less per ton. Be sure you know what you are purchasing when using by-product lime.

Summary

Table 12 (page 23) summarizes the fertilizer materials commonly used in Christmas tree production and their analyses.

Table 12.—Fertilizer materials commonly used in Christmas tree production and their analyses.

	Analysis (%)				
Fertilizer	**N**	**P_2O_5**	**K_2O**	**S**	**B**
Urea	46	—	—	—	—
Urea-Sul	40*	—	—	8*	—
Ammonium nitrate	34	—	—	—	—
Ammonium sulfate	21	—	—	24	—
Calcium nitrate	15	—	—	—	—
Ammonium phosphate	10–20	20–55	—	—	—
Potassium chloride	—	—	60	—	—
Potassium sulfate	—	—	50	18	—
Magnesium sulfate	—	—	—	25	—
Potassium magnesium sulfate	—	—	22	22	—
Sodium borate	—	—	—	—	10–20

*Analysis varies

Appendix 3

Frequently asked questions

Why does the analytical procedure used for soil or foliar testing matter?

Analytical methods may vary greatly from lab to lab and across the country. Test results may vary, depending on the method used. Some differences are insignificant; others can substantially change results and recommendations.

Recommendations in this publication are based on soil test methods listed in Table 3 (page 6). Compare the methods used by your laboratory to those in Table 3. For more information on soil test procedures, see EC 1478, *Soil Test Interpretation Guide* (Marx et al. 1999).

Are the lab results based on direct analysis or inferred from other data?

Some laboratories may estimate soil textural class (the amount of sand, silt, and clay) or cation exchange capacity (CEC) from a combination of extractable K, Ca, Mg, soil pH, and soil buffer pH. Ask the lab how results are determined.

Why are repeated foliar analyses important?

Repeated soil and foliar tests during rotations are important in identifying changes or trends over time. Growers generally use the same laboratory for many years. Performance over "the long haul" is desired.

Sometimes one sample does not fit past trends. The reason may be variation in sampling or in laboratory analysis. Call the laboratory if you have questions about results or recommendations. A laboratory should wish to ensure accurate results and should be willing to check results based on valid customer concerns.

How does nitrogen fertilizer affect cold hardiness and keepability of harvested Christmas trees?

Tests for cold hardiness are used to evaluate trees' needle loss rate when exposed to low temperatures. Tests for keepability are designed to evaluate tree response following harvest. Needle shedding during display is the measurement used to evaluate how well a tree "keeps."

Researchers at Washington State University compared needle loss from cold temperatures and during display for Douglas-fir and noble fir grown with high fertilizer rates to those receiving no fertilizer (Chastagner and Riley 2001).

In trials with noble fir, nitrogen fertilization did not affect cold hardiness or needle loss during display. From these trials, we can suppose that the moderate rates of fertilization suggested in this guide will not affect these characteristics.

In trials with Douglas-fir, needle loss during display was not tested. High levels of nitrogen fertilization did decrease cold hardiness, however. The needle loss on heavily fertilized trees exposed to temperatures between 3°F to -11°F was much higher than on trees receiving no fertilizer. Below -11°F and above 3°F, fertilized and unfertilized trees experienced similar levels of needle loss. At the moderate fertilizer rates suggested in this guide, cold-induced needle losses are not expected to differ greatly from unfertilized trees, but this assumption is untested.

What is soil health? Should I add bacteria and fungi to my plantation soils?

You may have heard of soil health concepts such as soil food chains, food cycling, or the addition of microscopic organisms such as mycorrhizae. Soil health is important for the success of any plant community, but it is difficult to describe, measure, and manage.

My soil test results include a value for "soil organic matter." What does this information mean?

Organic matter is an important component of soil; it provides a nutrient source for soil microorganisms, promotes soil aggregation, and aids in water and nutrient retention.

Some plant residues are taken into the cells of microorganisms as they grow and divide; some remain as plant tars and lignin. Residues decompose, releasing carbon as CO_2. After initial decomposition, residues are converted into a more stable form, which may remain in the soil for years. This stable form is "soil organic matter."

Changing a soil's organic matter content requires consistent, repeated additions of organic materials and minimal tillage disturbance. Current management practices do not encourage organic matter accumulation. Growers who wish to amend soils with organic material should consider the following.

Table 13. Calculating per-unit nutrient cost based on fertilizer price and grade.

Cost/ton ($)	Fertilizer grade 15	20	25	30	35	40	45	50
	Nutrient cost/lb (cents)							
100	33	25	20	17	14	13	11	10
125	42	31	25	21	18	16	14	13
150	50	38	30	25	21	19	17	15
175	58	44	35	29	25	22	19	18
200	67	50	40	33	29	25	22	20
225	75	56	45	38	32	28	25	23
250	83	63	50	42	36	31	28	25
275	92	69	55	46	39	34	31	28
300	100	75	60	50	43	38	33	30
325	108	81	65	54	46	41	36	33
350	117	88	70	58	50	44	39	35

- Materials should be generally free of weeds, weed seed, and diseases.
- Mulches may suppress some weed species but may encourage others by retaining surface moisture.
- To mulch 1 acre to a depth of 2 inches, 270 cubic yards of material is needed.
- Surface mulches provide shelter for tree-girdling rodents.
- Growing a green mulch between rows or between rotations does not dramatically improve soil organic matter, but it may help to reduce erosion.

There is no doubt that nutrient cycling and soil bacteria are important to tree growth. Yet, do not assume there is a problem simply because you have not added some product or amendment. In short—buyer beware.

If you are curious, evaluate the effectiveness of a product in a small trial. Don't assume that it will provide any benefit to trees just because it works well on lawns or tomatoes.

What N materials are suitable for my situation, based on material cost?

See Appendix 2 to review the suitability of various N sources. To determine the cost per pound of a nutrient from any source, you need to know the analysis, or grade, of the material and the unit cost. The unit cost is the cost per bag, ton, or gallon. For example, let's compare the cost of N from urea and ammonium nitrate, given the following per-ton costs and analyses.

Nitrogen source	Urea	Ammonium nitrate
Grade or analysis	46% N	34% N
Cost per ton	$200	$190
Cost of N/lb	$0.22	$0.28

In our example, urea costs $200/ton. The left-hand column of Table 13 is the per-ton cost of fertilizer material in $25 increments. Find $200 in this column. The urea contains 46 percent N. The top row in Table 13 is fertilizer grade in 5 percent increments. The closest grade to 46 percent is 45 percent. Follow the column under 45 percent down until you reach the $200 row. The result is 22. This is the cost in cents per pound of nitrogen.

Repeat the process for ammonium nitrate. The cost per ton is $190. The closest number in the left column is $200. Ammonium nitrate contains 34 percent N; 35 percent is the closest number in the top row. Follow the column under 35 percent down until you intersect the $200 row. The result is 29, so a pound of nitrogen costs 29 cents. Keep in mind that this number is an approximation since the exact grade and cost per ton are not listed in Table 13.

If you purchase fertilizer in 80-lb bags and know the cost per bag, multiply the cost by 25 to determine the cost per ton. For example, if an 80-lb bag of fertilizer costs $8, then $8 x 25 = $200. After determining the per-ton cost, use Table 13 to find the cost per pound.

Table 13 can be used for determining cost per pound of any nutrient if it is the only nutrient in the fertilizer material. For example, you can determine the cost per pound of potassium in 0-0-60, but not the cost per pound of phosphorus in 16-20-0-14.

What's in a fertilizer?

Fertilizer grade is the amount of nutrient in a fertilizer. The grade of a fertilizer material indicates the available nutrient content expressed as percentage of nitrogen, phosphorus (P_2O_5), and potash (K_2O), in that order. Nitrogen is expressed on an elemental basis and phosphorus and potash are expressed as oxides, rather than elemental P and K. A fertilizer with a grade of 10-20-5 contains 10 percent N, 20 percent P_2O_5, and 5 percent K_2O.

Fertilizers often contain other nutrients, such as S and Mg, or micronutrients, such as B and Zn. These nutrients are listed on the fertilizer label on an elemental basis and sometimes are included in the fertilizer grade. A 15-15-10-8(S) fertilizer contains 15 percent N and P_2O_5, 10 percent K_2O, and 8 percent S.

For more information

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