Spectrum Analytic Inc.

FERTILIZING CHRISTMAS TREES

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Introduction

Optimum Christmas tree growth and quality requires optimum fertility conditions. Most producers appreciate that different tree species have their own unique requirements. Supplying these unique requirements starts with identifying the present soil and tree conditions with coordinated soil and plant analysis. Proper fertility pays dividends year after year. Tree vigor and color will improve in the first year, but the greatest gain will likely be in the following years with better color, more dense trees, and optimum growth rates. All of this results in more top-quality trees in shorter time.

Soil and Plant Analysis

The first thing to understand is that soil testing is as important for trees as it is for other crops. However, plant analysis is much more important to tree producers than it is for annual crop producers. Woody perennial plants, like trees can store some amount of nutrients in various plant parts, for use in following seasons. They also have a much different root system than annual crops, and exploit the soil differently. While a tree does not grow nearly as fast as many annuals, most trees are actively absorbing nutrients for a longer time during a year. Most Christmas tree producers learn to depend on their ability to notice visual clues about the performance of their trees. However, like people, trees become stressed long before they show visual symptoms. Also, conifers do not exhibit well defined visual nutrient deficiency symptoms, like many annual plants. Visual symptoms are often not a dependable indicator of specific nutrient deficiencies in any crop. For these and other reasons, tree producers should use systematic, **annual plant analysis combined with a coordinated soil testing program to identify the true nutrient needs of their trees.**

Differences Between Species

Each species of conifer used as Christmas trees tends to put different demands on the soils ability to supply nutrients. While these differences are not always enough to require unique soil test fertilizer recommendations, Trees in different categories may respond differently to fertilizer programs, or to adverse conditions. Some species have been put into broad categories, as listed below. Growers can use this listing to guide them in how they manage and monitor their trees.

RELATIVE NUTRIENT DEMAND		
LOW	**MEDIUM**	**HIGH**
Scotch pine	Norway Spruce	Douglas Fir
Virginia Pine	White Spruce	Blue Spruce
	Austrian/Black Pine	Spartan Spruce
	Red Pine	Concolor Fir
	White Pine	Fraser Fir
		Balsam Fir
		Canaan Fir

Soil pH

Each species has a unique and relatively narrow soil pH range in which optimum growth can occur, as shown below

Species	Desirable pH Range	Species	Desirable pH Range
Balsam Fir	5.0 - 5.5	White Spruce	5.0 - 5.5
Douglas Fir	6.0 - 7.0	Scotch Pine	5.0 - 6.0
Fraser Fir	5.0 - 5.5	Virginia Pine	5.0 - 5.5
Concolour/White Fir	6.0 - 6.5	Red Pine	5.0 - 5.5
Grand Fir	6.0 - 6.5	White Pine	5.0 - 5.5
Canaan Fir	5.5 - 6.0	Yellow Pine	5.0 - 6.0
Noble Fir	5.0 - 6.0	Red Cedar	6.0 - 6.5
Norway Spruce	5.0 - 5.5	Junipers (All)	5.5 - 6.5
Blue Spruce	6.0 - 7.0	Hemlock	5.0 - 5.5

Changing the Soil pH

Changing the soil pH is best done prior to establishing the stand of trees. When attempting to change the soil pH, the soil should be sampled annually to monitor progress. Recommendations to change soil pH are made in terms of calcium carbonate ($CaCO_3$) to raise the pH or sulfur (S) to lower the pH. This is similar to making nutrient recommendations, in that the lab cannot know the purity of the material used in the field. Therefore, we make recommendations in terms of the “active ingredient” in all cases. Typically, the grower will not use a source of these materials that is equivalent to 100%. In these cases the applications should be adjusted accordingly.

The amount of amendment that is required to change the soil pH, either up or down, depends on the amount of pH change needed and the CEC (cation exchange capacity) of the soil. The CEC is a measurement of the soils capacity to hold and exchange positively charged elements called cations. The larger the soil CEC, the more amendment required to change the pH a given amount. The soil CEC is determined by two soil factors

- The amount and type of clay.
- The amount of organic matter.

An increase in either of these soil components will increase the soil CEC requiring higher rates to cause a given pH change. You will see in the following table data that we use the CEC directly for recommending sulfur to lower the soil pH. However, we use the soil buffer pH (BpH) in the $CaCO_3$ table. The buffer pH is a test that is run to determine $CaCO_3$ requirement. Without going into great detail, the buffer pH results are affected by the CEC.

Raising the Soil pH

Calcium carbonate recommendations assume that the lime will be thoroughly mixed in the top 7 inches of soil. This is not possible with established Christmas trees, so ***the lime rate should be adjusted proportionately to reflect the volume of soil that the lime will be mixed with***. Surface applied lime will typically affect only the top 2 – 3 inches in the first 6 -12 months, and the rates should be adjusted proportionally (use only 28% to 42% of the recommended rate, respectively). On very sandy soil (lower CEC); surface applied lime will tend to affect soil to a deeper depth. Split applications of a lower rate of lime will eventually increase the soil pH of the entire root zone with less chance of over-liming the soil surface. Recommendations should also be adjusted to account for the particle size of the lime source. Finer particle sizes react quicker and require lower rates to change the soil pH in a given amount of time. Re-test the soil annually to monitor the change in soil pH.

Sample Lime Recommendations (lbs/acre of 100% $CaCO_3$)						
Original Soil pH	Target Soil pH	Soil Buffer pH (BpH)				
		5.0	5.5	6.0	6.5	7.0
4.5	5.0	11,982	9,427	6,511	3,776	1,040
4.5	5.5	16,827	12,981	9,136	5,290	1,444
4.5	6.0	20,227	15,602	10,987	6,353	1,728
4.5	6.5	22,891	17,656	12,420	7,185	1,950
5.0	6.0	16,795	12,949	9,104	5,258	1,412
5.0	6.5	20,195	15,570	10,946	6,321	1,696
5.5	6.0	-	9,205	6,470	3,735	999
5.5	6.5	-	12,940	9,095	5,249	1,403
6.0	6.5	-	-	6,468	3,732	997

Converting $CaCO_3$ Recommendations to Local "Ag Lime"

1. **Tillage Depth Adjustment Factors:** Multiply Spectrum Analytic recommendation for $CaCO_3$ by the factor listed across from appropriate plow depth.

Effective Tillage Depth in Inches	Multiplying Factor
0–3	0.40
6	0.86
7	1.00
8	1.14
9	1.29
10	1.43
11	1.57
12	1.71

2. **Lime Type/Purity Adjustment Factors:** Select most appropriate lime type or purity and multiply the results of step 1 by the factor listed across from appropriate type or purity.

Lime Type, Purity or Analysis	Multiplying Factor
90% to 110% CCE/TNP	1.00
80% to 89% CCE/TNP	1.17
70% to 79% CCE/TNP	1.33
60% to 69% CCE/TNP	1.54
50% to 59% CCE/TNP	1.81
100% pure $CaCO_3$ (40% Ca)	1.00
Dolomitic Lime	
• 50% $CaCO_3$ + 50% $MgCO_3$ (22% Ca + 15% Mg)	0.92
• 75% $CaCO_3$ + 5% $MgCO_3$ (31% Ca + 7% Mg)	0.96
Other Materials	
• Calcium oxide (burnt lime)	0.56
• Calcium hydroxide (hydrated lime)	0.74
• Granulated slag	1.00

3. **Adjustments for Lime Grind Fineness:** Select the multiplying factor across from the applicable screen size, and multiply the results of step 2 by that factor.

Per Cent Passing Through Screen		Multiplying Factor
100-Mesh	**60-Mesh**	
80-100%	95-100%	0.80
60-79%	70-94%	0.85
40-59%	50-69%	1.00
30-39%	50-69%	1.25
20-29%	30-39%	1.45
10-19%	20-29%	1.70
0-9%	0-19%	2.00

Lowering the Soil pH

Sulfur (S) is the most economical, though still expensive, way to lower soil pH. This is a biological process where certain soil bacteria convert the elemental S to sulfate sulfur (SO_4-S). During this process, acid is formed. The drawbacks of using elemental S are:

- The soil must have a viable population of the correct bacteria.
- It is a slow process requiring time, soil temperature, and soil moisture.
- It is expensive.

A Spectrum Analytic soil test will include proper S recommendations to lower the soil pH for the listed species. Surface applied S, like lime will not immediately affect the entire root zone. However, applied S may change the soil pH to a greater depth than lime. It is still wise to apply several smaller applications in order to avoid changing the soil pH too much.

Sulfur Effect on Soil pH (lb.-S/acre)

Original pH	Target pH	Soil CEC						
		1	**5**	**10**	**15**	**20**	**25**	**30**
5.0	4.5	88	175	353	530	665	800	1,120
5.5		175	350	700	1,050	1,325	1,600	2,234
6.0		265	530	1,035	1,540	1,925	2,310	3,228
6.5		330	660	1,340	2,020	2,525	3,030	4,251
7.0		420	840	1,695	2,550	3,190	3,830	5,368
7.5		501	1,002	2,004	3,006	3,758	4,509	6,317
6.0	5.0	110	220	335	450	550	650	885
6.5		274	548	943	1,337	1,644	1,951	2,701
7.0		374	747	1,257	1,766	2,168	2,569	3,547
7.5		469	937	1,547	2,157	2,642	3,127	4,309
8.0		845	1,689	2,024	2,357	2,641	2,924	3,849
6.0	5.5	109	218	272	327	382	436	576
6.5		218	436	545	654	763	872	1,151
7.0		327	654	818	981	1,145	1,308	1,726
7.5		436	872	1,090	1,308	1,526	1,744	2,301
8.0		763	1,526	1,799	2,071	2,344	2,616	3,414
8.5		1,090	2,180	2,507	2,834	3,161	3,488	4,526
7.0	6.0	189	377	472	566	685	804	1,051
7.5		343	686	870	1,054	1,213	1,372	1,825
8.0		682	1,363	1,575	1,786	2,047	2,308	2,980
8.5		1,045	2,090	2,379	2,667	2,956	3,244	4,199
7.0	6.5	50	100	125	150	225	300	375
7.5		250	500	650	800	900	1,000	1,349
8.0		600	1,200	1,350	1,500	1,750	2,000	2,545
8.5		1,000	2,000	2,250	2,500	2,750	3,000	3,871

Adapted from the Western Fertilizer Handbook 7th ed.: Nursery Management, 2nd ed. H. Davidson, et al., 1988; the Highbush Blueberry Production Guide (NRAES-55), Northeast Regional Agricultural Engineering Service, M. Pritts and J. Hancock ed., 1992.; and Vegetable Growing Handbook, W. E. Splittstoesser, 1979.

In situations where the drawbacks of using elemental S are a problem, other materials may be better. The following table lists some other options and conversion rates.

Material	Chemical Formula	Percent Sulfur	lbs of Material to Equal 100 lbs of Sulfur
Elemental Sulfur*	S	90.0	110
Sulfuric Acid	H_2SO_4	32.0	306
Sulfur Dioxide	SO_2	50.0	198
Iron Sulfate	$FeSO_4.7H_2O$	11.5	896
Aluminum Sulfate	$Al_2(SO_4)_3$	14.4	694
Ammonium Sulfate*	$(NH_4)2SO_4$	23.7	422

*Note: The acidifying effect of elemental sulfur is caused by sulfur oxidizing bacteria. These bacteria must be present in the soil, in sufficient amounts, in order to have the desired effect. If a soils pH is above 7.2 in its natural state, it may not have a large population of sulfur oxidizing bacteria. In these cases it may be helpful to inoculate it by adding some soil from another source that is naturally acid. Also, the pH change caused by the bacterial oxidation of sulfur may be relatively slow (12 months or more) since they are dependent on sufficient soil moisture and temperature to accomplish efficient sulfur oxidation. The other products listed produce a chemical acidifying effect, independent of soil organisms and may be faster and more dependable than elemental sulfur.

Caution: Some authorities recommend that no more than 300-350 lbs. of S (or its equivalent)/acre/year is applied to established stands. This is because some data on low CEC soils with acid sub-soils indicate that high rates of S can cause a temporary excessively low pH. In this research, the trees were severely damaged and many died. Not all authorities report this effect and in our personal experience with high pH clay soils (high CEC), higher rates of S in a single application can be made. If your soil has a low CEC (less than 10), and has an acid sub-soil you should limit annual applications to no more than the equivalent of 350 lb. S/acre. Monitor these situations with annual soil tests plus additional S applications as needed until the desired soil pH is reached.

Fertilizer Application Methods

Soil Application

Unless otherwise noted, all soil fertilization rates and methods are assumed to be as a general broadcast application over the entire area. This is normally on an acre (43,560 sq.ft.) basis. Most tree producers will want to apply fertilizer in only the root zone of their trees, and leave the rest of the area unfertilized. Since the ratio of fertilized area to unfertilized area will be different for each producer, we have not attempted to calculate a rate of application for banding here. Each producer should make these calculations for their trees, and adjust the recommendations proportionately. For example, if your calculations show that by fertilizing a limited area around each tree you are fertilizing only 50% of each acre, you should reduce our recommendations by 50%.

Foliar Application

Tree producers should become familiar with the correct method of using foliar fertilization. It is often the best or only means of supplying the trees with the needed nutrients. Much of the information on foliar fertilization presented in this paper has come from North Carolina Dept. of Agriculture (NCDA) Laboratory, and William Huxster Jr., a retired Professor from North Carolina State University (NCSU). Conifer species used for Christmas trees can benefit from foliar fertilizer application of certain elements, under certain conditions. Foliar fertilization work at NCSU has been able to increase the number of buds set and needle length, plus improve the leader straightness and foliage color at harvest. Needle analysis has shown that, when done properly, most nutrients applied foliarly will correct nutrient shortages.

All commercially produced plants have evolved to obtain nutrients through their roots, so foliar fertilization is not “natural”. With the benefits, it also brings risk of foliar damage, or simply not working when done improperly. A grower must know when to spray, what materials to apply and their rates, and have the ability to deliver adequate water to cover the foliage, for effective use of foliar feeding. The first step is to identify the problem. This requires the use of plant (needle) analysis. Several interacting factors affect nutrient uptake. These include, but are not limited to…soil pH, soluble salts, soil moisture and temperature, diseases and insects, soil compaction and hardpans, and chemical injury. Soil testing cannot identify many of these problems, and is often not sensitive enough to indicate the differing effect of soil pH or soluble salts on each species of tree. Therefore, annual needle analysis is a must when foliar fertilizer is planned and used.

Nitrogen (N)

Soil Application

Optimum N rates differ according to the tree species being fertilized as shown below. One rule to keep in mind is that all N applications should be completed two or three months before the onset of freezing weather. This insures that the trees have adequate time to "harden-off" before freezing weather occurs. A tree that has had lush growth late in the season is often more likely to suffer low temperature damage than one that has not. The N rates shown below assume that the P and K needs of the trees have been met through good soil tests and proper fertilizer programs.

Seed and Lineout Beds

Apply 2.5 lb. N/1000 sq. ft. from a dry fertilizer when plants are dry and, if possible, irrigate with about ½ inch of water. If soil pH of bed is too high, adjust with appropriate materials, as shown earlier, and use ammonium sulfate as the N source.

Field Trees

Fertilizer N should be applied at least 2 weeks prior to bud-break. A considerable amount of research and experience has shown that when there is no competition from grass or other weeds, most species grown for Christmas trees can be produced with as little as 40 lb. N/acre. However, this is a minimal N rate and may not leave much room for error. Experience has shown that when grass is growing up to the drip-line of the trees, The N rate may need to be as high as 120 lb/acre. A "general" Nitrogen (N) recommendation of 1 oz. of N per tree per year (94 lb. /acre at 1,500 trees/acre) can be used if more detailed information on tree species and plant analysis results are not available. One approach to N application is as follows

Age of Trees (yr.)	Species	oz. N/Tree	
		Spring	**Fall**
1	All	0.5	
2	All	0.625	
3	Firs, Spruces	1.0	
	White Pine	0.5	0.5
	Virginia Pine	0.625	0.625
4+	Firs, Spruces	1.25	
	White Pine	0.625	0.625
	Virginia Pine	0.75	0.75

If the above rates do not produce adequate color or growth, and a plant analysis indicates the need for more N, increase the N rate by 0.5 to 0.75 oz/tree, per application, until condition improves. In the fall of the harvest year, apply about 40 lbs/acre of N to improve color.

Foliar Application

Foliar N fertilization can be a very effective practice, but it is intended as a supplement to a good soil fertilization program. Soil applied N is normally very quick and effective at solving an N shortage. The benefits of foliar N fertilization can be only temporary, and multiple applications in a season may be required. In any event, you should not expect to see more than one seasons effect from a foliar spray treatment. Also, excessive applications of foliar fertilizer can damage the needles. Some nutrients and fertilizer sources are more damaging than others when applied at excessive rates.

Urea is the preferred N source for foliar N applications. A good general rate is ½ lb. of urea/100 gallons of water/acre. This is equal to about ¼ teaspoon/gallon for single tree applications. The most effective growth stage for application is when the new needles are at about ½ of their mature length. However, the needles are soft at this stage, and more subject to salt damage from excessive application rates, so be careful to apply the correct rates. Where an N shortage is identified at another growth stage, it is recommended to make a corrective application, even if the growth stage and nutrient uptake efficiency are not perfect. Foliar N can be applied to actively growing trees at any stage of growth with a reasonable expectation of improvement. Avoid applying foliar N within 2 months prior to the onset of winter. Additional N at this time can reduce the trees ability to withstand winter temperatures. Late season foliar N can enhance the green color of trees in the year of harvest.

Phosphorus (P) and Potassium (K)

Soil Application

The optimum P_2O_5 AND K_2O nutrient rates, and soil phosphorus (P) and potassium (K) levels, vary according to other soil conditions such as CEC, pH, other nutrient balances, and to some degree the species of tree. However, since building a soil P or K level is a multi-year project, and the species of tree grown in a particular location changes periodically, the P and K soil test levels should be built up to "Good" levels according to soil test recommendations obtained from Spectrum Analytic's Agronomic Services Laboratory. As a general rule, you can build-up the soil P level at a rate of 1 lb. soil P per every 9 lb. of applied fertilizer P_2O_5, above the needs of the trees. Soil K builds up at about 3 lb. of applied fertilizer K_2O for every 1 lb. soil K. A general guideline for P_2O_5 and K_2O application rates are shown below. In the absence of more detailed information on the tree species, or nutrient content as shown by plant analysis, the following guidelines should produce adequate growth.

Soil P availability is strongly affected by the soil pH. When the soil pH is below 6.0 or above 7.0, the P availability can be dramatically reduced. Since many Christmas trees are grown on very acid soil, the soil P level should be higher than is often recommended. Soil P levels as high as 200 lb/acre or more may be needed for best growth on strongly acid soils. Producers should adjust their applications accordingly.

Spectrum Soil Test Rating	P_2O_5 lbs/acre to apply	K_2O lbs/acre to apply
Low	120	120
Medium	80	80
Good	40	40
High	0	0

Foliar Application

Good quality responses have been reported with foliar applications of various proprietary phosphorus products, but common agricultural phosphorus fertilizers are not generally adequate for foliar application purposes. Foliar applied potassium has been used successfully in several annual crops, but has not been found to be necessary with conifers. When using one of the proprietary products, follow the manufacturer's application recommendations.

Calcium (Ca)

Many species of conifers suffer from poor Ca nutrition. This occurs for several reasons, but primarily because the acid soils required by many trees are low in Ca supplying power. Also, many species require excellent soil drainage and these soils simply do not have the holding power (CEC) to retain a naturally large supply of most nutrients, including Ca. Where there is a need to increase the soil Ca level, most producers should combine soil applications with foliar applications. This is because the initial soil applications are likely to be "tied-up" by the soil, and leave the trees still short of Ca. As repeated soil applications start to increase the soil Ca levels, the trees will begin to acquire more of their Ca needs from the soil. Ideally, you would like to see your soils with a Ca saturation higher than 50%. Unfortunately, under the acid soil pH that many conifers require, the natural soil Ca saturation is often much less than 50%. Also, while there is no ideal ratio of one element to another, it is desirable to have the soil Ca:Mg ratio between 3:1 and 5:1.

Soil Application

Agricultural limestone will be the most economical source of Ca (and magnesium), so always apply lime when needed. Where no lime is needed, other Ca sources must be used. The most economical of these other sources is often gypsum ($CaSO_4$). In its chemically pure form, gypsum has an analysis of 23.6% Ca and 18.6% S. The analysis of commercial sources of gypsum will vary somewhat from this, due to impurities present. The Ca and S in gypsum are water soluble, and available to the trees. However, the Ca will not move deeply into the soil, so it is wise to correct any soil problems prior to planting if possible. Gypsum has little effect on soil pH so it is useful for conifer fertilizer programs. Required rates of gypsum to correct a low soil Ca problem will vary according to the soil needs and conditions.

North Carolina Department of Agriculture suggests the following guideline to develop a rate of gypsum to fertilize Christmas trees. Typical gypsum purity ranges are as follows:

Gypsum Source	Typical Purity
Anhydrite Gypsum (essentially pure gypsum)	94% $CaSO_4$
"Typical Commercial" Gypsum	79% $CaSO_4$
By-Product Materials	as low as 50% $CaSO_4$

Apply the equivalent of 100 lb. of pure anhydrite gypsum for every 1 CEC unit of the soil, using the following formula example to calculate the rate.

(100 x CEC) x (94 divided by the % purity of local gypsum) = rate/acre of local gypsum
Example: CEC = 5, and local gypsum purity = 79% • Formula: (100 x 5) x (94/79) • 500 x 1.19 • 595 lb./acre of local gypsum

Note: When applying high rates of gypsum, re-test the soil annually to monitor the soil Ca build-up. Other sources of soluble Ca can provide available Ca. However, the required application rates of Ca do not change with the Ca source, so cost becomes a significant factor. Beware of products that claim that you can apply a very small amount and provide all of the trees needs. These products are normally not effective.

FOLIAR APPLICATION

There are a number of commercial, proprietary sources of liquid Ca developed for foliar feeding that work well. Christmas tree growers should consider some of these products from a reputable company. When using these materials, follow the manufacturer's directions for application. The purpose of using these products is to avoid salt burn on the tender new needles. Christmas tree producers would probably do well to develop some contacts with apple producers and their suppliers for sources of these products because apples also have problems with Ca uptake.

A couple of common fertilizer Ca sources used for foliar feeding in other crops are Calcium Nitrate [$Ca(NO_3)_2$], which is 15% N plus 19.4% Ca, and Calcium Chloride ($CaCl_2$), which is 36% Ca. While effective, these sources make a rather high salt concentration solution at typically recommended rates. The commonly recommended rates and concentrations are suitable for crops such as apples, but they are a little strong for conifers. The "apple" rates for each material are… "Calcium Chloride at 1 to 2 lb. of product/100 gal. of water per acre. If the trees need additional N, apply Calcium Nitrate at 2 to 4 lb. of product/100 gal. /acre. In either case, additional applications 14 days apart may be needed to satisfy the trees needs. Avoid using Calcium Nitrate if the trees have been adequately fertilized with N previously, or if there is less than 2 months left before the normal first frost date." Christmas tree producers should cut these recommendations approximately in half for safety. Also, multiple applications are less likely to be needed with conifers.

Magnesium (Mg)

Conifers often have trouble taking up adequate amounts of Mg. Like calcium, the major causes of this are the acid soils that conifers typically require, and the low CEC values that these soils often have. If possible, it is desirable to build the soil Mg level up to 15% Mg saturation, or at least above 10%. While there is no ideal ratio of one element to another, it is desirable to have the soil Ca:Mg ratio between 3:1 and 5:1. Where there is a need to increase the soil Mg level, most producers should combine soil applications with foliar applications. This is because the initial soil applications are likely to be "tied-up" by the soil, and leave the trees still short of Mg. As repeated soil applications of Mg start to increase the soil Mg levels, the trees will begin to acquire more of their Mg needs from the soil.

Wilted or drooping leaders during elongation can be an indication of low magnesium levels in the conifer. Saturated soils for an extended period of time will also cause this same condition to occur. A needle analysis can help to confirm if the magnesium is in the normal range and help to better diagnose the problem.

Soil Application

As with calcium, the most economical source of Mg is lime. Dolomitic lime typically contains more that 10% Mg, so 1 ton of this lime will supply 200 lb/acre of Mg. Where lime is needed, use dolomitic lime to economically add large amounts of Mg to the soil. If lime is not needed, the most common sources of Mg are Magnesium sulfate, often called by its common name Epsom Salts ($MgSO_4$), 10% Mg and 13% S, and sulfate of potash magnesium ($K_2SO_4MgSO_4$), sold under the trade names of K-Mag and Sul-Po-Mag. Sulfate of potash magnesium has a typical analysis of 22% K_2O, 11% Mg, and 22% S. There are also sources of Mg such as magnesium oxide (MgO), magnesium chloride ($MgCl_2$), and various chelated forms. Most are adequate sources of Mg; however magnesium oxide is not considered soluble and is not likely to provide a quick crop response. Where the soil needs magnesium, it normally requires additions of large amounts of fertilizer to correct the problem, sometimes over several years. Where a quick response is needed, Epsom salts and sulfate of potash magnesium are typically the most economical sources, after dolomitic lime. Nutrient recommendations range from 11 to 66 lb. of Mg/acre, depending on the severity of need.

Foliar Application

Where plant analysis shows a need for Mg, the most practical foliar application will likely be 1 or more applications of 4 lb. of Epsom salts/100gal. of water/acre, applied 2 weeks apart, beginning when the leader is about 50% elongated, or when the new needles are at least 33% of their full length (50% length is preferred).

Sulfur (S)

Plants of all types take up only the sulfate (SO_4) form of sulfur. Often time's producers apply the most economical source of sulfur, which is typically dry 90% S granules. The elemental S in this product must go through a biological conversion to the sulfate form before plants can us it. This process typically requires several months of summer weather to accomplish, so the needed SO_4-S is not available until late in the year. When a quick response is desired, the producer must use a sulfate form of S.

Conifers rarely need supplemental S. This because native soil S is typically abundant in the acid soils that many of them require. However, if the soil is sandy and has low organic matter (light colored) it could have low S supplying capacity. Also, sandy soils can suffer temporary S deficiencies during periods of excessive rainfall, since the available SO_4 form of sulfur is subject to leaching.

Soil Application

Follow the soil test recommendations for sulfur fertilization. Recommended rates will range from 5 to 30 lb. of sulfur per acre on a general broadcast basis.

Foliar Application

In our experience, there is not a need to apply S as a foliar application. Some incidental S will be applied when another nutrient in the sulfate form is applied.

Micronutrients

As the name implies, micronutrients are needed in very small amounts by all plants. Producers should be careful to apply the proper amounts of micronutrients, because most of them have the potential to be toxic to the trees (and all plants) when excess amounts are applied. The proper method to evaluate micronutrient needs is with a plant analysis, plus a soil sample from the drip-line of trees that have had the tissue sampled. As with other nutrients, adjust the broadcast recommendation proportionately if the nutrient is not applied uniformly to the entire acre.

Boron (B)

There is some disagreement in the literature, and between authorities on the B requirement of most conifers grown for Christmas trees. Recent experience leads us to believe that most of these species require higher internal B levels than was originally thought. The producer should be careful to apply B at the proper rate, based on tissue analysis, to avoid over-application and tree damage. Boron is highly mobile in the soil and is readily absorbed by the roots, therefore soil applications are normally adequate to supply the trees needs.

Soil Application

As of this time, Spectrum recommends only broadcast applications of B. However, Christmas trees, and other tree crops normally are fertilized in a broad surface band at the drip line along both sides of a row of trees. The inter-row area is not normally fertilized. The recommended rate will range from 0.25 to 1.0 lb/acre of elemental B. However, research by William Huxster and personal communications with Christmas tree producers indicate that this rate is likely to be low. Where a tissue analysis confirms low B uptake, the grower should apply 2 lb. B/acre by the previously described surface band method. That same work by Huxster showed that Christmas tree species can tolerate a significant over-application of soil applied B without damage.

Foliar Application

Although other sources of soluble B are available, the most popular is probably Solubor™ (20.5% B). Most Christmas tree species will respond well to foliar B applied as Solubor™ at from 0.1 to 0.2 lb. B/acre. This would require 1 lb. of Solubor™ in 100 gallons of spray/acre, if applied alone. If you are combining multiple nutrients in one spray, drop the rate of actual B back to between 0.05 to 0.1 lb/acre, so as to keep the total amount of fertilizer products applied below 5 lb. /100 gal. /acre. See the separate section of this paper on foliar application for more information.

Copper (Cu)

Copper is a micronutrient that is not often limiting. When needed, it should not be applied indiscriminately, and **the soil should be tested annually to monitor the buildup of Cu**. It is relatively easy to correct soil deficiencies because Cu will not leach out with excess water. However, this also means that Cu will build up in the soil with repeated applications. It is possible to build up the soil Cu content to toxic levels, so **producers should apply no more Cu than is needed to correct a problem**. When soil Cu is increased to toxic levels, there is no practical way to fix the problem. The only quick solution is to increase the soil pH to above 7.0, which will be very harmful to many conifer species (see pH section). High soil phosphorus will also reduce the uptake of Cu (and Zn). Although this is not normally a problem with Christmas trees, the reader should be aware of the effect.

Soil Application

Recommendations from various sources will range up to 8 lb. /acre of actual Cu on a broadcast basis, but most producers will only receive recommendations from 0 to 3 lb. Cu/acre. Copper sulfate ($CuSO_4$) is the most common source of Cu; however there are liquid chelated Cu sources that may be used. If chelated Cu is used, follow the manufacturers label recommendations. It is possible to find soils that have an adequate amount of Cu in them, but the tissue test may confirm that the tree is low in Cu. In these cases, it may be preferable to use foliar Cu, until the soil is re-tested to fully confirm the cause of the low Cu uptake, and status of the soil Cu.

Foliar Application

Foliar feeding is an effective way to provide the annual Cu needs of Christmas trees. The need will re-occur each year as long as the low soil Cu condition is not corrected. **Take extra care to apply the correct rates, because Cu probably has the highest potential of any nutrient to "burn" the foliage when applied at excessive rates.** Normally, foliar application rates of from 0.1 to 0.2 lb/acre of actual Cu from copper sulfate will correct any deficiency. It is safer to make 2 applications of 0.1 lb. Cu/acre, about 2 weeks apart. Chelated, and other liquid Cu fertilizers, are also available. If these sources are used, follow the label directions. Copper containing fungicides have been effective in correcting Cu deficiencies in fruit trees, and may work as well with Christmas trees, but we have no first-hand experience with this. See the separate section of this paper on foliar application for more information.

Manganese (Mn)

Soil Mn availability increases dramatically as the soil becomes more acid (pH decreases), so Mn deficiency is not common in most conifers. Where the soil pH is higher than about 6.0, the availability of soil Mn can decrease sharply, and when the soil pH decreases below about 5.2, Mn solubility can increase to the point of being toxic to many plants, including conifers. Trees adapted to extremely acid soils (such as Fraser firs) typically have a higher tolerance of high Mn levels. On soils where the pH is too high or too low, and affecting the Mn uptake, the problem can be corrected by changing the soil pH. Excess Mn uptake can decease the uptake of Fe, leading to the need for foliar Fe to correct the Fe:Mn ratio

Soil Application

Broadcast applications of Mn to a soil that is either low in Mn, or has a high pH, or other condition that limits Mn uptake, is not likely to be effective in increasing Mn uptake by conifers, or other cultivated plants. Broad surface band applications may be somewhat superior, but still inefficient. If Mn can be applied in a very concentrated sub-surface band, the application rate should be from 3 to 6 lb. of elemental Mn/acre. In the absence of the option to insert Mn into the soil in a very concentrated zone, the producer should use annual foliar applications to supply the needed Mn.

Foliar Application

Manganese sulfate ($MnSO_4$) is the most commonly recommended source of Mn, although liquid chelates are available. Normally a foliar application of from 0.5 to 1.0 lb. Mn/acre/100 gallons (as $MnSO_4$) will correct deficiencies. Additional applications at this rate can be applied after 14 days. Manganese containing fungicides have been partially effective in correcting Mn deficiencies in fruit trees, and may have similar effects on conifers, although we do not have first-hand experience to confirm this.

Zinc (Zn)

Soil Application

The soil test level of Zn is relatively easy to “build-up”; however it typically requires a single, very large application, or a small number of applications that are much larger than typical recommendations. If the producer applies only the minimum required Zn per year, he may supply that years needs, but not see his soil Zn level improve significantly. Zinc sulfate ($ZnSO_4$) is the common Zn source, although liquid Zn chelates are also available. Typical Zn soil recommendations are made on a broadcast basis for trees, and range up to 10 lb. Zn/acre. Zinc applications are not likely to become toxic from annual use, even if somewhat over-applied. A single application, soil correction rate would typically be in the range of 20 lb. Zn/acre.

Foliar Application

Zinc can be effectively applied foliarly. Zinc sulfate, dissolved in water is an effective source. Zinc chelates and several other proprietary liquid Zn sources have also been shown to be effective. Zinc containing fungicides have been partially effective in correcting Zn deficiencies in fruit trees, and may have similar effects on conifers, although we do not have first-hand experience to confirm this. Typical application rates for foliar Zn are from 0.3 to 1.0 lb. Zn/acre/100gal. as zinc sulfate. If other sources are used, follow the label directions. As with all foliar applications, reduce the amount of Zn when multiple nutrients are applied in a single spraying. If the minimum rate is used, the grower may need to make a second application about 14 days later.

Iron (Fe)

Iron is not commonly deficient in conifers because

- most soils have adequate Fe supplying capacity
- many conifers are grown on acid soils, which increase the Fe availability.

One unique condition of Fe in plants is that many plants will often respond to foliar Fe when the internal (plant analysis) ratio of Fe:Mn is less than 1:1. In this case the absolute level of Fe may be within the sufficient range, but a higher level of Mn can cause the Fe to be ineffective. In these cases, foliar Fe can sometimes improve color and growth.

Soil Application

Iron is one of the most abundant elements in the soil, and deficiencies are rarely due to an inadequate supply. It is almost always the case that a Fe shortage in the plant is caused by other adverse soil conditions limiting the availability of soil Fe. In this case, soil applied Fe will not be effective. For this reason, we do not recommend soil applied Fe.

Foliar Application

Foliar application is the only dependable method of correcting a Fe shortage in trees, or other crops. There is very little published information on the effectiveness of various rates of foliar Fe on conifers, however recommendations for a wide variety of crops range from 0.2 to 2.0 lb. Fe/acre/100 gal. We normally recommend 1 or more applications of 1 lb. Fe/acre/100 gal. spaced 14 days apart. There are a number of proprietary commercial sources of Fe for foliar application that work well. Ferrous sulfate ($FeSO_4$, 19% Fe) is a common source of Fe for foliar sprays, however the grower must be careful not to use water with a high pH. As the water pH increases above about pH 6.5, the Fe in solution will tend to convert to iron oxide, which is unavailable and ineffective. This change can sometimes be seen in the water as a rusty or muddy color. Maintaining the solution at a mildly acid pH will increase the availability of the Fe. Iron chelates, and a few other liquid sources are also available. If these sources are used, follow the label directions.

Soil and Plant Sampling
Commerical Christmas Tree Plantings

1. Divide the field into blocks of trees of the same species, age, and general soil condition. Develop a 1-12 number/letter code system to identify each block to be sampled and use this code each time samples are taken in the future.

2. Select 5 to 10 trees in each block, that are typical of the block. Mark these trees in some permanent manner such as plastic or aluminum tags or ribbons. These trees will become the "indicator" trees for the entire block. A composite soil and plant sample from these 5 trees will be taken for each block, and used to evaluate and fertilize the entire block.

3. Take 3 to 4 soil cores around the drip line of each tree (15 to 20 cores in total). Place the soil cores in a plastic bucket and mix them thoroughly. Fill a soil bag supplied by Spectrum up to the line on the bag. Combine these cores to make the soil sample for that block of trees.

4. There are some options in plant sampling, depending on pruning/shearing practices. The nutrient analysis of any part of the current season's growth is acceptable and the terminal or lateral growth is similar. It is also acceptable to use the previous season's growth, but there can be some difference in this tissue and it should be noted on the sample history. From each of the same trees, take 3 to 5 laterals or terminals. (a total of 15 to 20 is enough). Do not sample current season's growth until it is hardened off. The best time is after it has become dormant in the fall (typically October in the Midwest). Trees can also be sampled between hardening-off and fall in the harvest year, or if there is another important reason. However, the trees will be absorbing nutrients during this time and the analysis has not fully stabilized until dormancy. It is possible to sample older tissue, but the interpretation of the results will be less accurate.

5. Mark the soil bag and plant sample envelope with the 1 to12 number/letter code for that block, plus the other requested information. Put the sample bags in a secure shipping container such as the boxes provided by Spectrum Analytic and send them to Spectrum.

6. Record this identification and all other information such as sample data, treatments, measurements, close-up photographs, and other data in a log so you can evaluate the progress of the crop.

Note: If you want to identify or confirm suspected nutrient problems with individual trees, sample the single tree as described above. Remember to take the total required "current years growth tips" and soil cores from that tree. In this case, it would be helpful to take an additional set of tips and soils from a normal tree to compare with.

References

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5. FERTILIZATION FACTS FOR CHRISTMAS TREE GROWERS, FS087, Dr. Roy L. Flanery, et al, Rutgers Cooperative Extension , New Jersey Agricultural Experiment Station