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Tree Health and Fertilization

The health of Alaska's forests has been declining in recent years as a result of increasing levels of stress. Stress factors such as drought, higher temperatures and poor tree vigor have lead to regional tree health concerns which also influence individual trees on woodlots and in yards on private property.

Trees planted on woodlots or within housing development areas are commonly planted in soils that have been modified or disturbed by compaction, topsoil removal, contamination and/or altered soil drainage. The health and growth of trees in Alaska has been impacted by a number of factors including a climactic warming and drying trend, previous fire control efforts, forest debris accumulation, slower tree growth, reduced production of protective compounds and increasing levels of insect and disease attack. Two effective ways of monitoring your trees' health are by measuring either plant moisture stress (PMS) or plant tissue and soil nutrient levels. There is a close relationship between these two factors as they influence tree health. This publication examines how knowledge and use of these two factors can be valuable in providing a tree health assessment.

Plant Moisture Stress (PMS) — Tree-Water Relations

A partial vacuum develops in tree leaves as they lose water through photosynthesis and transpiration (loss of water vapor from the leaves). This partial vacuum serves to draw water up from the soil through the roots and stem in response to the vacuum (negative pressure) found in the leaf. The amount of internal pressure experienced by tree leaves in order to uptake water is directly influenced by the availability of soil-water. Dry soils, compacted soils, soils low in nutrients and root systems compromised by insects and/or diseases will typically exhibit higher levels of plant moisture stress in a tree as a result of the trees' inability to obtain sufficient water. PMS also is directly related to the duration of photosynthesis occurring in the tree leaves. Consequently, trees exhibiting high levels of PMS also will exhibit lower or nonexistent levels of photosynthesis during periods of high PMS.

Artwork by Laura Weaver

Transpiration, resulting in the loss of water vapor through the stomata (cellular pores or openings commonly found on the lower surfaces of the leaves), is an important part of the normal biological water and nutrient uptake processes occurring in the tree. Transpiration in trees can account for as much as 20 percent of the total water volume lost per day. To remain healthy, the tree must then rehydrate overnight in preparation for the next day's water usage.

How does water get to the tops of tall trees?

One theory to explain this has been called the Cohesion Theory. Proponents of this theory believe that the combination of a negative pressure or force found internally in the tree as the attractive force between water molecules and cell walls (adhesion) and the attraction of water molecules in the tree conducting tissue caused by the hydrogen bonding (attraction of water to itself) result in trees being able to draw water up to the top of the tree canopy, even in trees more than 300 feet tall.

In a manner similar to a pumping mechanism, water is absorbed through the roots, transported up the stem of the tree in the sapwood (xylem) tissue and released by transpiration through the stomata (pores) in the leaves.

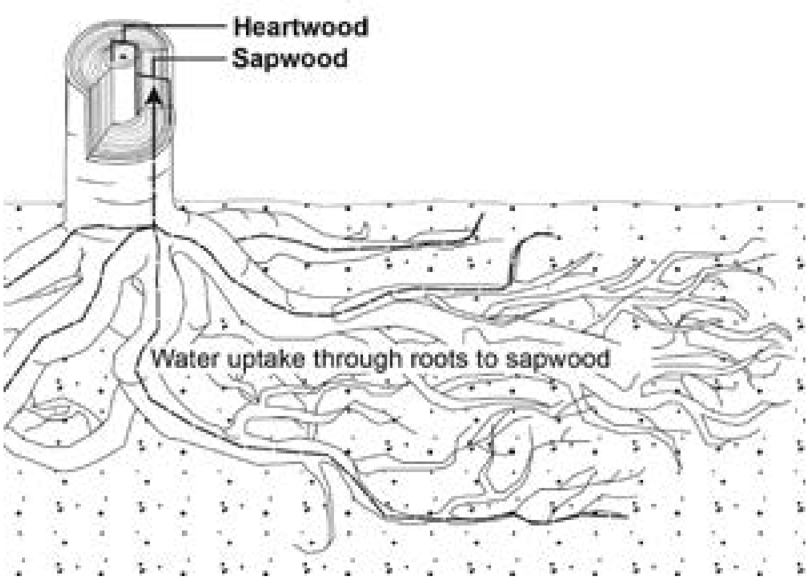

Illustration of the movement of water from the soil, through the fine root hairs to the roots and upward through the xylem (sapwood) tissue of the tree stem. *Artwork by Laura Weaver*

This loss of water from the leaves creates an internal pressure or partial vacuum that serves to further draw water up from the roots (similar to how a soda straw functions). As the availability of water in the soil declines, such as under drought conditions, water lost from the leaves results in an increasing internal negative pressure within the leaves. The amount of internal pressure is measured in atmospheres or BARS or megaPascals (MPa) (1MPa = 10 BARS = 9.83 atm). As the internal negative pressure or partial vacuum increases, the leaf stomata will close in order to try and prevent further water loss from the tree. Following stomata closure, the influx of carbon dioxide, which is used during photosynthesis, is also blocked, leading to a shutdown of photosynthesis in the leaves. Less photosynthesis means less potential growth and less of an ability for the tree to deal with environmental stress conditions. As a result, PMS should be a helpful tool in assessing tree health and management.

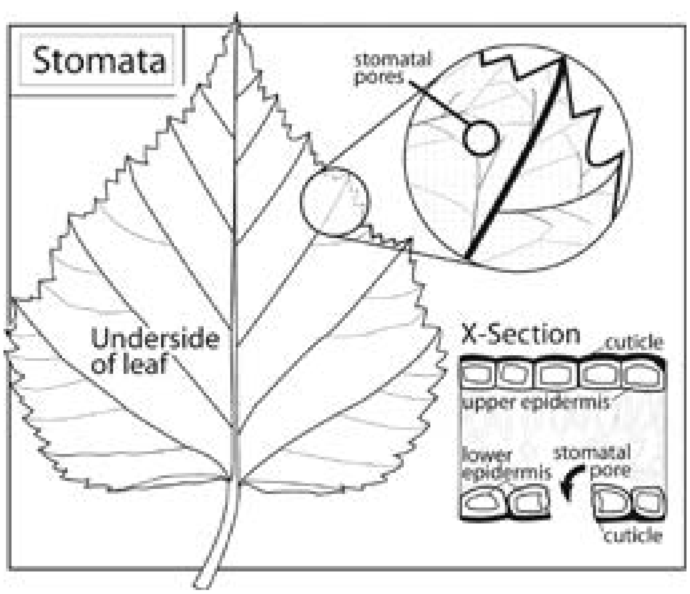

Illustration of the stomatal pores typically found on the underside of tree leaves that influence the transpirational water vapor loss from trees. *Artwork by Laura Weaver*

The response to moisture stress by trees is strongly influenced by characteristics of the individual tree species. Birch, a common tree species in the boreal forest, contains diffuse porous wood with relatively small vessel cells in the xylem sapwood tissue, which results in the wood having relatively high resistance to water flow and slow stem water volume flow rates. These characteristics result in birch leaves having to maintain a high leaf water potential gradient (internal leaf negative pressure) in order to obtain water for photosynthesis. Birch have shallow root systems, making them very susceptible to drought (moisture stress) which can result in early leaf loss as a means of reducing water loss under drought conditions.

How Do You Measure Your Trees' Condition?

Using PMS as a measure of tree health, several techniques have been used to measure PMS through leaf water potential, however, one of the best is the use of a pressure chamber. The pressure chamber (known as a pressure bomb) involves the use of a sealed metal chamber into which a fresh leaf or stem sample is placed. The pressure bomb measures the amount of pressure needed to force water out of the cut stem or leaf. This technique is accurate and reliable but requires access to a pressure bomb and a gas chamber (usually carbon dioxide).

A pressure bomb is used to measure the amount of pressure needed to force water out of a cut leaf or stem. *Photograph by Bob Wheeler*

Table 1. Macronutrient tree fertilizer functions and deficiencies

Nutrient	Function	Deficiency Symptoms
Nitrogen (N)	Promotes growth, green leaves and photo-synthesis.	Chlorosis of older leaves turning pale green to yellow; oc-casional scorching of leaf tips and margins.
Phosphorus (P)	Used in the production of roots, flowers and fruit.	Accumulated anthrocyanins cause a blue-green or red-purple coloration of leaves; flowering and fruiting are reduced. Lower leaves tend to turn yellow.
Potassium (K)	Assists in flowering and fruiting, sturdiness, disease and stress resistance, cell growth, stomata control and photosynthesis.	Leaf margins become scorched, turn brown or mottled and curl downward. Chlorosis first begins at the tips and margins of leaves and progresses toward the base of the leaves.
Calcium (Ca)	Assists in cell wall formation, growth in root tips, bud elongation and fruit development.	Chlorosis and necrosis of leaves; distorts growth of root tips and shoots.
Magnesium (Mg)	An important component of seed develop-ment and chlorophyll for photosynthesis.	Chlorosis of leaves followed by a brilliant yellow color between the leaf veins.
Sulfur (S)	Used for plant hormones and is an important component of plant proteins, contributes to green leaf color.	General chlorosis and small leaf size. Symptoms typically occur in the youngest leaves and shoots. Leaves may have a reddish tint, especially on the lower side.

Information provided by: (1) Tree Fertilization Reasons and Methods: Southern Urban Forestry Associates
(2) Nutrient Deficiencies in Trees: University of Tennessee Agricultural Extension Service

Nurseries and research universities will often have pressure bombs for use in monitoring PMS. Research has shown that maintenance of internal tree moisture stress levels below 8 BARS is considered desirable. Although a tree's ability to endure high levels of PMS varies depending upon species, exceeding a threshold level of 10–15 BARS will likely result in a significant reduction of photosynthesis. Conversely, plant dormancy can be induced by developing high levels of PMS within the tree or by reducing the availability of soil nitrogen.

Elevated levels of PMS can reflect symptoms of several site-related conditions, including low soil moisture availability, soil compaction, physical damage, competition from other plants, root diseases, insect damage and low soil nutrient availability.

Tree Tissue and Soil Nutrient Analysis

Even if the growing conditions are within tolerable limits, low soil nutrient availability will limit the growth and vigor of your tree, potentially leading to further problems associated with increased plant moisture stress and susceptibility to insect and disease attack.

As mentioned prior, tree health is directly affected by soil nutrient deficiencies. Three macronutrients and three secondary nutrients are considered essential for tree growth: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulfur (S) (see Table 1). However, nitrogen, phosphorus and potassium comprise about two-thirds of the total mineral content of tree tissue. Deficiencies of these nutrients can appear as a variety of symptoms in trees.

Nitrogen Deficiencies

Nitrogen (available as either NO_3^-, NH_4) is one of the most important nutrients required to maintain tree health and vigor. As trees become increasingly nitrogen deficient, their leaves first turn a light green, then become yellow or chlorotic (caused by inadequate chlorophyll synthesis) as the deficiency increases. Under severe levels of nitrogen deficiency, the leaves may appear scorched on the margins and may even senesce or die. Nitrogen deficiency symptoms typically begin with older, less productive leaves or needles and progress to newer ones.

Research has shown that increasing nitrogen uptake can increase photosynthesis in deciduous trees as much as 500 percent, whereas increasing nitrogen uptake in conifers (such as spruce) may only increase photosynthesis by up to 25 percent. To some extent, the conifers can make up for this lower rate of photosynthesis increase by adding more needles (leaves) to the tree.

Soil nutrient deficiencies (such as nitrogen) can have dramatic impacts on photosynthetic rates in the tree as well as carbon dioxide uptake, which is needed for photosynthesis. Phosphorus, potassium and iron soil deficiencies are also linked to reduced rates of photosynthesis. Trees with reduced photosynthetic rates, resulting from soil nutrient deficiencies, will not be able to develop their canopies and their root systems as they should, which can result in trees that are less able to cope with localized stress conditions such as enhanced temperatures or limited water availability.

Table 2. Common nitrogen fertilizer – Granular fertilizer

Name	N% (N)	P% (P_2O_5)	K% (K_2O)
Milorganite	6	2	0
Urea	46	0	0
Ammonium nitrate	33–34	0	0
Ammonium sulfate	21	0	0
Monoammonium phosphate	11	52	0
Diammonium phosphate	18	46	0
Osmocote Fast Start (8–9 month release) CRF	18	6	12
Osmocote High N (8–9 month release) CRF	24	4	8
Polyon; 25-4-12 (8–9 month release) CRF	25	4	12
Nutricote 270 (8–9 month release) CRF	18	6	8

CRF: Controlled release fertilizer – Suited for containers

Table 3. Common nitrogen fertilizer – Liquid fertilizer

Name	N%	P%	K%
Potassium nitrate KNO3	13	0	45
Plant Products; 20-20-20	20	20	20
Scotts Excel Cal-Mag; 15-5-15	15	5	15
Scotts Peters Foliar Feed; 27-15-12	27	15	12
Scotts Peters Plant Starter; 9-45-15	9	45	15

CRF: Controlled release fertilizer – suited for containers
Tables 2 and 3 were obtained from Macronutrients – Nitrogen: Part 2. Thomas D. Landis and Eric van Steenis. Forestry Nursery Notes. Winter 2004.

Phosphorus Deficiencies

Phosphorus, commonly applied as the oxide of phosphorus (P_2O_5), is an important macronutrient necessary for good tree growth and development. Soil phosphorus levels are typically much less than those for either nitrogen or potassium; however, many of the phosphorus compounds found in soil are insoluble and not available for plant uptake. Additionally, when phosphorus is added to soils it can become fixed, forming insoluble compounds which further limits its availability. For leaf tissue analysis, total phosphorus content of healthy vigorous tree leaves should be in the range of 0.2–0.4 percent of the leaf dry matter.

Phosphorus deficiencies are likely to occur in early spring, especially during cool and/or dry conditions, which can limit root development during a period of otherwise rapid growth. Symptoms of phosphorus deficiency include stunted, slow tree growth and potential purpling of the tree leaves. Although phosphorus fertilizer is believed to stimulate root development, research with phosphorus fertilizer applications has found that there is little evidence to support the notion that heavy phosphorus applications stimulate root development and in fact were shown to stimulate more shoot than root growth.

Phosphorus availability in soils can be strongly influenced by soil pH. Slightly acidic soil conditions (around 6.5) are considered best for maximizing phosphorus availability. Plant tissue analysis can be used to test for phosphorus deficiencies (below .10 percent) or toxic levels (exceeding 1.0 percent). Phosphorus availability can be especially important to support rapid early seedling growth. Because they can become fixed or insoluble and bind with surface soil particles that can be eroded from the site, phosphate fertilizers can contribute to eutrophication (explosive algal growth) of surface water, resulting in water quality problems. When applying phosphorus fertilizer, it is better to incorporate the fertilizer into the soil than to simply broadcast it on the surface.

Early season soil applications of phosphate fertilizer is best for enhancing plant growth. Because of the problems with the fixing of phosphorus and formation of insoluble compounds, banding of phosphate fertilizer in the growing soil horizon has been used effectively to deliver phosphorus. Fertilizers combining both phosphorus and nitrogen, such as monoammonium phosphate and diammonium phosphate, have been used to enhance the availability of phosphorus. The following table summarizes several of the commonly available phosphorus fertilizers.

Table 4. Common phosphorus fertilizers – Granular fertilizer

Name	N%	P% (P_2O_5)	K% (K_2O)
Milorganite	6	2	0
Single superphosphate	0	16–22	0
Triple superphosphate	0	44–53	0
Diammonium phosphate	18	46	0
Monoammonium phosphate	11	52	0
Osmocote Fast Start (8–9 month release) CRF	18	6	12
Osmocote High N (8–9 month release) CRF	24	4	8
Plyon; 25-4-12 (8–9 month release) CRF	25	4	12
Nutricote 270 (8–9 month release) CRF	18	6	8

CRF: Controlled release fertilizer – Suited for containers

Table 5. Common phosphorus fertilizers – Liquid fertilizer

Name	N%	P% (P_2O_5)	K% (K_2O)
Potassium phosphate	0	41–51	35–54
Phosphoric acid	0	54	0
Plant Products; 20-20-20	20	20	20
Scotts Excel Cal-Mag; 15-5-15	15	5	15
Scotts Peters Plant Starter; 9-45-15	9	45	15
Scotts Peters Foliar Feed; 27-15-12	27	15	12

Tables 4 and 5 were obtained from Macronutrients – Phosphorus. Thomas D. Landis and Eric van Steenis. Forestry Nursery Notes. Summer 2004.

Potassium Deficiencies

Potassium deficiencies directly influence the rate of photosynthesis in the leaves. An imbalance of high nitrogen (for growth) with a shortage of potassium can result in an accumulation of protein building blocks and reduced carbohydrate production that increase the tree's susceptibility to diseases and insects. Potassium deficiencies result in reduced tree growth, the formation of smaller leaves and branches, and a more compact tree form. Trees are also more susceptible to stress by drought and cold. Potassium is especially important to trees for control of stomatal activity in the leaves. Insufficient levels of potassium can influence carbon dioxide uptake needed to support photosynthesis, transpiration water loss in leaves and oxygen availability needed to support plant respiration. Recent research has shown that there is little support for the notion that late season applications of potassium fertilizer will improve winter hardiness.

How do I know if my tree needs to be fertilized?

Factors that fertilizing can improve:

- Low moisture availability (when applied during a period of sufficient moisture in order to increase root surface)
- Soil compaction (enhanced root development leads to reduced compaction)
- Recovery from physical damage
- Ability to compete with turf and other vegetation
- Insect and disease problems

Testing to Determine if You Need Fertilizer

In order to determine if you need to fertilize your trees and what rate of fertilizer you should use, you need to take a representative soil sample and have it tested and analyzed. A leaf or foliar nutrient analysis can also be conducted in order to determine the nutrient content of the leaves. However, leaf nutrient analysis alone does not provide an indication of why the nutrients are deficient.

To begin the process, first collect soil samples from the area around the tree. Usually 6 to 10 soil samples are collected from the root zone area. Each of the soil samples should be collected at a depth of 0 to 6 inches using a shovel or soil probe. These individual soil samples should then be mixed together in a clean bucket or soil sample bag (1-quart zipper-type bags). Any root and plant materials should be removed. Properly label and send to a soil testing service for analysis. Based upon the results from the soil analysis, a fertilizer prescription can be made that will directly address the soil deficiencies that your trees are encountering.

Tree demands for N, P and K will vary during the growing season and the species of tree. For example, for spruce seedlings, it is recommended that the leaf nitrogen levels be maintained between 2.5 percent to 3.6 percent. The higher level is recommended to support spring growth and the lower levels for later in the summer as the plant is conditioned for winter. The type of nitrogen fertilizer can also be important since there are three basic nitrogen fertilizers—those based on ammonia (NH_3), ammonium (NH_4^+) and nitrate (NO_3^-). The ammonium-based fertilizers have been found to support more upper shoot growth relative to root expansion, compared to nitrate fertilizers that tend to support more stem and root development.

The use of organic fertilizers, urea (ammonia) or ammonium-based fertilizers tend to make soils more acidic (lower pH) while nitrate fertilizers tend to cause the soil medium to become more basic (higher pH). The buffering capacity of some soils, such as those found on the Kenai Peninsula, can result in much less soil pH impact from ammonia/ammonium-based fertilizers.

Cold Soils

Although there is no established soil temperature that defines cold soils, it is has been found that crop productivity is considerably restricted in soils with temperatures ranging from 45–50°F. Soil temperatures in cold soils may average only 45–60°F for the duration of the growing season. However, due to the mechanics of soil development, cold soils commonly exhibit similar characteristics.

Cold soils are typically wet soils, in part because of the high energy input needed to evaporate a given amount of water. Cold soils typically exhibit limited root development and restricted availability of plant nutrients partly because of the slow process of nutrient mineralization from parent material in the soil. Nitrogen availability is commonly low in cold soils, resulting in yellowing of plant leaves grown on these soils. Cold soils exhibit slow organic matter decomposition, resulting in an increase of organic matter content and a buildup of humus or duff. Low soil temperatures also restrict phosphorus and potassium availability because of lower solubility and limited root development. Consequently, it is recommended that fertilizer banding be used to assist in nutrient availability in cold soils. Fertilizer banding involves the application of fertilizer in an area near and below the soil depth of a planted seed or seedling root mass. Within cold soils, root development has been shown to be more pronounced in the region of phosphorus fertilizers bands than was found in warmer soils. Growing season starter applications of (P) phosphorus fertilizer in cold soils are recommended at a rate of 10 lb. P_2O_5 /acre.

Alternatives to enhancing cold soil yields by soil warming have been studied at the University of Alaska Fairbanks and have included the application of raised beds, cold frames, portable shelters, use of south-facing slopes, coal dust and mulches. Research on mulches conducted in the 1960s at UAF evaluated the application of clear sheets of polyethylene plastic, black polyethylene plastic, black petroleum and black paper. More recently, mulching with infrared transmitting polyethylene plastic (IRT) has shown promise for increasing soil temperatures while controlling weed development under the plastic sheeting.

Research with cold-adapted fruit trees has found several dwarf root stocks that are very cold hardy and this hardiness can be transferred to grafted less hardy but more productive scion material.

Within the boreal forest, the presence of spruce trees, and especially black spruce, is closely associated with colder soils. The presence of the spruce and moss ground cover can promote the development of cold soils, leading to limited site productivity for other trees such as hardwoods and plants. Cold forest soils dominated by spruce overstory and associated moss ground cover can be warmed to some extent by reducing stand density and scarification of the soil surface. However, significant stocking reduction of overstory trees can result in an increased incidence of windthrow, especially in wind prone areas.

Fertilizer Toxicity – Can Too Much Cause Problems?

Most fertilizer toxicity concerns are associated with an overapplication of nitrogen. An overapplication of nitrogen can produce symptoms similar to high salt toxicity, which produces scorched or curled needle tips and/or leaf margins. Ammonium-based nitrogen fertilizers can also, in high concentrations, cause mortality of fine roots leading to further problems with water and nutrient uptake. Also, high levels of ammonium ions (NH_4^+) can compete for absorption sites with other charged ions of micronutrients such as sulphur, which can lead to plant deficiencies of other macro and micronutrients. If the other micronutrients are mobile and not absorbed by the tree, leaching and deficiencies of mobile micronutrients may develop.

Overfertilization Impacts on Trees and the Environment:

- Poor shoot-to-root balance: High levels of nitrogen fertilizers, especially those based in ammonium (NH_4), can result in excessive shoot development. Seedlings with excessively high shoot-to-root ratios are more susceptible to planting shock and stress following planting in the field.
- Delayed dormancy of hardiness: The continued application of fertilizers, especially nitrogen-based, can

stimulate tree growth when they should be preparing to harden off for winter. This can result in severe cold weather injury to the trees.

- Nitrogen fertilizer, especially in the form of nitrates that are very mobile in the soil, can easily escape the planting site through leaching or runoff. Escaped nitrates contribute to pollution in waterways and unwanted buildup of algae and other plants.
- Care should be exercised when considering the application of high rates of phosphorus. Excessive P fertilizer can cause excessive algae growth in waterways (lakes and streams) which can ultimately result in the mortality of fish and other aquatic life due to lack of oxygen and thermal pollution.

Source: United States Department of Agriculture – Forest Service, Forest Nursery Notes – Winter 2004 (R6-CP-TP-01-04)

The Effects of Fertilizer on Tree Susceptibility to Pathogens

Research in alpine forests of the Pacific Northwest found that older trees were increasingly susceptible to root pathogens when soil nitrogen levels were low or when shade restricted photosynthesis. Only trees that exhibited low growth efficiency, low growth per leaf area and nitrogen deficiency were successfully attacked by root pathogens. As a result of the increased mortality rate associated with these older, less efficient trees, it was found that as these dead trees decomposed, there was an increase in nitrogen availability and growth efficiency of newly established (young) trees (in close proximity to the decaying trees) which also promoted root disease resistance.

Plant defenses have generally followed two alternate paths for development. The first path is based upon building high concentrations of hydrocarbon-based compounds, which can reach as much as 10 to 15 percent of the cell content on a per weight basis. The second path involves the use of nitrogenous compounds, which are much more toxic and found in much lower concentrations (often less than 1 percent on a cellular weight basis). Tropical trees that are found in environments with lush plant growth typically exist on the nitrogen (and other nutrients) released from the decomposition of large amounts of surface organic matter and not from the low nitrogen soils below. When forest soil nitrogen levels are adequate, defensive compounds commonly related to alkaloids are produced. However, if nitrogen is not adequately available, defensive compounds composed of carbon-based structures such as phenols and tannins will predominate. A common rule is that fast growing trees will have more carbon-based defensive compounds, while slower growing or nitrogen fixing trees will have nitrogen-based defensive compounds. The concentrations of defensive compounds in tree tissues can have a direct bearing on the resistance of the trees to fungal and insect attack.

Applying Fertilizer

In Alaska, the best time to apply fertilizer for established trees is in the spring after the ground clears of snow and tree leaf-out has occurred. Repeated applications may need to be made depending upon soil sample results (soil nutrient deficiencies). Since there are more than 2,000 formulations of fertilizers, it is necessary to determine your specific plant nutrient needs in order to obtain the most cost-effective fertilizer.

Summer fertilizing should be concluded by early July. Tree nursery growers often switch to calcium nitrate for a winter-hardening fertilizer since it slows down rapid cell division found with ammonium-based fertilizers and helps build stronger, thicker cell walls in preparation for winter conditions. This is usually applied from August to September before the ground is frozen.

Once you have tested your soils and/or tree tissue and determined your fertilizer needs, there are many forms and brands of fertilizer available. You should check with your local Cooperative Extension Service and local greenhouses and/or nurseries for cost comparisons and recommendations on fertilizers that work well in your area. You can also obtain product information on the Internet (organic vs. inorganic, slow release vs. fast release, balanced vs. weighted formulas, nitrates vs. ammonium/ammonia-based).

In general, if rapid stem growth is not a priority, it is better to apply a nitrate-based (NO_3) fertilizer for nitrogen. It is also suggested that slow-release fertilizer be used (it will appear on the label as Controlled Release Nitrogen (CRN).

Top dressing (spreading evenly over the soil surface) the fertilizer onto the soil is the most common form of fertilizer application; however, there is growing interest in the use of liquid fertilizers. Liquid fertilizers can be formulated to meet specific plant needs and are very mobile for immediate uptake by the plant and are particularly suited for micronutrient applications.

General Guidelines for Fertilizer Application Rates

Once you have determined a need to apply fertilizer based upon tissue or soil analysis, you need to determine the type of fertilizer you intend to use and its application rate. Fertilizer application rates can vary greatly depending upon environmental conditions, soils, plant species and type of fertilizer. Unfortunately for Alaska, there is very limited information on tree fertilizer application rates for either N, P or K.

Forest Soil Analysis and Nutrient Deficiency Application Rates

Forest soils are complex, and reporting a standard for comparison of soils from diverse locations has several complications, making accurate interpretations of nutrient availability and deficiencies challenging. High levels of soil organic matter can result in a high level of buffering, cold soils have reduced mineralization processes and forest trees are commonly associated with fungal mycorrhizael formations on their roots, which can dramatically increase their ability to uptake needed soil nutrients. Also, there can be a big difference between soil nutrients and those nutrients that are plant-available. With these concerns in mind, the following table can serve as a standard for forest soil comparison. The reported ranges in soil nutrients are based upon a report developed by the Oregon State University Cooperative Extension Service (*Soil Test Interpretation Guide*, EC 1478). The following table assists with interpreting if soils have low, medium or high nutrient levels and in some cases provides specific recommendations for application rates in order to address this deficiency. Once you have determined, based upon your soil testing, if the nutrients are low or not, then you can proceed to determine whether you need to augment soil nutrition based upon your intended crop demands. These applications can vary depending upon soil characteristics, mobility of the nutrient in the soil and the crop demands for each nutrient.

Table 6. Range of soil nutrients

Nutrient of soil component	Actual soil test results	Range of values (low, medium, high, excessive)	Recommended application rates for nutrient deficiencies	Soil deficiency considerations
Organic matter content (%)	17.47			Alaska soils are quite high in OMC.
Soil pH (H_20 1:1)	5.4	Alaska soils commonly are in the 5-6 pH range.		
Soluble sulfur (ppm)	31	L<2, M 2-10, H>10		
Phosphorus — easily extractable P as P_2O_5 (lb./acre) P (ppm)	147 32	L<10, M 10-30, H>50 Above 15 ppm is considered sufficient.	If soils are below 10 ppm, apply 180 lb. P_2O_5 per acre. If soils are 11-15 ppm, apply 90 lb. P_2O_5 per acre.	
Bray II (lb./acre) P as P_2O_5 (acid soils)		L<20, M 20-40, H 40-100, E>100		
Olsen (lb./acre) P as P_2O_5 (alkaline soils)		L<10, M 10-20, H 20-40, E>40		
Calcium (lb./acre) ppm	1,424 712	L<2,000, M 2,000-4,000, H>4,000 L<1,000, M 1,000-2,000, H>2,000		Soil Ca can be augmented by lime application but rate is dependent upon soil SMP buffer value, soil pH and preference of crop to be grown.
Magnesium (lb./acre) (ppm)	248 124	L<120, M 120-360, H>360 L<60, M 60-180, H>180	If the soil Mg is below 50 ppm and the soil pH is below 5.5, add 1 ton of dolomitic lime per acre. If the soil Mg is below 50 ppm and the soil pH is above 5.5, add 100-200 lb. Mg/acre of dolomitic lime.	

Table 6 Range of soil nutrients (continued)

Nutrient of soil component	Actual soil test results	Range of values (low, medium, high, excessive)	Recommended application rates for nutrient deficiencies	Soil deficiency considerations
Potassium (lb./acre) (ppm)	238 119	L 200, M 390, H 975, E 1,560 L<75, M 100-250, H 250-800, E>800	If soil K is below 75 ppm, apply 100-200 lb./ac of K_2O.	
Sodium (lb./acre) (ppm)	50 25	Preferred levels are less than 100 lb./acre		Sodium is not a required nutrient and is more of an issue with arid soil not commonly found in Alaska.
Nitrogen NO_3-N (ppm)	1.4	L<10, M 10-20, H 20-30, E>30		Tree requirements for N will dictate the amount of additional N required. The difference between the soil nitrate levels and crop N recommendations will determine the required N application rate.
Nitrogen NH_4-N (ppm)	4.9	L<2, M 2-10, H>10		Soil ammonium is plant available but converts to nitrates so it can add to the pool of residual N that need to be considered when determining soil N application rate.
Boron (ppm)	0.66	L<0.5, M 0.5-2.0, H>2.0		General recommendation is for 1-2 ppm.
Iron (ppm)	404			Difficult to test for and so not recommended for general testing or treatment. Recommended range is from 100-300 ppm.
Manganese (ppm)	17	Low<1.5		Generally deficiencies only exist in soils above 7.0 pH. Mn toxicity can occur in acidic soils.
Copper (ppm)	1.73	Low<0.6		Recommended range is 2-5 ppm.
Zinc (ppm)	3.38	Low<1.0		Recommended range is 5-10 ppm.
Aluminum (ppm)	1599			Recommended range is less than 1,400 ppm.

Nitrogen (N)		(lb./acre) N	
Application Rates (soil N content)	**Low (lb./sq. ft.)**	**Medium (lb./sq. ft.)**	**High (lb./sq. ft..**
Evergreens	70 (1.6/1000)	57 (1.3/1000)	45 (1.0/1000)
Hardwoods (less than 2.5 inches)	85 (2.0/1000)	65 (1.5/1000)	45 (1.0/1000)
Hardwoods (greater than 2.5 inches)	120 (2.8/1000)	100 (2.3/1000)	85 (1.9/1000)

Note: Actual pounds of fertilizer applied can be calculated for a given fertilizer such as 16:16:16 by dividing the lb. N/ac by the percentage of N in the fertilizer formula. In this example 45 lbs.N/.16 = 281 lb. of 16:16:16 fertilizer per acre of area.

Phosphorus (P)		(lb./acre) P_2O_5	
Application Rates (soil P content)	**Low (lb./sq. ft.)**	**Medium (lb/sq. ft.)**	**High (lb/sq. ft.)**
	60 (1.3/1000)	40 (.9/1000)	20 (.5/1000)

Note: An annual application of phosphorus may be needed, especially if preplanting fertilization was not done or the soils are low in phosphorus.

Potassium (K)		(lb./acre) K_2O	
Application Rates (soil K content)	**Low (lb./sq. ft.)**	**Medium (lb./sq. ft.)**	**High (lb./sq. ft.)**
	80 (1.8/1000)	50 (1.1/1000)	25 (.6/1000)

Research has shown that most landscaping plants and trees will benefit from a fertilizer application ratio for N:P:K in the range of 3:1:2 or 4:1:2. Care should be exercised to determine whether or not the fertilizer applied is slow release. Trees and woody plants will typically benefit more from use of a slow release fertilizer.

Note: Due to the limited research base for fertilizer recommendations in Alaska, application rates may need modification to take into account cold soils, wet soils or soils strongly deficient in one or more of the three major nutrients.

Granular Fertilizer

The nutrient needs of the tree will have some impact on the fertilizer application procedure. Soils that are low in nitrogen typically require fertilizer applied at the rate of 0.1 to 0.2 lb. of actual N per 100 sq. ft. of bed area per year (equivalent to 1 to 2 lb. of actual N/1000 sq. ft. of bed space). [Note that a 10-10-10 fertilizer will require 1 lb. of fertilizer/100 sq. ft. in order to provide 0.1 lb. N/100 sq. ft. (0.1 lb. N needed/.10 (10%) = 1 pound of 10-10-10 fertilizer.)] Young, fast growing trees may require as much as .2 to .4 lb. N/100 sq. ft. For larger or established trees, broadcast applications of fertilizer should be spread on the surface of the soil from the area near the tree trunk to about 2 feet beyond the drip line of the canopy.

Because soil samples from Alaska are commonly sent out of state for testing, for the sake of matching Alaska soil fertilizer needs with nitrogen, phosphorus and potassium testing, it is strongly recommended that for evaluating the nitrogen component that the 2 Normal KCL extraction be applied for the nitrates (NO_3 – N) and ammonium (NH_4 – N) testing. If you are using Brookside Labs for your soil testing, you should request the soil test package S001AN in order to specify use of the 2-N KCL extraction procedure. For further information, consult Extension publication FGV-00045, *Factors to Consider in Selecting a Soil Testing Laboratory.*

Injected Liquid Fertilizer, Tree Spikes and Drill Hole Applications

An alternative to the broadcast technique is to use a liquid fertilizer applied with a hose-attached root-feeder that is inserted into the soil through an injector needle to a depth of about 8 to 12 inches. Another method is to apply fertilizer tree spikes that are inserted into the soil near the tree. These spikes tend to be more expensive and have been found to limit nutrient availability. If your soil analysis indicates phosphorus and/or potassium deficiencies, these f need to be applied hole method since they are less mobile in the soil than nitrogen. The holes should be applied in a grid

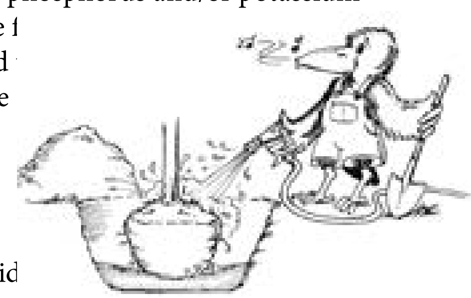

Table 7. Determining the amount of fertilizer to apply for an application rate of 0.1 lb./100 sq. ft.

Formulation	Fertilizer	lb. nitrogen fertilizer/100 sq. ft.	lb. phosphorus fertilizer/100 sq. ft.	lb. potassium fertilizer/100 sq. ft.
46-0-0	Urea	.2	0	0
34-0-0	Ammonium Nitrate	.3	0	0
21-0-0	Ammonium Sulfate	.5	0	0
18-6-12	Osmocote	.5	1.7	.8
16-16-16	Osmocote	.6	.6	.6
14-14-14	Osmocote	.7	.7	.7
12-12-12	Osmocote	.8	.8	.8
10-10-10	Osmocote	1.0	1.0	1.0

pattern starting 3 feet from the tree trunk and spaced 2 feet apart. Each hole should be about 8 to 12 inches deep and 1.5 to 2 inches in diameter. To determine the amount of fertilizer to apply in each hole, use the formula (100/analysis of N, P or K needed in the fertilizer x 0.12 = the amount to apply in each hole in teaspoons). For example, if your fertilizer formula is 10-10-10, then you need to apply (100/10 x .12 = 1.2 teaspoons/hole). After fertilizer is added, water each hole and then refill with soil.

Phosphorus and Potassium Fertilizer Recommendations

Beyond the use of a balanced fertilizer to provide N:P:K, the application of heavier applications of phosphorus and potassium should be based upon results from a soil or foliar analysis.

Foliar Sprays (consider this especially when you need a fast release application)

Foliar fertilizer spray applications are becoming more popular and are especially useful for treating deficiencies in micronutrients such as iron, calcium and manganese. A typical foliar application rate is 1 lb. of actual N per 1,000 sq. ft. of bed space. Formulation application rates are usually provided on the product label. Foliar fertilizer applications are intended especially for fast release applications in situations where prompt response is needed for a nutrient deficiency.

In order to determine the amount of liquid fertilizer needed, measure the area under each tree to be fertilized. The area can be considered a circle and the radius of the circle is from the tree trunk to the drip line. Square (multiply the radius length times itself) the radius (in feet) of the circle and then multiply by 3.14 to determine the area (sq. ft.) to be fertilized.

Area of a circle = 3.14 × r2 (radius (ft.) × radius (ft.)

Example: For a radius of 4 feet, the area for fertilizing becomes: 3.14 × 4 × 4 = 50.24 sq. ft.

If you want to add fertilizer at the rate of 1 lb. of actual N fertilizer per 1000 sq. ft., you would need to use 10 lb. of 10-10-10. However, you only have 50.24 sq. ft. to fertilize. By using simple algebra you can quickly determine the amount of fertilizer needed to cover 50.24 sq. ft.

$$\frac{50.24 \text{ sq. ft.}}{1{,}000 \text{ sq. ft.}} = \frac{x \text{ lb.}}{10 \text{ lb.}}$$

By cross multiplying, we get 50.24 × 10 = 502.4; and 1000 × x = 1000x; therefore 502.4 = 1000x. Solving for x, we divide both sides by 1000 = 502.4/1000 = 0.502; 1000x/1000 = x; therefore 0.502 lb. of 10-10-10 is required per 50.24 sq. ft.

Planting and Fertilizing Your New Trees

When preparing to plant a tree on your property, you should consider the soil condition and nutritional needs of the tree at the time of planting. The following guide is intended to provide a quick and easy reference to proper planting and fertilizing techniques.

Selecting a Tree

Select a tree from the nursery that appears healthy, leaves are free of insects or spots caused by disease, exhibits good but not excessive growth and is free of mechanical damage such as damaged roots or stems. If the tree leaves appear yellowish or off color and it appears to have poor growth, it should be avoided. Make sure that you select a tree whose growth characteristics are suited to the location where you are planting it. Improper species selection for a site can lead to expensive management or removal costs as the tree grows and develops.

Planting Your Tree

Time of year will directly influence tree fertilization recommendations. The best time to plant a tree in Alaska is typically in the spring once the ground has thawed, usually during early to mid-May in the Interior and Southcentral Alaska and earlier in Southeast Alaska. If possible, you should get your soil tested for the area you intend to plant your tree. A soil analysis will help to accurately determine existing soil nutrient levels and fertilizer requirements. Planting trees in the fall can make it more difficult to achieve satisfactory survival rates due to limited establishment time before winter. It is also recommended not to fertilize trees during fall planting due to the need to trigger the tree into hardening off in preparation for winter. Never use a fertilizer that includes an herbicide near your tree.

The tree should be placed in the new hole and positioned so that the top of the tree root/soil mass is about the same level as the surrounding soil. The tree should be watered several times during the planting process to help settle the soil, prevent air pockets and help reduce planting shock.

Watering Recommendations

- Water the tree before it goes into the hole.
- Water when half of the soil has been placed in the hole.
- Water when all the soil has been placed around the tree.

How Much Fertilizer:

When Planting a Tree

Alaska soils typically are high in organic matter content. Under these soil conditions, the rates of fertilizer application for planting new trees, maintaining the health of existing mature trees and young trees and shrubs planted in areas of restricted growing conditions should be based upon .2 lb. of N fertilizer/100 sq. ft. For example, 1.2 lb. of 16-16-16 fertilizer per 100 sq. ft. will provide .2 lb. of N per 100 sq. ft. Smaller trees occupying less than 100 sq. ft. would require less fertilizer. If you are using fast release N fertilizer, you need to use only .1 lb. N/100 sq. ft. and do not incorporate this fertilizer into the backfill as you plant the tree.

For Existing Trees

Trees respond best to application of fertilizer applied near the new roots which are found at or near the drip line of the canopy. If there is grass or lawn in this area of the tree, application rates should not exceed .1 lb. N/100 sq. ft. If the fertilizer is broadcast applied, it needs to be applied beginning about 2 feet from the tree trunk and extending out about 2 feet beyond the drip line of the canopy of the tree.

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