# STAND SELECTION GUIDELINES
# FOREST FERTILIZATION IN BC APRIL, 2017

This guidance is not applicable to stands with free growing or green-up obligations. It considers the use of nitrogen alone or in combination with phosphorus, sulphur or boron. It is directed at increasing timber production and carbon sequestration. Note the standards are available at Forest Fertilization Standard  on the Forests for Tomorrow (FFT) website. This guide will generally assist in locating appropriate stands; however a Return On Investment (ROI) should be conducted which indicates that the target stand is truly suitable.  Information on ROI and the use of TIPSY v4.3 with Fan$ier is available at FFT Return on Investment.

Consider a stand's site conditions, health, biodiversity and potential for integrated resource management in the selection process. Stand level activities should be consistent with forest level objectives. Evaluate candidate stands according to biological factors. Those stands that are biologically acceptable should then be checked for operational feasibility to ensure they can indeed be treated and are suitable for treatment.

**Species preference:**

**Coast** – Species preference are Douglas-fir 1$^{st}$, western red cedar 2$^{nd}$ & western hemlock 3$^{rd}$, unless otherwise indicated in the Land Based Investment Strategy or Silviculture Strategy.  A decision to fertilize western hemlock (Hw) should be made in the context of a strategic objective to increase mid-term timber supply as identified for a specific management unit within the Regional Land Based Investment Strategy (LBIS). Fertilization of Hw should only be done with combined nitrogen-phosphorus fertilizer blends and only on sites where research has demonstrated a positive response to this treatment. Hemlock stands eligible for fertilization should have room for crown expansion and be located in the CWHvm1/01, 03, 04 and 05 north of Barkley Sound on western and on northern Vancouver Island. Drier 03 and more fertile 05 sites should be avoided.

**Interior** - Douglas-fir, spruce and lodgepole pine.

**Site quality:**

**Coast** – Douglas-fir: Sites that are slightly dry to fresh moisture and poor and medium nutrient regimes should receive the highest priority.  Western redcedar:  Sites can be slightly dry to moist and have poor to medium nutrient regimes.  Suggest any site index > 17 be eligible Western hemlock: any site index > 22 is eligible. Confirm funding edibility with current FFT Silviculture funding criteria.

**Interior** – Douglas-fir: avoid dry-belt D-f, otherwise D-f responds on all sites. Spruce and Lodgepole pine: generally SI 15-25, but limited on lower sites by ROI.

**Tree and stand conditions:** The stand should be healthy, fully stocked with room for the crowns to expand. The live crown of the crop trees should be greater than 30%, to utilize the added nutrients. This may be dominant and co-dominant trees or a spaced or thinned stand. The height/diameter breast height (dbh) ratio should be less than 100, preferably less than 85.

The following four **operational factors** should be considered during the evaluation of candidate stands.

***Location*****:** Choose sites closest to communities as distance to haul the fertilizer affects transportation costs. Also, costs of future harvests are partly determined by hauling distances to manufacturing plants and markets.

***Access*****:** Conditions of access also affect costs of transporting material and personnel in fertilizer operations, in addition to later expenses of hauling timber to manufacturing plants. Avoid areas that require long ferry flights, choose areas less than 2km from roads.

***Slope*****:** Costs of future management and harvesting usually increase as terrain becomes steeper. Furthermore, flying over steep or irregular, contoured land may not be conducive to efficient and uniform aerial distribution of fertilizer.

***Project and Block Size*****:** Project and block sizes effect efficiency and cost of operation. Large-scale projects (e.g., >300 ha) are generally more cost effective than small-scale. A railcar contains enough urea for about 200 hectares.

## Ground Application

In some specific situations ground application may be considered, particularly where aerial application is not feasible and there is easy road access to do ground application, minimal slope and easy within block access to distribute fertilizer within the crop trees' drip lines. At this time only late rotation Fdc will be considered for these applications because of the good response and the use of straight Urea application. Projects should be small in size (< 50ha), have similar costs to an aerial application.

## Stand selection supplement

The following discusses broadcast aerial fertilizer applications used to increase tree growth. This information does not deal with fertilization at the time of planting. This information is primarily excerpts from the Forest Fertilization Guidebook.

### Response to fertilization

Fertilization accelerates the rate of stand development. Fertilization is a silvicultural treatment that can be effectively used to increase the merchantable yield and value of established forests. By adding nutrients that are limited on a site, fertilizers can improve the growth of individual stands. However, with knowledge of the timber supply profile and the timing and magnitude of wood supply needs, fertilization can also be strategically used to accelerate the development of specific age classes and timber types. This is done to facilitate an even supply of wood at the forest level.

**Forest level planning**

Forest level plans may require an increase in forest production in order to meet timber supply objectives. A large-scale forest fertilization program may help meet these objectives.

**Stand level planning**

Stand selection should be consistent with forest level objectives. The stand level objectives for a fertilization treatment are chosen considering a stand's site conditions, health, biodiversity and potential for integrated resource management. The costs incurred to achieve the necessary stand level objectives should be kept at a minimum.

With the decision to fertilize comes the need to evaluate candidate stands for suitability and priority. Evaluate candidate stands according to biological factors. Those stands that are biologically acceptable should then be checked for operational feasibility to ensure they can indeed be treated and are suitable for treatment.

The following section explains the major factors to be considered.

## Biological principles

Trees respond to added nutrients by increasing the rate of photosynthesis per unit of foliage area (i.e., photosynthetic efficiency) and by increasing photosynthetic surface area through the production of more foliage and expansion of live crowns. These response mechanisms will apply regardless of the treatment objectives.

Increased bole wood production during the first year after fertilization is primarily due to increased photosynthetic efficiency caused by higher foliar nitrogen concentration. However, foliar nitrogen levels of fertilized trees generally return to pre-fertilization levels after about three years. It is the increased foliage mass caused by increased needle size, number of needles per shoot, and number of shoots that results in enhanced bole wood production over the majority of the response period (five or more years). This is why it is critical that crop trees have room for crown expansion following fertilization. If not, the growth response to fertilization will be limited to the short-lived increase in photosynthetic efficiency, rather than the prolonged response due to increased foliage mass.

The growth response to fertilization is largely dependent on the amount of the added nitrogen that is taken up by trees during the short period following treatment. In most forest soils, urea fertilizer is quickly converted to ammonium ($NH4+$) nitrogen, which is readily taken up by trees and other vegetation. However, the recovery of added nitrogen in crop trees is generally quite low, ranging from less than 10% to approximately 30%. Most of the added nitrogen is rapidly immobilized in soil microbial biomass and organic matter. The immobilized nitrogen is largely unavailable for tree uptake and is generally mineralized too slowly to have much practical value in improving the growth of crop trees.

Under certain conditions, significant losses of added nitrogen can occur from gaseous losses of ammonia ($NH_3$). Volatilization losses will increase with high air temperature, wind speed, and soil pH. Volatilization can be minimized by timing nitrogen applications to coincide with cool (<10°C), calm weather with a high probability of rain in the next 24 hours.

## Biological factors

### Species

Coast – One or more nutrients such as nitrogen (N), phosphorus (P) and boron (B) are generally limiting growth. Douglas-fir usually responds positively to fertilization with N, while western redcedar and western hemlock sometimes require a nitrogen/ phosphorous mix to respond positively. Hw requires addition of P but Cw does not require P for a N response on salal dominated sites. See the Salal Cedar Hemlock Integrated Research Program (SCHIRP) publications for details on nutrients in such systems.

Interior - Douglas-fir, spruce and lodgepole pine respond positively to fertilization with nitrogen. Other species, including dry-belt Douglas-fir, black spruce, western redcedar, western hemlock, and western larch, are not recommended for operations at this time.

### Age and size

Stands age 80 and older should only be treated on a trial basis.

Because of the unfavorable structure of many older stands in the B.C. Interior, the highest fertilization priority is generally assigned to free growing plantations. Stands 15-20 years old should not be fertilized unless trees are at least 2 m taller than competing vegetation. Plantations less than 15 years old may exhibit a large relative response to fertilizer additions but a small absolute stem volume response due to their small stem diameter. The site occupancy of such stands may also be too low to efficiently utilize the applied fertilizer. Well stocked Interior stands taller than eight metres are expected to occupy sites sufficiently to capture fertilizer.

| Height preference (Interior) | |
|---|---|
| Tree height (m) | Priority |
| 8+ | 1 |
| 6 - 8 | 2 |
| < 6 | Do not treat |

**Financial consideration**

The best financial return is with a short duration following fertilizer application. Applying ten years prior to harvest allows time for the maximum volume response with a short financial time frame.

Potential Hw stands targeted for fertilization will be prioritized based on a calculated return on investment and ability to contribute to meeting the strategic timber supply objective.

Preference should be given to fertilizing stands about ten years prior to harvest, provided that live crowns are of favorable size and vigor, and there is room for crown expansion (i.e., naturally occurring lower density or a suitable number of well-spaced dominants) and that other forest level objectives, such as mid-term supply, do not take priority.

**Stand density**

The magnitude of fertilizer response is related to the space available for crown expansion. Stands selected for fertilization should have well-spaced dominant and co-dominant trees. This means that stands which have been spaced or commercial thinned are a high priority. Hw that has been too widely spaced may provide opportunity for insect pests (i.e. black headed budworm in Haida Gwaii).

**Soil moisture regime**

Sites that are slightly dry to fresh should receive the highest priority (e.g., submesic and mesic), with lesser priority assigned to drier (subxeric) and wetter (subhygric and hygric) sites. Because soil moisture, either by deficiency or excess, may exert the primary limitation on tree growth, fertilization of stands with very dry (xeric and very xeric) or very wet (sub hydric) conditions should be avoided. Avoid sites in dry-belt Douglas-fir.

**Nutrient regime**

Although benefits from fertilizing occur most consistently on infertile sites, very infertile sites (site quality is low) are unsuitable for treatment because natural growth rates are too slow. Avoid very rich sites also, since the soil probably contains adequate nutrients. Stands on poor and medium regimes should respond best, and therefore will be given the highest priority. The most reliable information on nutrient availability is obtained from foliar analysis. While evidence of chlorotic tree foliage can indicate soil infertility, caution should be used in making interpretations based on these indications (see Crown condition).

**Site quality**

Preference should be given to fertilizing medium sites (e.g., submesic to mesic soil moisture regimes and poor to medium soil nutrient regimes). A lower priority should be assigned to extremely rich sites until such time that additional research information is available. Fertilization on poor sites will have low priority since site productivity is probably influenced strongly by inadequate soil moisture or extreme climate. Even where relative growth responses are favorable, the absolute volume gains on these lower productivity sites may be too small to make fertilization profitable. Fertilizer should not be applied on low sites. Interior - Douglas-fir, avoid dry-belt D-f, otherwise D-f responds on all sites. Spruce and Pl respond on most sites although ROI may be unacceptable on poorer sites.

**Crown condition**

The size and condition of live crowns provide an indication of the nutrient status and productive potential of stands. Considerations related to crown size and foliar characteristics are described below.

**Size**

Evidence of many trees with short, narrow crowns suggests competitive stress is, or has been, strong. Application of fertilizer to stands in this condition will enhance crown expansion by stimulating growth of branches and foliage. Assign a priority to the treatment of these stands provided they meet the criteria described in the guideline in the section on stand density.

**Foliage color**

Small, yellowish, and sparse foliage throughout the stand may indicate that one or more soil nutrients are deficient. In this situation fertilization may achieve a substantial growth response. However a chlorotic appearance may also be caused by drought or pathological conditions. In the absence of chemical analysis of soils or foliage, the interpretation of visual symptoms requires expertise and local knowledge. Look for other symptoms that may identify insect, disease or animal damage. Also consider soil conditions, ground vegetation, and rainfall patterns to infer drought.

If foliar appearance in a stand can be reliably interpreted to indicate nutrient deficiency and sufficient response is anticipated to make the treatment economical, the site can be assigned a high priority for fertilizing. However, an absence of visual symptoms does not preclude the possibility of growth limiting nutrient deficiencies.

## **Foliar analysis - Nutrient diagnosis**

When used properly and efficiently, foliar analysis can be an effective tool for planning and monitoring operational fertilization projects. Foliar analysis information can be used to:

1) confirm that candidate stands are nitrogen (N) deficient (stands that are not N deficient should not be fertilized);

2) identify secondary nutrient deficiencies (e.g., sulphur [S], boron [B]);
3) make appropriate fertilizer prescriptions; and
4) assess post-fertilization uptake of applied nutrients and foliar nutrient balance.

However, stand nutrient status is only one of several factors to be considered when assessing the suitability and priority of candidate stands for aerial fertilizer operations. Foliar sampling should only be undertaken on sites that satisfy other forest- and stand-level selection criteria. For example, foliar sampling is a wasted expense if stand structure or health indicates poor fertilization response potential or if there are serious non-nutritional constraints on site productivity.

The collection and handling of foliage samples, laboratory analysis, and interpretation of results adds to the operational costs of a fertilization project. Therefore, it is important to strategically allocate foliar sampling in order to avoid unnecessary expenditures and to obtain maximum value from analytical results.

Extensive foliar nutrition and fertilization research has been undertaken by the B.C. Ministry of Forests, Lands and Natural Resource Operations to determine the nutrient status and fertilization response potential of interior forests. Foliar sampling may be unnecessary if foliar nutrient data or fertilizer growth response information is available from nearby stands with similar characteristics. Prior to sampling, candidate blocks should be stratified into homogeneous combinations of species, age (± 10 years), site history (e.g., planted, natural, site preparation), BEC subzone/site series, and stand conditions (e.g., thinned, unthinned). Representative, composite foliage samples should be collected from each major combination. Multiple composite samples may be needed for combinations that cover a large portion of the projected treatment area. Consideration should be given to removing small blocks representing minor site/stand combinations (and a small fraction of the total project area) from the operational fertilization project. Where minor combinations occur within large and predominantly homogenous treatment blocks, it may be acceptable to omit foliar sampling within the minor component. An operational fertilization project comprised of a small number of large and uniform treatment blocks will require a relatively small amount of foliar sampling.

Nutrient concentrations in conifer foliage can be strongly influenced by factors such as crown position, foliage age, time of year, and sample handling. It is important, therefore, to use standardized procedures when sampling and processing foliage; otherwise, a reliable comparison of measured foliar values with published interpretative criteria may not be possible. These standardized foliar sampling and handling procedures are outlined in Extension Note 52 .

Following laboratory nutrient analysis, foliar analytical results are compared with published interpretative criteria to confirm nitrogen (N) deficiencies, and to infer whether other nutrients will either limit growth response or become growth-limiting after N is added. Analytical results are often used to develop appropriate fertilizer formulations to correct inferred nutrient deficiencies. To arrive at the correct diagnosis of stand nutrient status, appropriate weight must be assigned to several different components of foliar nutrition: 1) absolute levels of individual foliar nutrients, 2) balance of foliar levels of one nutrient to another, and 3) levels of inorganic fractions of specific nutrients (e.g., $SO_4$-S). Finally, foliar analytical results may differ depending on the methodology used for laboratory extraction and determination. In some cases, differences may be large enough to affect diagnoses of nutrient sufficiency or deficiency based on available interpretative criteria. Published nutrient interpretative criteria do not typically account for differences in laboratory analytical methodology. However, known differences in laboratory analytical results for different nutrients can be used to "normalize" foliar nutrient data prior to interpretation. By removing the effect of differences in laboratory analytical methodology on results, "normalization" can improve both interpretative reliability and the development of appropriate fertilizer prescriptions. Updated foliar nutrient interpretative tables and a "normalization" spreadsheet are both available on the fertilization program website.

**Screening trials**

Screening trials are not normally necessary. The advice of a specialist is recommended.

**Forest Health**

The health of stands must consider both the stand and forest conditions to ensure that the response to fertilization endures until the stand will be harvested. The susceptibility of a stand to certain damaging agents may, or may not, be increased by fertilization. The degree of damage that can be accepted will vary by forest health factor and severity of impact. Plans to treat stands that are infected with any type of root disease should be carefully reviewed.

Coast - Laminated root rot (*Phellinus weirii*) is the most significant fungal pathogen affecting growth and survival of Douglas-fir. On coastal sites, fertilization appears to have little effect on the incidence or spread of the disease. Minimally infected stands (<6% incidence of trees infected) close to rotation age may be treated. Fertilization of these stands may help them achieve harvestable size before they become severely infected. Evaluate immature Douglas-fir stands infected with laminated root rot and concentrate fertilizer operations on non-infected strata.

Swiss Needle Cast (SNC) – Coastal Douglas-fir areas with incidence of SNC should be discussed with a local forest health specialist and district stewardship staff to ensure a benefit from the fertilization treatment. Consideration should be given to the severity of SNC infection in the stand and the duration the treatment investment needs to be carried prior to harvest.

The western spruce budworm is found in parts of the Coast and Southern Interior Forest Regions. The implications of budworm infestations in relation to fertilizer programs cannot be generalized. Problems regarding specific candidate stands should be referred to forest health specialists.

Little is known about the effects of fertilization on the spread of root diseases in interior forests. However, N-fertilized Douglas-fir in the Inland Northwest (northern Idaho, Montana, and eastern Washington) appears to be more susceptible to Armillaria (*Armillaria ostoyae*) root disease than unfertilized stands. There is some published evidence linking susceptible stands with low foliar potassium (K) status (< 0.60% foliar K). Foliar N/K imbalance and subsequent mortality may be related to fertilizer-induced changes in root biochemistry (i.e., reduced phenol/sugar ratio) that favours the spread of *Armillaria*. In the B.C. interior, Douglas-fir candidate stands within the Interior Cedar-Hemlock (ICH) biogeoclimatic zone should be carefully assessed for the presence of root disease.

The white pine weevil (*Pissodes strobe*) is the principal insect that may affect priorities for fertilizing interior spruce stands. Results from a recent study indicate that fertilization of young spruce plantations in the SBSwk and SBSmk biogeoclimatic subzones will exacerbate weevil leader damage. However, despite the increased weevil damage to fertilized trees, the height losses due to weevil attack were not as great as the height gains due to fertilization. When combined with large increases in stem radial increment, the beneficial effects of fertilization on the growth of young interior spruce plantations in the SBSwk and SBSmk subzones likely outweigh the negative effects associated with increased incidence and severity of leader damage from the white pine weevil. Study results also indicated that large-scale fertilization of spruce plantations in the SBSmc biogeoclimatic subzone probably entail a low risk of increasing damage by the white pine weevil, because the climate is likely too cold to sustain large weevil populations. An extension note is available on Fertilization and White Pine Weevil Attack.

## Fertilization Re-Treatments

Currently the re-treatment period for the Forests for Tomorrow Program projects is set at a ten year interval. This is consistent with TIPSY. Some exceptions have been made to the ten year period, for operational reasons in a given area (e.g. to ensure a reasonable treatment area in a given location, one or two blocks were re-treated with less than a 10 year interval from previous treatment) or future harvest schedules (e.g. re-treating sooner to ensure there is sufficient time prior to harvest).

## Small wildlife

In the interior, sharp increases of red squirrel feeding damage on lodgepole pine have been observed after fertilization. If any pre-fertilization animal damage is noted in the general area of the stand, caution might be indicated.