FOREST SEEDLING NUTRITION TRENDS[1]

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INTRODUCTION

Trends don't just happen. They are driven by change, which in turn has its own motivating forces. In our industry change is driven in large part by the product end user or customer. Change in this case is often positive since it involves a healthy degree of economic and biologic analysis as well as consultation between affected parties. Change brought about as a result of implementation of research findings also impact positively. It generally requires the ability to translate research from the laboratory to an operational setting. Change imposed by government can be a major driving force of trends we observe. Actual objectives set out in legislation are generally positive but unless rules and regulations are carefully drafted so as to achieve them results can be anything but... positive.

This presentation delineates some client driven trends in the BC reforestation industry. It then focuses on one particular aspect of mineral nutrition of forest seedlings that growers can use to help meet customer expectations.

FOREST SEEDLING PRODUCTION TRENDS IN BRITISH COLUMBIA (CLIENT DRIVEN)

In accordance with an increased emphasis on field performance of nursery stock, there have been general trends in favor of:

- Copper treated containers for regulation of root growth.
- Larger stock-types to overcome site limiting factors.
- Summer delivery or "hot" planted stock-types to take advantage of the summer planting season.
- Earlier delivery dates of summer planted 1-0 stock (shorter crop rotations) which facilitates its substitution for summer delivery 2-0 and cold-stored 1-0 products.
- A-class seed sources to take advantage of genetic gain.
- Hardwoods and other native plants for site rehabilitation and alternate wood products.

In order to live up to client expectations, the use of all available resources at the nursery has to be optimized. This requires an intimate knowledge of resource availability and how each contributes to final product quality. Aspects of nursery culture which can be limiting are light, temperature, water, mineral nutrition, pests and time. A basic trend is to acquire this intimate knowledge or greater understanding which will ultimately lead to optimized use and increased product quality.

For the mineral nutrition component the following are concepts studied:

- Individual nutrient function within plants.
- Functional relationships between nutrients within plants.
- Functional relationships between nutrients outside plants.
- Relative proportion requirements based on the above.
- Timing and optimization of availability.
- Timing and rate of application.
- Nutrition and stress.
- Interactions with water, growing media and atmospheric environment.
- Monitoring.
- Custom blends.

EMPHASIS ON FIELD PERFORMANCE

Imparting appropriate levels of hardiness, stress and pest resistance, and growth/differentiation balance to seedlings is important. In conjunction with field personnel, work continues to bridge the knowledge gap between nursery culture and its impacts on field performance. Seedling quality and stress tests are available to help predict seedling performance. Knowing how to alter nursery culture so as to effect a positive change on the aforementioned test results can be a challenge. Nutrition is integral to the final anatomy, morphology, physiology, and phenology we package and call a seedling.

K/N Ratio as an Example

The importance of the K/N (Potassium/Nitrogen) ratio within plants is well documented in the literature, thus making a good example for this presentation. The relative amounts of these two nutrients within a seedling have a profound impact on its growth/differentiation balance, affecting the level of hardiness it is able to acquire, its disease and insect resistance, degree of succulence, and timing and degree of dormancy. It basically impacts on the overall performance of a plant's metabolic machinery.

Optimum K/N ratios for seedlings will vary somewhat between species, growth stage, cultural context at the nursery and the K status of the planting site. Careful monitoring and keen observation of stock performance will allow us to start focusing in on appropriate ratios. Moore and Mika (1997) listed foliar status as poor when foliar K<6000 PPM or 0.6 percent and K/N<0.5.

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[1]van Steenis, E. 1999. Forest seedling nutrition trends. In: Landis, T.D.; Barnett, J.P., tech. coords. National proceedings: forest and conservation nursery associations—1998. Gen. Tech. Rep. SRS-25. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 104-107.
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In order to understand why a particular nutrient element ratio is important and how it impacts on seedling quality one must look at the function of each of the elements, paying particular attention to any biochemical relationship between them, as well as particular functions that might impact on final product traits (qualities) of interest.

Nitrogen—
- Constituent of proteins, nucleic acids, chlorophyll.
- Mineral nutrient element required in highest amount.
- Often used to control growth rate.
- Supplied as ammonium and/or nitrate ions.
- Ammonium drives growth, and requires carbohydrate resources in roots to detoxify it at uptake.
  (Carbohydrate depletion in roots may attract low sugar pathogens.)
- Nitrate is not toxic and can be stored in vacuoles until needed
- High N induced succulence reduces overall stress resistance and physical barriers to penetration by fungal and insect pests.
- Affects growth~ differentiation balance, excess favoring growth.

Nitrogen is obviously very important. Being a constituent of proteins in general makes it an integral component of all enzyme systems and plant structure. In addition it is also a component of nucleic acids, hence integral to cell division and reproduction. Then, as part of the chlorophyll molecule it basically asserts itself as a kingpin within all creation.

Potassium—
- Highly mobile in plants at all levels.
- Involved in osmotic regulation and water movement
  - maintenance of turgor
  - cell extension
  - stomatal control.
- Stabilizes internal pH (7 - 8).
- Enzyme activation
  - protein synthesis.
  - Starch synthesis.
  - Photosynthesis/ATP production/energy relations.
- Membrane transport and ionic balance
  - Translocation of carbohydrates.
- Promotes thickening of cell walls
  - involved in synthesis of complex carbohydrates, lignin
  - promotes "structural" vs. "cytoplasmic" nutrition.
- Increases resistance to stress in general.

Why a K/N ratio?—Potassium, although not a constituent of any physical plant parts, is involved in virtually all plant processes, being a facilitator of most. What is interesting to note is how the two interrelate or depend on each other. The relative levels of each basically determine the efficiency or usefulness of the other.

Potassium deficiency—In this case what we are really interested in is Potassium deficiency symptoms. Potassium toxicity as such does not occur although excessive levels of potassium can induce deficiencies of other elements, namely magnesium. Deficiency symptoms appear when potassium is low or the K/N ratio is too high resulting in a N induced K deficiency. From the list of functions above it can be seen that a K deficiency basically results in an inability to process/utilize nitrogen properly. The difference in symptom expression if any, reflects on whether the seedling is operating in the deficiency, sufficiency or luxury range of nutritional status. Yellowing of foliage from the bottom up occurs if operating in the deficient to sufficient range.

Without adequate potassium, overall plant metabolism slows and building blocks for various biosynthesis reactions start to accumulate. An absence of potassium is akin to inserting a bottleneck into virtually every biochemical and physical process occurring within the plant.

Soluble carbohydrates and nitrogen compounds accumulate because their K facilitated incorporation into macromolecules such as starch, proteins, DNA and chlorophyll is impaired. This reduces or eliminates their subsequent functions, e.g. photosynthesis, protein synthesis, etc. Source to sink transport diminishes leading to localized deficiencies of metabolic products (usually roots loose out with respect to carbohydrates). New cell expansion (plant growth) is reduced due to an inability to generate and maintain adequate turgor pressure. Even though accumulating soluble carbohydrates and nitrogen compounds help with osmo-regulation in the absence of K they are unable to fulfill this function completely.

All in all, the plant has to respire or expend extra energy to grow and maintain itself, reducing its rate of net photosynthesis or overall efficiency as a converter of light energy to chemical energy. For the grower this means lower production and/or longer production, in addition to the possibility of producing lower quality stock.

Concepts—Reduced stress resistance occurs due to a general decrease in biochemical function at all levels. When potassium levels are depressed, plant tissues mature more slowly hence are unable to prepare or repair themselves as quickly as might otherwise be possible. One result is that wilting (loss of turgor) occurs more easily when the soil water supply is limiting, i.e. the plant has a lower tolerance to drought. Susceptibility to frost is also increased for similar reasons as well as the fact that crop maturity in general is delayed.

Potassium is involved in the further metabolism/utilization of sugars into starches and plant structure, etc. An accumulation of these basic building blocks due to depressed levels of potassium can increase susceptibility to high sugar pathogens. *Botrytis cinerea* is an example of a high sugar pathogen, bark beetles are an example of a high sugar parasite. These two take advantage of high levels of available simple sugars and free nitrogen compounds (amino acids and amides) in foliage and phloem tissues.

A high ammonium (NH_4+) nitrogen feed can, especially under conditions of low photosynthetic rates such as occur during winter growing where nights are long and available light is of poor quality, lead to a depletion of carbohydrates in the roots. This can result in a low sugar pathogen attack

Table 1— Foliar analysis "adequate levels" for Sx - young stands - Ballard and Carter (1986)

Nutrient	PPM	mmoles	Presence/100 N atoms
N	14500.	1035.	100.
P	1600.	52.	5.
K	4500.	115.	11.
Ca	2000.	50.	5.
Mg	1200.	49.	5.
S	1600.	50.	5.
SO4-S	600.	19.	2.
Fe	45.	.81	.08
Fe (active)	30.	.54	.05
Mn	25.	.46	.04
Zn	12.	.18	.02
Cu	3.	.05	.0005
B	12.	1.11	.11
Mo	.30	.003	.0003
Al	400.	14.83	1.43

Table 2—Foliar nutrient ratios for Sx - young stands - Ballard and Carter (1986)

Macro/Macro	Concentration based	Weight based ppm/ppm
N/P	20.0	9.1
N/K	9.0	3.2
K/N	.01	0.3
N/S	20.7	9.1
K/Ca	2.3	2.3
K/Mg	2.3	3.8
Ca/Mg	1.0	1.7
Mg/Ca	1.0	0.6
P/Ca	1.0	0.8
Macro/Micro		
Ca/B	45	166.7
P/Fe	64	35.6
P/Cu	1094	533.3
P/Zn	281	133.3
N/Zn	5640	1208.3
P/Al	3.5	4.0
Micro/Micro		
Fe/Mn	1.8	1.8
Mn/Fe	0.6	0.6
Fe/Cu	17.1	15.0
Cu/Fe	0.1	0.1
Zn/Cu	3.9	4.0
Cu/Zn	0.3	0.3

on roots. *Fusarium oxysporum* is an example of a low sugar pathogen.

Because potassium is also involved in transporting of products between sources (photosynthetic products in needles/leaves) and sinks (roots requiring carbohydrates as an energy source to fuel growth and nutrient uptake), low K can also induce susceptibility to low sugar pathogens in the root zone.

Obviously the worst combination is high nitrogen (especially NH_4+) coupled with low potassium in terms of whole plant status. This can result in an accumulation of soluble N compounds such as amino acids, amides, NO_3-, as well as simple sugars such as glucose in the foliage and bark, encouraging high sugar pathogen attacks on the shoot (*Botrytis cinerea* /aphids). In addition, due to reduced source/sink transport it can also result in increased susceptibility of sinks (roots) to low sugar pathogen attacks such as *Fusarium oxysporum*.

K and N levels—Below are 4 tables (tables 1-4) depicting average foliar nutrient levels and ratios. One and two represent data from young *Picea glauca* (White Spruce) stands from Ballard and Carter (1986). Three and four represent average data from 1990 - 1996 for BC nursery grown *Picea glauca* seedlings. Note the differences between seedlings in the nursery and young forest plantations with respect to absolute levels as well as the nutrient ratios.

CONCLUSIONS

Obviously mineral nutrition is a key component of seedling quality and performance potential. However, the interactions with other cultural factors cannot be ignored. The K/N relationship is only one of many important in plant production.

Understanding how mineral nutrients function and interrelate with each other allows better utilization of the contribution each can make to the overall quality and performance potential of seedlings being produced. As a business, it is important to become better before getting bigger. Paying attention to details that allow maximization of benefits from resources at hand will help achieve the former.

The ultimate goal is to accurately define, based on requirements imposed by the plantation environment, seedling quality in terms of morphology, anatomy, and physiology. Then, coupled with an understanding of how mineral nutrition can be used to alter the aforementioned, progress can be made.

Table 3—Foliar analysis "averages" for Sx seedlings- 1990-1996

Nutrient	PPM	mmoles	Presence/ 100 N atoms
N	20400	1456	100
P	3300	107	7
K	11200	286	20
Ca	5100	127	9
Mg	1500	62	4
S	1400	44	3
SO4-S	241	8	1
Fe	162	2.9	.2
Fe (active)	98	1.75	.12
Mn	326	5.93	.41
Zn	63	.96	.07
Cu	7	.11	.008
B	26	2.41	.17
Mo	1.42	.015	.001
Al	149	5.52	.38

Table 4—Average foliar nutrient ratios for Sx seedlings 1990-1996

Macro/macro	Concentration based	Weight based ppm/ppm
N/P	13.7	6.2
N/K	5.1	1.8
K/N	0.2	0.5
N/S	33.4	14.6
K/Ca	2.3	2.2
K/Mg	4.6	7.5
Ca/Mg	2.1	3.4
Mg/Ca	0.5	0.3
P/Ca	0.8	0.6
Macro/Micro		
Ca/B	52.9	196.2
P/Fe	36.7	20.4
P/Cu	967.2	471.4
P/Zn	110.6	52.4
N/Zn	1511.5	323.8
P/Al	19.3	22.1
Micro/Micro		
Fe/Mn	0.5	0.5
Mn/Fe	2.0	2.0
Fe/Cu	26.3	23.1
Cu/Fe	0.04	0.04
Zn/Cu	8.7	9.0
Cu/Zn	0.1	0.1

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