NUTRIENT REQUIREMENTS OF CONTAINERIZED NURSERY STOCK

Philip F. Hahn
Forestry Research Manager
Georgia-Pacific Corporation
Eugene, Oregon

Abstract:

The principles of nutrient requirements for containerized nursery stock are outlined and general guidelines are given for practical applications of nutrients in operational nursery stock production.

Introduction:

Growing of containerized seedlings is a new art and a new science. It is often difficult to determine where one ends and the other begins or where one or the other plays a larger role.

Containerized seedling production is mostly carried out in an accelerated form where the growing environment can be controlled to a certain degree and the seedlings are raised in a special soil mix placed in various sizes and shapes of containers. This is quite different from the old conventional site in good climatic environment and on a soil which lends itself for good growing and lifting conditions.

In either case, besides a good growing environment, the seedlings need food, like all living things, in order to develop into good plantable trees.

Most conventional nursery soils have a good nutrient reserve, which frequently needs to be balanced. However, the seedlings' root system in nursery beds are seldom restricted in their travel to pick up nutrients and moisture from wider areas and deeper zones. And the seedlings are often given two to three years to develop into plantable size. Also, the frequent feeding of needed nutrients isn't so important throughout the growing season as it is in a containerized nursery.

Containerized seedlings are raised in fairly small container cavities with only a 2-10 cubic inch of soil holding capacity. So the frequent watering and metering of the proper nutrients is a key factor in growing a good seedling crop.

All green plants require at least 15 elements to thrive and develop normally (Kramer and Kozlowski, 1960). These elements are carbon, oxygen, hydrogen which comes from CO_2 and H_2O through the photosynthesis process in which green plants are using an enormous amount of solar energy and water to fix carbon dioxide to build organic material.

The other 13 elements are taken up from nutrient solutions or from soil nutrients. The most frequently used three elements out of these are nitrogen, phosphorus and potassium. Sulphur, iron, calcium, magnesium, boron, zinc, copper, molybdenum and chlorine are equally important, but are often used in lesser amounts. These elements, before use, are usually mixed into water soluable nutrient compounds and generally applied in a highly diluted form through an irrigation system in a container nursery.

Each plant species has specific nutrient requirements which change with the growing stages of the plant and with the growing season. This is further complicated by the growing environment. Therefore, using the proper nutrients in a form to support optimum growth in a containerized nursery is not a simple matter. The growing of a good crop largely depends on the nutrients used while properly adjusted to the species, to its growing stages and to the growing environment during the entire growing season.

The Actual Mineral Needs of Seedlings:

All 15 elements required for seedling development have a special function to perform (Kramer and Kozlowski, 1960). Carbon, hydrogen, oxygen build organic material and make up most of the plant weight. Nitrogen and sulphur are important constituents of proteins. Phosphorus is found in the genetic material of the cell and is important in energy transfer. Calcium pectate is the glue that holds cells together. Magnesium is the constituent of chlorophyll, and iron a constituent of precursors of chlorophyll. Potassium makes the stomata operate and helps maintain ionic balance. Boron is involved in sugar transport. Zinc, copper, molybdenum, and chlorine activate enzymes (Tinus and McDonald, 1978).

Plants have a way of showing their nutrient deficiencies in symptoms which are readable in their outward appearance to expert eyes. Certain symptoms for a given element may vary by species which makes them even more difficult to recognize.

Symptoms for deficients are good signs and are very important to an expert grower in trouble-shooting problems, but they are not recommended to solely rely upon in containerized operations, because the active growing season is very short in such operations - only weeks in most cases. So, the reactions to corrective measures after the symptoms are read are often too late in order to reach the target size of the seedlings on the target date.

A more reliable way to monitor nutrients is through laboratory analysis. Before one can depend on this it is important to know the quantities of each element required for optimum growth by species and development stages. It is also important to know what the maximum values are before given elements become toxic to the plants.

Optimum Growth of Seedlings:

Optimum growth is often equated in container nursery operations with the most possible growth one can get out of a seedling crop. The reason for this is because of improper rearing practices applied in the past by many nursery operators. Containerized seedling production for forestry use is a fairly new practice. Many nurseries have been started lately with mostly inexperienced operators, and often the nurseries are not properly designed for local conditions. This has resulted-in the production of subpar crops, far from optimum, which has caused much of the controversies about the value of containerized seedlings in the past.

It is possible to grow good crops of seedlings in container nurseries. This has been demonstrated for years by good operations, including Georgia-Pacific Corporation operations. Such seedlings performed very well in the nurseries and are doing very well in the field, also.

In order to achieve optimum nursery growth to produce well-developed, field-ready seedlings, an optimum rearing practice with an optimum nutrient regime is required. This has to be planned before the crop is started. A decision has to be made on the target date for delivery of the crop and on the target size of the crop. This has to be done by actually plotting a graph on paper with the target heights and calipers of the crop by species and container size in weekly intervals for the entire growing season. This target graph needs to be matched by the seedling development as close as possible throughout the growing season with actual data gathered from pre-designated sample seedlings. When there are deviations, corrections are made for certain nutrients when needed.

In order to achieve the targeted crop, the operator needs to know the quantitative nutrient requirements of the seedlings for optimum growth. An actual table needs to be constructed showing the required amounts of each nutrient element by growing stages for each species. Such information is available to a certain degree, but would seldom fit local needs. An example is given in Table 1.

Table 1. Target nutrient ion concentrations successfully used for western conifers on their accelerated growth stage by Tinus (Tinus and McDonald, 1978).

Table 1.

	Desired Concentration in Ppm														
Element	NO_3	NH_4	P	K	Ca	Mg	S	Fe	Cl	Mn	B	Zn	Cu	Mo	pH
Amount ppm	156	67	27	155	60	40	63	4	4	0.5	0.5	0.05	0.02	0.01	5.5

The best way to approach the development of similar tables is to find out the amount of nutrient needed to support optimum growth under local conditions throughout the entire growing season. This can be done by using available guidelines from other sources while actually growing a crop experimentally or on an operational scale. This crop is then closely monitored while analyzing the nutrient content of the soil, foliage, and stems of the seedling systematically. Nutrients are added in measured quantities in order to restore the nutrient balance as needed, and this is always recorded. Through this, a table for optimum growing conditions could be assembled.

Once the optimum levels in a given area for a given species for different growing stages is known, the operator may start designing a nutrient regime taking into consideration some of the other elements which greatly influence the type and amount of nutrients to be added for optimum growth.

In order to achieve the targeted optimum growth, the operator needs to know the desired environmental conditions like heating, cooling, the use of supplemental lighting, C02 if needed, and their interaction in the utilization of nutrients. The operator needs to know how the container types, size of containers, soil media, compaction rate of soil, and seed cover will interact in the reception and retention of the nutrient solutions.

Disease and disease control may influence the use of certain nutrients. Naturally, an optimum nutrition regime will have its positive effect on disease control, also.

The other three, perhaps the most important factors, which are often overlooked or neglected when designing a nutrition regime are the mineral contents of the water supply, and its pH, and the pH of the growing media.

In a container nursery operation, relatively small amounts of nutrients are applied frequently, as pointed out earlier. This is done generally with each watering, and as often as three times a week during the most active growing season. Irrigation water used for metering the nutrients often contains some nutrients. These could be equal to or could even exceed the desired quantities of a given element. This needs to be taken into consideration and corrections should be made before the water is used. If corrections are not possible, the water supply should be rejected and if another source isn't available, the nursery should be relocated or the site for development should not be chosen.

The pH of the Growing Medium:

The pH of the water highly influences the pH value or hydrogen ion activity of the soil mix which is its most important chemical property as a medium for optimum plant growth (Jackson, 1958). The activity in the soils of the 12 or more different ions that enter into plant nutrition are highly dependent upon the activity of the hydrogen ion. Each tree species achieves optimum growth under a very narrow pH range. For conifers, this is between 5.0 - 6.0, while the optimum is at 5.5. For hardwood species, this is between the range of 6.0 - 7.0.

Control of the *pH* value of the growing medium in a container nursery operation, because of the small amount of soil used, is quite practical. The initial pH value of the growing medium is generally set by taking into account the pH value of the irrigation water which will bring it within the desired range. The *pH* of the irrigation solution and growing medium needs to be constantly monitored and adjusted if necessary. Monitoring of this is a relatively easy task with a simple pH meter.

The pH of the growing medium can be raised with the application of calcium nitrate or sodium hydroxide. It can be lowered by applying acid solutions like hydrochloric, sulphuric, phosphoric or nitric acids. Phosphoric and nitric acids are the safest to handle and also contribute often-needed nutrient ions. Sulphuric acid contributes sulphur if needed, but also contributes additional salt if sulphur is not needed. This may not be beneficial. Sulphuric acid reacts violently with water
if it isn't used properly. It can, therefore, be dangerous. Hydrochloric acid is the least used and recommended, because very little chlorine is needed as a nutrient and there is always a sufficient amount available in the irrigation water and impurities in other fertilizer solutions used.

Sometimes, the adjustment of the pH does become a problem, especially when certain elements like sulphur and chlorine are abundantly available in the irrigation water, and when, at the same time, nitrogen and/or phosphorus isn't needed, because of the seedlings' development stage. So, if possible, an irrigation water which is low in minerals and which has a relatively low pH, in the range of 5.5 - 6.5 is highly desirable.

Preparation of Needed Nutrients:

The mineral content of the water is very important, as pointed out earlier. Therefore, it should be analyzed for all minerals before it is used. And if, because of its source, there is a chance of potential fluctuation during the season, it is important to analyze it frequently while considering this information when stock solutions are prepared.

Assuming that the operator is familiar with the pH and mineral content of the irrigation water, and has good knowledge of the growing medium, and nutrient requirements of the crop to be grown, then the next step is to choose the mineral compounds for the desired nutrition tegime. Mixing of the chosen compounds may be approached from different ways. Some of them are the following:

1. The needed nutrients are prepared by the operator from individual chemical compounds into the desired quantities. This is the most accurate and most scientific way which can be achieved if the operator has a good chemistry background while knowing the composition, soluability, mixability, and general nature of the chosen compounds. This, however, could become a problem. There are very few nursery operators with good chemistry backgrounds, and the mixing of compounds is often delegated to nursery aides in large operations which may lead to serious mistakes, and subsequent disasters.

2. Needed nutrients in proper mixes may be ordered from fertilizer suppliers as a custom mix. The custom mixing is normally done by reputable firms with high chemistry knowledge. To avoid potential problems, samples from such large, pre-mixed batches may be analyzed for nutrient contents to assure mixing accuracy before the mix is used.

3. A whole range of ready-mixed fertilizers are also available. They may come very close to desired nutrient compounds and levels and, therefore, could be used easily and quite successfully.

Out of the three approaches, in practical application, the third is probably used more than any other. However, for accuracy, and from a practical point of view, the second approach is recommended.

During the growing season, a well-balanced fertilizer is needed while increasing or decreasing only the ratio of the nutrients of N, P, K, Ca, and Fe while the ratio of the others are seldom changed. The changes of said ratios are done to accommodate special needs for certain species during the different growing stages and other conditions. Needs are monitored through soil tests, foliar tests, and other physical measurements such as height, caliper, root growth, and through special visible symptoms.

General Principles in Using Nutrients While Growing a Seedling Crop:

Good nutrient utilization greatly depends on the growing medium. A well mixed 1:1 peatmoss and vermiculite is a light-weight soil for field handling, it has good moisture, and nutrient holding capacity. Such soil, when only slightly wetted, fills the container cavity evenly, and provides good aeration for the roots. However, care should be taken during the growing season that the peatmoss doesn't dry out too much, because re-wetting dry peatmoss is very difficult.

At the beginning of the growing season, the pH of the growing medium should be set to a pH of 4-5 or more on the acid side to minimize dampingoff problems. Some lime in the soil. will raise the pH later, while some nutrients will do the same. If the irrigation water has a high pH, the pH of the soil should be set even lower, in the range of 3-4.

Normally, during germination, there is no need for nutrients. The seed will contain enough nutrients to sustain the new germinants until the seed coats fall. Small amounts of balanced nutrients will not hurt germination, however, such amounts are often completely washed out of the growing medium before they are utilized by the seedlings.

The first major nutrients beneficial to the young seedlings shortly after the seed coats fall is a mix which has a higher phosphorus ratio and is low in nitrogen. The nutrient of P enhances root development, which is essential in order to support a good top growth later, while N at this point could be detrimental in promoting damping-off. After a couple of applications of a nutrient solution which yields 1:5:1 N, P, K ratio plus all other elements in the approximate amount of 500 ppm, the nutrient levels are chanced to a mix with the lower P. K, and with a higher N content. (The amounts given are only very general guidelines and should be used with discretion.)

The Phase of Accelerated Height Growth:

During the early seedling development when the danger of damping-off is gone, a higher level of N ratio is beneficial. Normally, .a 3:1:1 N, P, K ratio •lus all other needed elements is used for 4-5 weeks starting with a nutrient solution rate of 500 ppm which is gradually increased to about 1,000 ppm or doubled. While all this is going on, and during the entire growing season, supplemental iron in the form of chelated iron is added about every four weeks or more when tests indicate that it is needed. The amount in the solution is normally 3-500 ppm.

Testing of the nutrient content of the soil, foliage, and the pH of the soil and solutions added to the soil need to be monitored constantly. During the most active growing period, the soil should be monitored weekly. Special emphasis should be given to areas with potential problems. Test results of soil and foliage nutrient contents should be compared to previously established optimum levels and adjustments made accordingly.

Also, routine measurements of height and caliper of seedlings are compared to previously set charts, and if there are any deviations, the nutrition regime must be slightly altered to correct the growth differences.

The Phase of Accelerated Height and Caliper Growth:

Normally, when the seedlings reach 50% of their desired height growth in the nursery, the caliper growth needs to be increased more rapidly. Therefore, the fertilizer regime should be changed back to a higher P ratio alternating with fertilizers containing higher Ca, Mg, and K to promote more root, caliper growth, and side branch development while starting to slow down height growth. The amount of fertilizers in the solution could be increased to about 1200-1500 ppm if needed, depending on fertilizer compounds. Some compounds may cause detrimental effects if over-used.

A sufficient amount of water should always be used with each nutrient application (normally some chemicals are applied with each watering) to wet the entire plug well, and to leach some salts out of the soils. Additional leaching is also important, if needed, to avoid salt concentrations in the growing medium. Salt build-up is a real danger in any operation. This could be measured with a solubridge or conductivity meter, which is a simple instrument, and should be used regularly.

High salt concentrations will result in stunted and chloratic seedling growth, and if not corrected, could reach a level where the seedlings die.

The Phase of Hardening of Seedlings:

During the entire growing season, and especially during the accelerated height and caliper growing period, the crop must be gradually exposed to near natural field conditions. In a shelterhouse system this means the opening of sides, and roof vents for unrestricted natural air flow while the container blocks are separated by 1-2 inches from each other for good air penetration and ventilation.

If the crop reaches the targeted size and the target date for hardening, the process must begin. The date for this in a one-crop cycle on the west coast, normally, is the middle of August. The process is generally preceded with 1-2 applications of a high ratio of K compound with all other elements except nitrogen to promote bud setting. The hardening process starts with the moisture-stressing of the trees. Artificial shortening of the photoperiod, if physically possible, helps considerably, but this is seldom possible in a large scale operation. The stressing is done to the wilting point, and then the moisture is brought back to normal without adding any fertilizers. This process is repeated about 2-3 times or more often, if necessary, to drastically slow down height growth, and initiate bud setting. While this is going on, extreme care should be taken to avoid dry plugs. The use of wetting agents will help in re-wetting. If the initiation of bud setting in achieved. adding of nutrients may begin again with a balanced fertilizer. very low in N. and high in K, while using only moderate amounts of P. Iron should he used in limited quantities at this stage or avoided altogether. The aim during this period is to achieve very firm bud setting, and to promote accelerated diameter growth for the seedlings so they could be overwintered without any problem or shipped to the field for field planting. This phase is very important in areas where the trees are planted during the dormant season.

Naturally, containerized seedlings may be planted in the field while the seedlings are not dormant. However, in a case like this, the field conditions have to support an active growth of seedlings while proper moisture is available, and the climatic conditions wouldn't have an adverse effect on the actively growing trees.

If seedlings are overwintered, a certain amount of fertilization is necessary to sustain root growth and a small rate of diameter growth. Root growth in styroblocks is normally going on all winter while root tops are staying active. This is one of the biggest advantages for such containerized seedlings, because after they are planted in the field, they maintain the same root growth rate. This often accelerates in the field, because the roots are free to spread out and down in deeper zones. This definitely helps seedling establishment while the new plantations are maintaining a higher survival and growth rate without the usual planting shock.

Application of fertilizers with a higher rate of N during winter helps on promoting frost hardiness. Protection of seedlings from excessive freezing in containers must be assured, especially in styroblock containers. The polystyrene container has a very good insulating capacity which helps in protecting the roots from mild freezes (-4 - 6°C). However, when the soil plug freezes, thawing of the plugs is slow, and there is a real danger of desiccating the seedlings, which may damage them considerably.

Summary:

Growing a good crop in a relatively short period of time, hardy enough to perform well in the field, is a complex task. There are many variables which depend on each other, and if one is out of balance, it will effect some of the others. Such variables are container types, soil mixes, growing areas, growing seasons, disease control, light conditions, water supplies, C02 supplies, pH, nutrition supplies, and their interaction with all other variables just to mention the major ones. Out of all these, the feeding and monitoring of the nutrients is perhaps the most important. This article deals with this aspect from a large scalepractical application point of view, while mostly giving only certain principles and general guidelines. Each operation needs to be handled as a special case, and a specific program has to be developed to fit given local needs.

References:

Jackson, M.L., 1958, Soil Chemical Analysis, Prentice Hall, Inc. Englewood Cliffs, New Jersey, p. 485.

Kramer, P.J. and T.T. Kozlowski, 1960, Physiology of Trees, McGraw-Hill, New Jersey, p. 224-275.

Tinus, R.W. and S.E. McDonald, 1978, Unpublished container manual.