

Hardwood Seedling Nutrition

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Abstract: Hardwood seedling production presents several challenges that differ considerably from pine seedling production. Because of a nearly double water requirement, hardwoods need to be planted where they can be irrigated separately from pines. Nutrient requirements are generally higher for hardwoods, including especially nitrogen (N), phosphorus (P), calcium (Ca), and magnesium (Mg). Other nutrients are required in a slightly higher level. The form of N is very important. Sources of N that are “reduced,” including ammonium and urea, are used efficiently. “Oxidized” forms, including mostly nitrate, are used less well. Requirements are usually described as how many pounds per acre of fertilizers are required. However, because the seedbed density for hardwoods is lower than that for pines, the cost of production per seedling is especially high.

Keywords: fertilization, irrigation, bareroot seedling production, mycorrhizae, sulfur

Introduction

Many years ago, at the University of Illinois, a professor named Cyril Hopkins taught nutrition of agronomic crops. Some of his students had difficulty remembering which elements were essential for plant growth. Professor Hopkins developed an easy way to remember the list. It was useful then, and despite the fact that the list is longer today than it was then, the idea is still useful. Cyril Hopkins said that he was going to open a fancy cafe. It will be known as C Hopkns, Cafe Mighty good (C HOPKNS CaFe Mg). The students could remember that, and they automatically learned that plants needed: carbon (C), hydrogen (H), oxygen (O), phosphorus (P), potassium (K), nitrogen (N), sulfur (S), calcium (Ca), iron (Fe), and magnesium (Mg). His name also includes iodine (I), but plants don't need it. Animals, including humans, need iodine.

Since Professor Hopkins came up with this idea, the list of essential nutrient elements has grown considerably longer. However, the idea has stuck and today the entire reminder goes like this:

C Hopkns, Cafe, Mighty good, managed by cousin Mo, and Clara is the waitress (C HOPKNS CaFe Mg Mn B CuZn Mo). This shows us that carbon (C), hydrogen (H), oxygen (O), phosphorus (P), potassium (K), nitrogen (N), sulfur (S), calcium (Ca), iron (Fe), magnesium (Mg), manganese (Mn), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), and chlorine (Cl) are needed for tree seedling growth. So, the next time you are either hungry or thinking about seedling nutrition, just hurry over to C Hopkns Cafe Mighty good.

Now that we are sure that we have the complete list, we can become serious and discuss the individual nutrient elements and say somewhat more about a few of them.

Nutrient Elements From Air and Water

The main building block element in all living things is carbon. In plants, it comes from carbon dioxide in the atmosphere by way of photosynthesis. Because there is never a shortage of carbon dioxide in the field, we never worry about a carbon deficiency.

Hydrogen is the most numerous atom in all living things. Plants get their hydrogen from breaking down water into hydrogen and oxygen. They use a little of this oxygen, but most of it goes back into the atmosphere where we breathe it. Interestingly, plants also use oxygen from the atmosphere in respiration.

For many millions of years, plants got their nitrogen from the atmosphere. After all, the atmosphere is almost 80% nitrogen. Interestingly, plants, by themselves, cannot use any of that N. There are certain microbes that can convert the atmospheric N into protein N and eventually into N that is usable by plants. Since the development of the Haber process, in 1909, to convert atmospheric N into ammoniacal N, we have become mostly dependent on fertilizer N for seedling production. Thus we could say that our seedlings get their N from the soil as fertilizer N. However, in reality, it still comes from the air.

Nitrogen Fertilization

A useful comparison between pines and hardwoods is in the amount of fertilizer N required. The minimum amount of N needed by a pine crop is 150 lb/ac (168 kg/ha) while hardwoods require a minimum of 225 lb/ac (252 kg/ha). Many people apply more than these amounts, but the ratio stays about the same. That is, hardwoods take about 1.5 times as much N per acre as pines. On a per seedling basis, the ratio is closer to 3 times as much. That is because of a lower seedbed density for most hardwoods.

The N in commercial fertilizer is available in several forms. If the N is associated with oxygen, as in nitrate (NO_3), it is called oxidized N. If the N is associated with hydrogen, as in ammonium (NH_4), it is called reduced N. The N in urea is also reduced because it is associated with H. Most plants can use either reduced or oxidized N, but their efficiency of use varies tremendously.

The relative use of different forms of N by hardwoods has been studied in considerable detail (Deines 1973; South 1975; Villarrubia 1980; Auchmoody 1982). In the study by Villarrubia (1980), 7 sources of nitrogen were tested on sweetgum (*Liquidambar styraciflua* L.) and green ash (*Fraxinus pennsylvanica* Marsh.) at 3 different rates of application. Very little effect of rate was observed, but source was very important. Growth was most favorably affected by reduced sources of nitrogen. These included 2 slow-release sources of sulfur-coated urea, ammonium sulfate, ammonium nitrate, and urea. The poorest growth was associated with sodium nitrate. A polymer of urea (IBDU) was also poorly utilized. This resulted from the fact that the urea was converted to nitrate just as fast as it was released from the polymer. Thus, in effect, it was an oxidized source of N rather than a reduced source. The only study where nitrate was found to be advantageous was in the study of Auchmoody (1982). In that one case, germination of cherry seeds was favorably affected by nitrate.

Slow-release, sulfur-coated urea was compared with regular urea and ammonium nitrate by Deines (1973). Both forms of urea were superior to ammonium nitrate in producing large seedlings. The sulfur-coated urea was applied once, preplant; the regular urea and ammonium nitrate were applied in 5 split applications over the summer. The savings in cost of application of the sulfur-coated urea were offset by its higher cost. Split applications allow the nursery manager to adjust the nitrogen regime as affected by weather. This flexibility is quite advantageous.

Foliar N Concentration

Villarrubia (1980) found that foliar N concentration, in September, varied both by species and by source. In green ash, foliar N varied from 2.4% to 2.9% with ammonium nitrate, ammonium sulfate, and urea. With both sulfur-coated ureas, it was somewhat below 2%. This difference is probably attributable to the fact that ammonium nitrate, ammonium sulfate, and urea were applied in 5 split applications, whereas the sulfur-coated urea was all applied at once, preplant. Seedlings that received split applications of sodium nitrate had foliar N concentrations from 2.2% to 2.3%. That is mostly attributable to the fact that the plants were quite small. Finally, those seedlings that received a

single preplant application of IBDU were both small and had a low N concentration in their foliage (1.3% to 1.7%).

The foliar N pattern in sweetgum was quite similar to that in green ash. The ammonium nitrate, ammonium sulfate, and urea all were high and ranged from 2.7% to 3.1%. The sulfur-coated ureas were again somewhat lower at 2.1% to 2.7%. The small seedlings that received sodium nitrate had foliar N concentrations of 2.5% to 2.6%. This again shows that, because the leaves were small, a little N produces a high percentage. Finally, the IBDU again produced small seedlings and their foliage contained a low concentration of N (1.3% to 1.6%).

Soil Nitrate

There are bacteria in soil that are called nitrifiers. They will slowly convert reduced N to nitrate. Villarrubia (1980) found the soil nitrate level in September varied considerably. The highest levels were associated with the 2 sources that contained nitrate. Sodium nitrate soil contained more than 50 lb/ac (56 kg/ha) of nitrate-N. Ammonium nitrate soil contained about 45 lb/ac (50 kg/ha). Urea soil was third at about 30 lb N/ac (34 kg N/ha) as nitrate. All other sources of N were below 15 lb N/ac (17 kg N/ha) as nitrate. Thus, nitrification was only mildly active in the nursery soil.

Root Collar Diameter, Seedling Height, and Seedbed Density

An important characteristic of seedling quality is root collar diameter (RCD). At lifting time, green ash showed conclusively that the nursery soil did need sulfur, as well as N. The 3 sources of N that produced seedlings with the largest RCD were ammonium sulfate and the 2 sulfur-coated ureas (Villarrubia 1980).

Despite the fact that the sweetgum seedlings were small, IBDU had the lowest seedbed density at 12.3 seedlings/ft² (137 seedlings/m²). The sweetgum had the highest seedbed density (20.4 seedlings/ft² [227 seedlings/m²]) with ammonium sulfate. The lowest seedbed density with sweetgum was 15.0 seedlings/ft² (167 seedlings/m²) with the very slowly soluble SCU-11. High levels of fertilization did not increase height or quality of seedlings, but they did often result in lower seedbed densities. Height did vary considerably as a response to N source (Table 1).

Nutrients From Soil

Calcium

Evidence shows that hardwoods require more calcium than pines. In general, however, most nursery soils have been supplied with ample Ca. Deines (1973) tested both calcium carbonate (lime) and calcium sulfate (gypsum). A low rate of the sulfate form produced a growth response in sweetgum. He believed it was a sulfur response rather than a calcium response because there was no positive response to the carbonate form. At high levels, there was a negative response to the carbonate form, which was attributed to the adverse effect on soil pH value.

Table 1—Height of sweetgum and green ash seedlings, at lifting, as affected by nitrogen source (from Villarrubia 1980).

N-source ^a	Seedling height at lifting ^b	
	Sweetgum	Green Ash
<i>- - height rounded to nearest inch^c - -</i>		
SCU-24	26	29
SCU-11	26	28
Urea	25	29
Ammonium sulfate	24	30
Ammonium nitrate	24	29
IBDU	18	27
Sodium nitrate	15	22
Average	23	28

^aN source abbreviations: SCU-24 is sulfur-coated urea that releases N at a moderate rate; SCU-11 is sulfur-coated urea that releases N at a very slow rate; IBDU is isobutylidene diurea, which is a slow-release polymer of urea.

^bSeedling height was not significantly affected by rate of N application. Thus the heights in this table are the averages of all rates.

^cConversion: 1 in = 2.5 cm.

Potassium

Studies in 2 nurseries with contrasting soil (Deines 1973) showed that potassium was needed, but its source was not important. Where K was needed, either the chloride or the sulfate source was satisfactory. The sulfate source gave some better growth than the chloride source, but again it was apparently a sulfur response.

Magnesium

Increasing applications of ammonium nitrate reduced Mg uptake by sweetgum at 2 nurseries (Deines 1973). Also, high levels of ammonium nitrate reduced the foliar content of K and Ca.

Mycorrhizae

In a study of endomycorrhizal inoculation of fumigated nursery soil, South (1975) reported an improvement of mycorrhiza formation from inoculation. However, there was a reduction of mycorrhiza formation when a high level of phosphorus was applied to sweetgum and sycamore. Trees that are endomycorrhizal are likely to suffer a lack of mycorrhiza formation because of over-fumigation of the soil. This is because the inoculum spores are soil-borne and thus are slow to reinfect soil. Spores of the fungi of ectomycorrhizal tree species (pines and oaks, for example) are air-borne and can reinfect the soil much more quickly. In a study by Danielson (1966), inoculum for pines was introduced from a pine straw mulch and from the air. Mycorrhiza formation was delayed by only a few weeks with loblolly pine. From personal observation, it can be reported that endomycorrhizal fungus reintroduction, without intentional inoculation, requires more than a year. Using pine straw mulch on the beds of hardwood seedlings greatly increased the amount of hand weeding needed, but it did not increase the endomycorrhizal fungus inoculation (South 1975).

Outplanting Study

In an outplanting study with green ash, tall seedlings from the nursery grew well in the field. The small seedlings that received IBDU or sodium nitrate grew the poorest in the field in the first year (Villarrubia 1980). With hardwood seedlings, it seems that bigger is better.

Conclusions

- The low (normal) rate of N tested was as effective as the highest (3X normal) rate. Thus, the nursery manager can save money by not applying excess fertilizer.
- The N sources tested fell into 2 groups. The sodium nitrate and the IBDU were each poor N sources. Despite some small differences, all other sources were useful.
- Ammonium sulfate and SCU-24 produced rapid early growth of the seedlings. They captured the bed quickly and reduced weeding costs.
- Soil acidity changes were complex. As expected, acidification with ammonium sulfate was greatest. Acidification was correlated with rate. The IBDU and S-coated ureas, which were plowed down, produced early and strong acidification. However, this decreased with time. The sodium nitrate changed the soil from being slightly acidic to alkaline.
- Foliar N concentration was highest with the sources that were used in split applications. The IBDU was lowest. It was applied preplant and was used poorly. Foliar N concentration increased with rate, regardless of source or species. Some of this was undoubtedly luxury consumption.
- Nitrogen sources that contained sulfur were superior to those that didn't. Thus, in most soil, sulfur was needed. The sulfur containing sources produced an early start in growth and a rapid bed capture.
- In sweetgum and green ash, Villarrubia (1980) reported the following in regard to the effect of the various N sources on the concentration of foliar nutrients:
 1. N: Sodium nitrate and IBDU were not satisfactory N sources. All other sources tested were satisfactory.
 2. P: Sodium nitrate resulted in poor P uptake. All others were satisfactory.
 3. K: Sodium nitrate resulted in high foliar K concentration. Other N sources varied slightly in their effect on K uptake. In general, as the N application rate increased, foliar K concentration decreased.
 4. Ca: Sodium nitrate resulted in the lowest foliar Ca concentration. IBDU resulted in the highest.
 5. Mg: Sodium nitrate resulted in the lowest foliar Mg concentration. The other N sources were satisfactory.
 6. Sulfate S: Ammonium sulfate, as expected, resulted in the highest foliar sulfate concentration.

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