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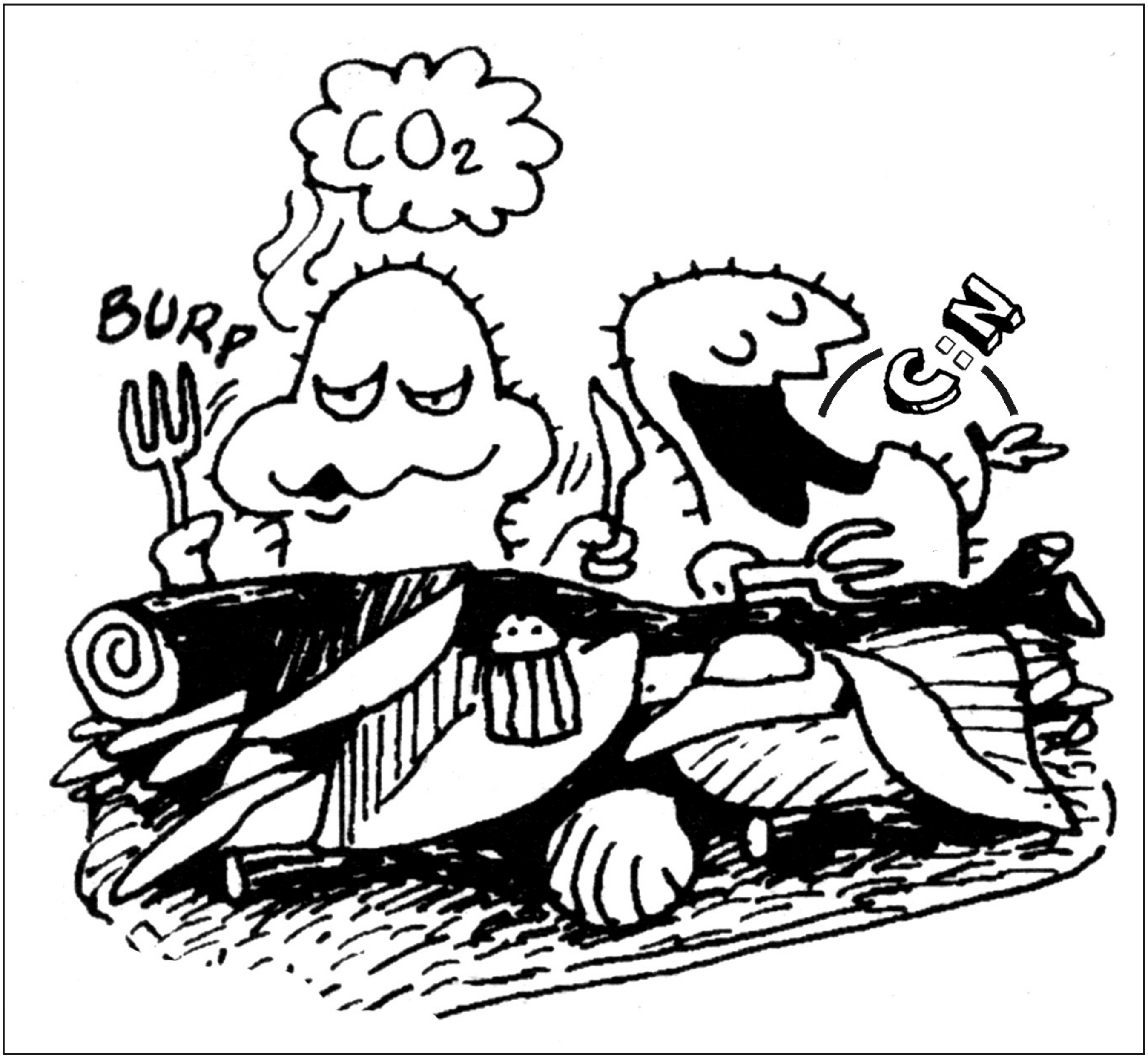

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Nursery Meetings

Restoration of Disturbed Sites with Native Plants: An Integrated Approach

This three-day training session will be held February 8 to 10, 2011 at the Rogue Regency Inn and Suites in Medford, OR. Based on the recently published book "Roadside Revegetation: An Integrated Approach to Establishing Native Plants", this popular training is a comprehensive review of how to use native plants in the restoration of all types of disturbed wildlands. The previous three sessions have sold out so register early. For more information, contact:

Michele at TEL: 888.722.9416 or 503.226.4562
E-mail: michele@westernforestry.org
Register On-line at:
www.westernforestry.org

Western Forest and Conservation Nursery Association

This annual meeting will be held this coming August or September, 2011 - most likely in the Denver, CO area. Topics covered will be of specific interest to growers in the Intermountain/Southwest/Great Basin/Great Plains areas such as growing for windbreaks, field trials, propagation protocols, storage issues, riparian restoration, etc. Meeting details are still being developed and will be posted at website: <www.rngr.net> early in the year. Please contact Diane if you would like to be a speaker, would like to request specific speakers or topics, and/or are interested in attending:

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Northeastern Forest and Conservation Nursery Meeting

This year's meeting is being jointly hosted by the Kentucky Division of Forestry and the West Virginia Division of Forestry and will be held in Huntington, WV, on July 26 to 28, 2011. The meeting agenda and arrangements are still being finalized but for more information, contact:

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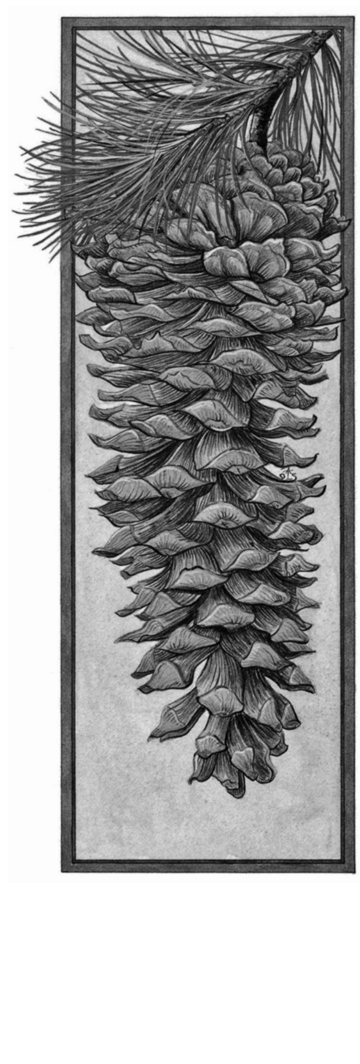

Recycling Old Styroblock™ or Copperblock™ Containers

By Thomas D. Landis

Styroblock™ containers ("blocks") are very popular in the Pacific Northwest, but disposal of used blocks has become a real problem because Styrofoam™ can't be readily recycled and Styroblock™ containers are rejected by most landfills. So, at many nurseries, valuable storage space is filled with used blocks (Figure 1A) with no disposal method in sight.

Figure 1 – Many nurseries are plagued by stacks of used Styroblock™ and Copperblock™ containers, that cannot be recycled or taken to landfills (A). A new process grinds and compresses the used blocks into a more easily disposable product (B).

Just recently, EPS Plastics Solutions has developed a new method of disposing of used Styroblock™ and Copperblock™ containers The used blocks are run through their custom machines that grind and compress them into a "densified" product (Figure 1B) that can easily be removed from the nursery. This process costs from 15¢ to 20¢ per Styroblock™ and each machine can consume up to 400 blocks per hour. While most of the work has been in western Canada, they are currently looking for new customers.

For More Information, contact:

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Using History Plots to Improve Seed Use Efficiency and Fine-Tune Cultural Practices

By Thomas D. Landis

Every nursery uses some sort of inventory procedure to estimate how many seedlings will develop into shippable plants. History plots are unique in that they are permanent monitoring plots that are established in sections of a seedbed or in a block of containers at the time of sowing. History plots are not a new concept, as many different aspects of the history plot procedure have been used in forest tree seedling nurseries for years. Belcher (1964) provided one of the first published procedures for monitoring bareroot tree seedlings with history plots.

Efficient nursery management involves producing the maximum number of high-quality seedlings with the least amount of seeds. Often, however, seed and seedling losses are hard to identify and harder yet to quantify. Because sown seeds are buried, preemergence losses are hidden from view and even postemergence mortality happens so quickly that it often goes unnoticed. With history plots, the nursery manager can measure these losses empirically and obtain objective data on their amount and timing (Landis and Karrfalt 1987).

Sowing Factors

The major sowing factors and the associated seed and seedling losses can be illustrated by the example in Figure 1 and are defined as follows:

Pure live seed - This describes the percentage of a quantity of seeds that are expected to germinate after sowing.

Nursery loss factors - This accounts for the seeds and germinants lost due to damping-off and other diseases, insect and bird predation, as well as other losses during the crop cycle. These can only be measured with history plots.

Crop inventory - This is the total count of live plants at the end of the crop cycle as measured during the final inventory prior to harvesting. Some nurseries just use gross inventories whereas others estimate culling losses to produce a net inventory.

Cull factors - These are the plants that are discarded during grading because they are outside of size

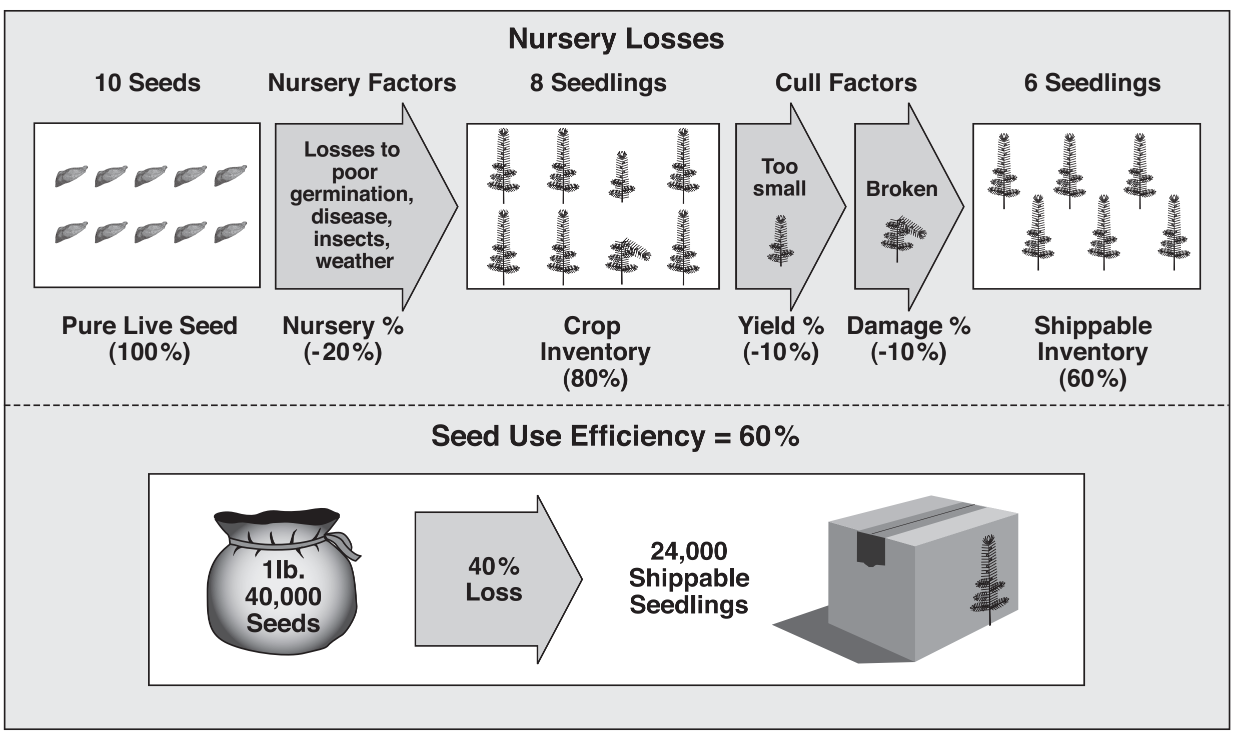

Figure 1 - History plots provide an accurate method of measuring losses that occur during the nursery crop cycle, and precisely calculate seed use efficiency.

specifications (Yield %) or damaged in some way (Damage %). These can be directly measured during grading or calculated by subtracting the shippable inventory from the crop inventory.

Shippable inventory - These are the plants that meet all specifications that will be packed and shipped to customers.

Seed use efficiency - The number of plants in the shippable inventory expressed as a percentage of the pure live seed.

In addition to supplying data on seed-use efficiency, history plots also provide several other immediate benefits to nursery management. Excavating sown seeds provides a check of seed drill or sowing equipment calibration and sowing depth.

Design and installation of history plots

The design of a history plot is unique in that it features a paired-plot design, which permits destructive sampling (Figure 2). Nondestructive, repetitive measurements such as live seedling counts and size measurements can be made throughout the crop cycle in Subplot 1, whereas one-time destructive measurements involving seed and seedling excavation are done in Subplot 2. In bareroot nurseries, history plots should be laid-out with the subplots side-by-side in the same seedbed with a narrow buffer zone between them. The subplots should extend across the full width of the seedbed to eliminate any possible variation between seed rows. The same concept can be applied to container nurseries; for example, one half of a Styroblock™ could be designated as for destructive sampling and the other used for long-term monitoring.

The ability to excavate and examine sown seeds is a unique feature of history plots. Although the approximate number of seeds that are sown per area of seedbed or container cavity can be estimated from sowing calculations, the only way to really know is to count them directly. Small seeds can be difficult to locate and separate from the soil in bareroot beds, but coloring the seed coat has made this job much easier. Fluorescent powders (Day-Glo 2010) are easy to apply to seeds and, because they are organic, do not interfere with germination (Landis 1976). Once the sown seeds are counted, they can be replanted in the container or seedbed. If they are carefully sown at the same depth, they will germinate and emerge normally. Container nurseries have a real advantage in that the sown seeds can more easily be extracted and resown in the destructive sampling subplot.

History plots should be monitored at regular intervals, at least one a month, beginning immediately after sowing and continuing until harvest. The fate of the sown seeds and emerged seedlings can be determined during each visit. After emergence is complete, the destructive plot can be sampled for ungerminated seeds, which can be bisected to determine if the seed is dormant or diseased. Decayed seeds give a direct and accurate measurement of pre-emergence damping-off, a statistic

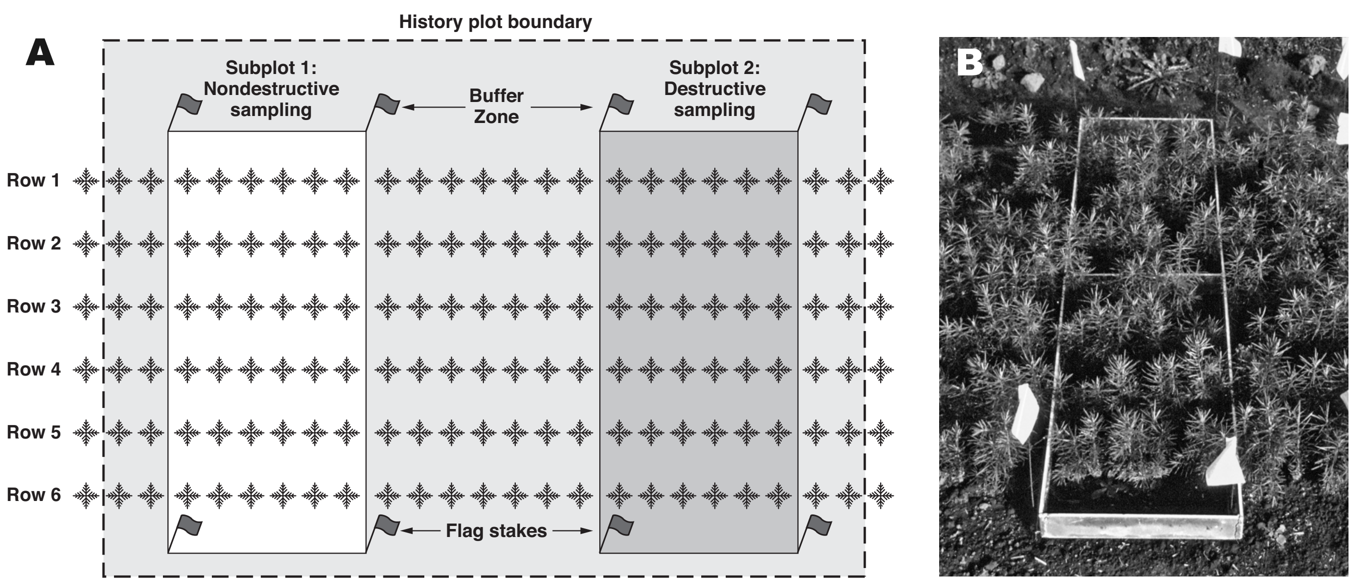

Figure 2 - History plots differ from normal inventory plots in that they feature a pair of subplots (A): destructive sampling is done in Subplot 2 immediately after sowing, whereas inventory plant counts and measurements are monitored in Subplot 1 through the growing season (B).

that could only be estimated by normal monitoring. Dead seedlings should be recorded and then removed during each visit to avoid possible confusion as to when the loss occurred. Damaged seedlings can be marked with colored toothpicks to see if they die between the monitoring visits. Close-up photographs during each visit will great aid in the diagnosis and, when viewed in sequence at the end of the growing season, present an excellent visual chronology of crop development. The history plot area can also be equipped with weather recording data which can be most useful in determining microsite conditions and diagnosing winter injury. Soil samples can be collected at the history plot locations during the growing season and analyzed for pathogen populations. This information can prove most useful in determining the efficacy of soil fumigation and other subsequent soil fungicide treatments later in the growing season.

Using History Plot Data in Nursery Management

Seed-use efficiency - A major benefit of history plots is that they can be used by nursery managers to develop or refine sowing calculations that govern sowing density and seed-use efficiency. Many nursery managers use sowing factors that were developed through years of experience but are not based on any actual measurements. Monitoring history plots yields specific information on the fate of sown seeds that can be used to adjust future sowing rates. The numerical data on seed and seedling losses have obvious applications the determination and refining nursery factors (Figure 1) that can be used in sowing rate calculations. Once the specific causes of the losses are identified, corrective actions can be taken to reduce or eliminate them completely. Although not often recognized, improving seed-use efficiency can have significant economic impacts, particularly with expensive seeds. South (1986) estimated that a southern forest nursery with an annual production of 30 million seedlings could realize a yearly savings of $15,000 by increasing seed-use efficiency from 50 to 55%.

Scheduling and evaluating cultural practices - The cost effectiveness of nursery cultural operations, such as seedbed fumigation that can cost well over $1,000 per acre, can also be critically examined through the use of history plots. When history plot data from Mt. Sopris Nursery in Colorado were analyzed, it was obvious that the greatest seed and seedling loss occurred during the germination and emergence period (Landis 1976). Direct observations during checks of the history plots and associated soil testing for pathogenic fungi identified the cause of the losses as damping-off and seed predation by birds. Consequently, regular seedbed fumigation was prescribed to reduce damping-off fungal populations, and early morning bird patrols were established to discourage bird predation.

Other cultural practices, like root pruning or top mow-

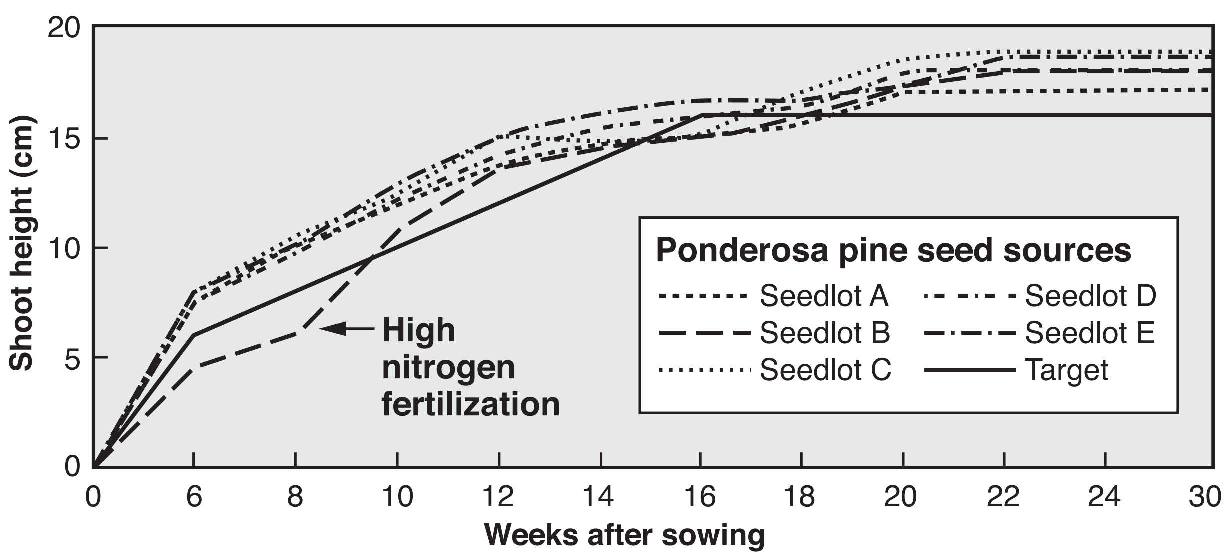

Figure 3 - Plant measurements taken during history plot monitoring can be used to construct detailed growth curves, which have many applications for nursery managers. In this example, a target height growth curve for ponderosa pine seedlings was developed using history plots from previous years. In this current crop, all seedlots performed well except seedlot B, so the nursery manager increased nitrogen fertilization to stimulate more height growth in those plants.

ing, have extremely narrow operational windows that must be carefully scheduled. Many nursery managers try to prune the roots of pine seedlings in the fall of the 1+0 year to sever the dominant tap root and stimulate a more fibrous root system. The timing of this operation is critical, however. If it is done too early, it may reduce shoot growth, but if it is done too late, the seedlings will not have time to reestablish a good root system and may undergo frost-heaving during the winter. The best time for root pruning, as determined from the history plot data, is a narrow time period after budset but before the fall root growth period.

Developing crop schedules - The plant height and stem diameter measurements made when monitoring history plots can be used to generate detailed seedling growth curves that illustrate the annual cycle of seedling growth (Figure 3). Not only do these growth curves provide an excellent visual representation of the timing of significant events, such as emergence, bud break, and bud set, but they can be used to help schedule cultural practices such as fertilizer applications. Nitrogen fertilizer should be applied early in the growing season, so that sufficient N is available during the rapid shoot growth period, but not so late that it could interfere with the onset of dormancy.

Problem solving - One of the most useful applications of the history plot procedure is for nursery problem solving. Installations of history plots in seedbeds of a particularly troublesome species or seed lot can provide invaluable information on the fate of the seed and seedlings during the crop cycle. Without the focused perspective provided by history plots, nursery managers often are unable to determine the specific causes of seed and seedling losses or poor growth (Figure 3).

Summary

The history plot technique has many applications in forest and conservation nurseries; it provides an excellent way to monitor seedling development and diagnose the true cause of injury and mortality. Although history plots often provide information to late for nursery managers to make any corrective treatment, this data can be used in future crops to improve seedling quality and nursery efficiency.

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Understanding Common Fertilizer and Plant Nutrition Units

By Diane L. Haase

Fertilizer Labels

Fertilizer products are always labeled with three numbers denoting the percentage (%) by weight of nitrogen (N), phosphoric acid (P_2O_5), and potash (K_2O). It's important to note that N is expressed on an elemental basis but P and K are denoted by their oxide forms (P_2O_5 contains 44% P and K_2O contains 83% K). For example, a 15-10-15 fertilizer product contains 15% N, 10% P_2O_5, and 15% K_2O. If you have a 100 lb bag of that 15-10-15 product, it would contain 15 pounds of N, 10 pounds of P_2O_5, and 15 pounds of K_2O. To calculate the amount of elemental P, multiply the amount of P_2O_5 by 44% (0.44 x 10 = 4.4 lb P). Likewise, to calculate the amount of elemental K, multiply the amount of K_2O by 83% (0.83 x 15 = 12.5 lb K).

The analysis on a liquid fertilizer means the same as that on a granular fertilizer (that is, the three numbers represent the percentage of N - P_2O_5 - K_2O by weight). There can be some confusion, however, because liquid fertilizers are often applied by volume rather than by weight. Most liquid fertilizers provide the number of pounds of N and other elements on a per gallon (or liter) basis that can then be used for calculating application rates.

Lab Reports

Percentage - This unit of measure is the easiest for plant practitioners to understand. It is used most often for plant or soil macronutrients (N, P, K, Ca, and Mg) because they are present in relatively large amounts and are therefore usually expressed as a percentage of the whole.

Parts per million (ppm)- This is an expression of concentration often used to describe very small amounts, such as the amount of micronutrients in plant tissue or soil. It refers to how many parts of a solute that are in a million parts of the whole solution. This is usually expressed on a mass basis.

Some simple conversions:
ppm = mg/kg = mg/L = (% * 10,000)

Milliequivalent per liter (meq/L) - This is a chemistry term that is determined by the concentration of a nutrient and its molecular weight and charge. The formula for meq/L is to divide a given ppm by the equivalent weight. Equivalent weight of an element or compound is simply its atomic weight (found in the periodic table) divided by its valence (electrical charge). For example, the equivalent weight for Ca^{++} would be 40/2 = 20. Similarly, the equivalent weight for K^+= 39/1 = 39. If the ppm of Ca^{++} is 100, then the meq/L would be 100/20 = 5 meq/L Ca.

To convert to meq/100 g, divide meq/L by 10. So, 5 meq/L/10 = 0.5 meq/100 g.

Nutrient Concentration Versus Nutrient Content

The traditional approach for determining plant nutrients is to send a tissue sample to a laboratory; results come back reporting the concentrations of selected elements using units of % and ppm. However, looking solely at concentration data can lead to inaccurate conclusions because concentration is related to the plant's biomass. For instance, when the plant is actively growing (that is, increasing in biomass), concentrations of nutrients can be diluted even though their total amount (content) may be increasing within the plant. Examining the nutrient proportion (concentration) and amount (content) can give a more accurate look at the plant's nutrient status than evaluating concentration and/or biomass individually.

Nutrient content can be calculated from the biomass and concentration (that is, concentration x biomass = content). The portion of biomass must be clearly defined in order to interpret the results. Common portions of biomass are a specific subsample of needles or leaves, the entire shoot (including the stem and buds), the entire root, or the entire plant. This can be based on an individual plant or on a composite of several plants. For example, a sample of 50 pine needles weighing 680 mg with a nitrogen concentration of 1.7% would have a nitrogen content of 680 mg x 0.017 = 11.56 mg.

These data can be further examined in an easy-to-use integrated graphic format, which is a useful tool for comparing samples, determining treatment effects, or evaluating plant responses over time (Figure 1).

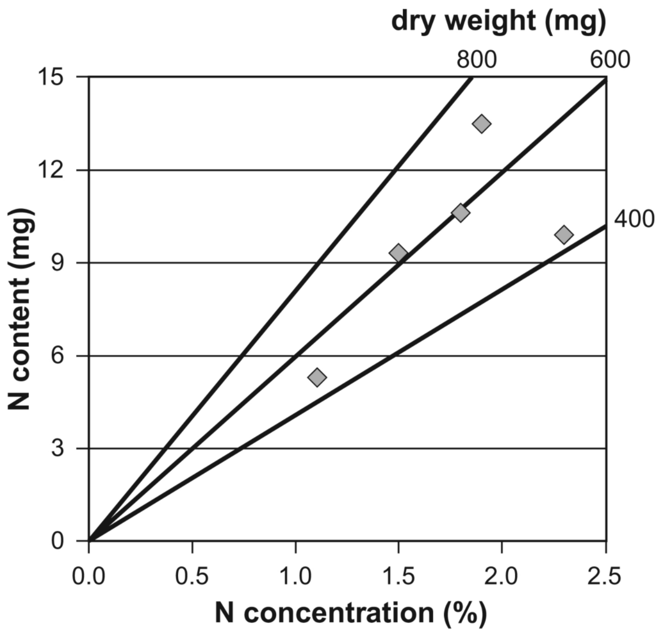

Figure 1 - Example of integrated graphic format that allows for simultaneous comparison of nutrient concentration, nutrient content, and biomass. See Haase and Rose (1995) for additional information on how to use this technique to evaluate plant nutrient data.

Useful Metric Conversions For Use In Nutrient Calculations

1 pound (lb)	=	454 g
1 square meter (m^2)	=	10.76 ft^2
1 hectare (ha)	=	10,000 m^2
		2.47 ac
1 kilogram (kg)	=	1000 g
		2.2 lb
1 lb/acre (ac)	=	1.12 kg/ha
1 kg/ha	=	0.89 lb/ac
1 lb/1000 ft^2	≈	0.5 kg/100 m^2
1 liter (L)	=	1000 ml
		0.264 gal
1 gallon (gal)	=	3785 ml

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Understanding & Applying the Carbon-to-Nitrogen Ratio in Nurseries

By Thomas D. Landis

You probably remember something called the carbon-to-nitrogen ratio (C:N) from your soils or ecology class in college. This relatively simple index provides a lot of practical information on the horticultural properties of organic materials and how they can be used in both bareroot and container nurseries.

What It Is

To really understand C:N, it's necessary to discuss some basics of soil microbiology. The soil contains a wide variety of microorganisms but we are only interested in the ones involved with the breakdown of organic matter. Decomposition is initiated by insects, snails, and earthworms, which physically breakdown the material into smaller pieces. Then, smaller microbes (Figure 1A) complete the process through chemical decomposition (Martin and Gershuny 1992).

Bacteria - These single-celled microbes are so small that one million bacteria could be found in a pea-sized crumb of soil. However, they are the most versatile of soil microorganisms and can produce enzymes to digest any type of organic matter.

Actinomycetes - These thread-like bacteria are morphologically more similar to fungi. Although they are not as numerous as true bacteria, actinomycetes release ammonia when decomposing organic matter into humus. Actinomycetes are responsible for the sweet, earthy smell when a biologically active soil is tilled.

Fungi - These primitive plants exist in many sizes and shapes in the soil, and perform many biological functions during the decomposition of organic matter. Most importantly, fungi are able to breakdown the more resistant hemicellulose and lignin that found the structure of woody plant tissue.

Organic materials that could be useful in nurseries have a wide range of C:N (Table 1). The C:N is one of the most important considerations when evaluating organic matierals because it is an indicator of whether nitrogen will be limiting or surplus in the soil or growing media. The higher the C:N, the greater the likelihood that nitrogen will be unavailable for plant uptake. On the other hand, when an organic source with a high C:N is incorporated into the soil, carbon becomes available as an energy source for soil organisms.

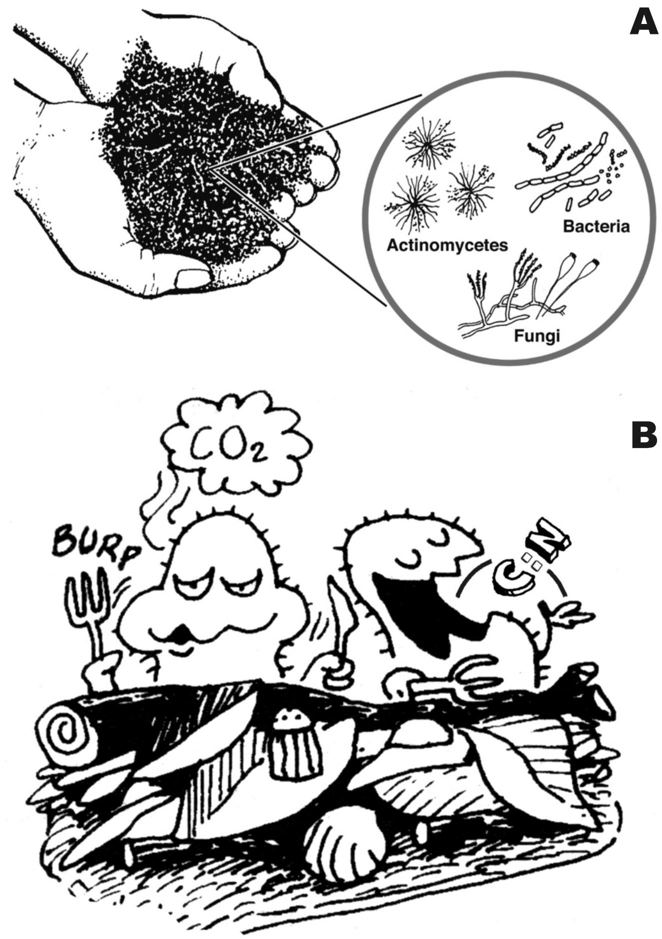

Figure 1 - Organic matter is chemically decomposed by bacteria, actinomycetes, and fungi (A); these microbes consume organic material and incorporate nitrogen (N) into their bodies and release carbon dioxide (CO_2) (A, modified from Crespo 2000; B, modified from Martin and Gershuny 1992, and Dindal 1982).

Composting literature states that soils or organic matter with C:N of 20:1 to 30:1 are relatively stable (Table 1). Most common organic amendments have a C:N greater than 50:1 with sawdust and bark having the highest ratios. Sawdusts from broadleaved tree species have C:N around 400:1 and with their bark around 75:1; conifers woods and bark can be 2 to 4 times higher. Organic materials with C:N of 20:1 or lower are considered fertilizers because their decomposition results in a net release of nitrogen. Animal manures have C:N of around 10:1, which explains why they are the world's oldest fertilizers. Leguminous cover crops such as clover also have low C:N so, when they are tilled into the soil, their decomposition provides nitrogen for future crops (Table 1). One of the most comprehensive evaluations of C:N of common organic materials used in horticulture can be found in Bollen (1953).

Why Does Nitrogen Tie-up Occur?

Traditionally sawdust has been one of the most readily available and inexpensive organic amendments for forest and conservation nurseries, but many nursery managers are reluctant to use wood wastes because of growth problems with subsequent crops. Even if growers haven't experienced stunting themselves, they have surely heard horror stories from others. Although many blame "toxins" for these growth problems, the main cause is the high C:N of wood wastes and many other common organic amendments (Table 1).

Soil microbes have a C:N of approximately 30:1 so, when they are decomposing organic materials with a higher C:N, they have to obtain extra nitrogen from the surrounding soil or growing medium. Therefore, nitrogen "tie-up" occurs when inorganic nitrogen is converted to organic forms by microbes that use these nutrients to build their tissues. The stunting occurs because most of the nitrogen is temporarily immobilized in the microbial bodies, and little, if any, nitrogen is available for crop uptake. Visual symptoms of nitrogen tie-up are those of classic nitrogen deficiency: chlorosis and stunting. Symptoms often appear in a scattered "mosaic" pattern (Figure 2), because sawdust and other organic amendments are often not uniformly incorporated into the soil or growing medium. Plants in areas with too much high C:N amendment will appear chlorotic and stunted.

These conditions persist until the populations of decomposing bacteria, actinomycetes, and fungi decrease and the organic nitrogen in their tissues is mineralized to inorganic forms (nitrate and ammonium) that are readily available to plants. Therefore, addition of high C:N amendments to soil or growing media results in a temporary reduction of plant available nitrogen, but the final result is a slow release source of organic nitrogen and humus.

Compensating for Nitrogen Tie-up

Most nursery managers realize that organic amendments require supplemental nitrogen to facilitate breakdown and prevent chlorosis and reduced growth.

Material	% Nitrogen (Ovendry)	C:N
Chicken manure	5.50	7:1
Cow manure	2.60	15:1
Clover	2.20	18:1
Stable Carbon-to-Nitrogen Ratio		20:1 to 30:1
Corn stalks	1.20	33:1
Sphagnum peat moss	1.00	54:1
Tree leaves	0.70	60:1
Red alder bark	0.70	71:1
Straw of wheat & oats	0.40	100:1
Corn cobs	0.45	108:1
Rice hulls	0.30	140:1
Red alder wood	0.13	377:1
Douglas-fir bark	0.04	471:1
Douglas-fir sawdust	0.05	944:1

Table 1 - The percent nitrogen and carbon-to-nitrogen ratios of organic materials used in nurseries (modified from Allison 1965, Bollen 1969, and Handreck and Black 1994).

Figure 2 - Incorporating uncomposted sawdust in soils or growing media can result in stunting due to nitrogen tie-up (photo courtesy of Davis and others 2009).

So, the real question is: how much nitrogen, what form of nitrogen, and when is the best time to apply it? To be completely safe, the best procedure is to compost the organic matter beforehand but somehow there's never enough time or space for that.

In bareroot nurseries, the most practical solution is to "compost in place", which means to apply the organic matter as soon after harvest as possible and allow it to decompose over the fallow year. Applying nitrogen fertilizer at a rate of 15 to 20 pounds of nitrogen per ton of dry material is a good place to start (California Plant Health Association, 2002), but actual nitrogen demand will vary with type of amendment, soil type, moisture, temperature, and other factors. One of the most comprehensive studies with Douglas-fir (*Pseudotsuga menziesii*) sawdust recommends applying 25 to 50 pounds of ammonium sulfate or its fertilizer equivalent for each ton of sawdust. Half of the fertilizer should be incorporated with the sawdust, with the second half being broadcast later and irrigated into the soil (Bollen and Lu 1975). Some nurseries have sown field peas or other leguminous crops after the organic matter incorporation so that their naturally-fixed nitrogen will help compensate for the increased nitrogen demand.

In container nurseries, it's much easier to satisfy the nitrogen demand created by the increasing populations of decomposing microorganisms. When using high C:N components, some growers incorporate slow release fertilizer when mixing the growing media. For example, Robbins and Evans (2010) recommend that growers using fresh bark in their growing medium incorporate a starter charge of nitrogen at the rate of 0.25 to 1 pound N/yd^3 of medium. However, the easiest way to keep up with the projected nitrogen tie-up is to fertigate with a nitrogen solution with each irrigation. This ensures that some nitrogen will always be available for crop uptake.

As you can see, that results will vary considerably so the best procedure is to try a test in your nursery to see what works best under your conditions. Again, remember that this fertilizer is not being lost but is being converted to an organic form that will be available to your crops later in the season.

Applying the Carbon-to-Nitrogen Ratio in Nurseries

The effect of using organics with high C:N varies considerably with intended use and method of application. In nurseries, this is an issue when using organic mulches, amending bareroot soil, or creating a growing medium for containers.

Mulches - Mulches are one of the most widely used cultural practices in bareroot and container nurseries because they offer many benefits (Borland 1990). Fibrous mulches create a textural change at the soil surface that stops water from moving upward through capillarity and evaporating. All types of mulches reduce soil erosion by dissipating the energy of raindrops and wind that can dislodge soil particles and leave them vulnerable to wind and water erosion. Mulches stop soil crusting and allow irrigation and rainfall to slowly soak into the soil that improves water infiltration. Thick mulches form an insulating layer that dissipates solar energy and prevents soil temperatures from reaching damaging levels. When applied over cold or frozen soils, mulches slow soil warming which can prevent loss of dormancy or premature germination of fall-sown crops. A thick mulch can prevent soluble salts from moving upward as water is lost from the soil surface by evaporation. Because they insulate the soil surface, mulches prevent the recurring freeze and thaw cycles, which cause frost heaving. Mulches physically supress weeds and reduce light levels to the soil surface, which inhibits germination of many weed seeds (Mathers 2003).

Sawdust has been used for covering seeds in bareroot and container nurseries. Because only the mulch along the soil or growing media interface is accessible to microorganisms, nitrogen tie-up has not been a serious problem with high C:N mulches (Figure 3). To be safe, however, calculations for determining how much nitrogen fertilizer to add to various types and thicknesses of wood waste are provided in Rose and others (1995). In one bareroot nursery, seed germination under a mulch of 0.50 to 0.75 inches of fresh sawdust was actually better than the germination test (Knight 1958). Because of its lower C:N and slower decomposition rate, tree bark has even better advantages as a seed mulch.

Soil Amendments - Traditional organic soil amendments include sawdust, bark, peat moss, and manure, but innovative nursery managers have also used many other organic sources including mushroom compost, dried sewage sludge, ground cones, mint waste, and even dead fish from hatcheries. Regardless of the source, organic amendments provide many benefits (Davey 1984). As microbes consume organic material, they produce glomalin which binds soil particles into crumbs. Organic matter decomposes into humus, which acts like a sponge and retains water in the soil. Humus has a very high cation exchange capacity and prevents mineral nutrient ions from leaching. As organic matter decomposes, mineral nutrients are gradually released, especially the anions phosphorus and sulfur which are easily lost to leaching. In addition, the nitrogen which was added to speed decomposition becomes gradually available as the soil microbes die off. The high cation exchange capacity binds excess hydrogen ions. Improved soil structure helps create and maintain macropores, which are essential to water drainage and air exchange. Decomposing organic matter binds soil particles into stable crumbs instead of monolithic pans.

Unfortunately, traditional organic amendments such as sawdust and bark are becoming more expensive and less available to nurseries, so other sources such as municipal and industrial composts should be considered. Because seedlings and other nursery crops are not foodstuffs, nurseries are able to accept municipal and industrial organic wastes that cannot be used on food crops. Besides organic soil amendments, green manure crops are the only other way to maintain soil organic matter. Recently, however, cover crops and green manure crops have been discouraged due to concerns about the buildup of soil pathogenic fungi (Hildebrand and Stone 2001). So, as sawdust and other wood wastes become more unavailable, nursery managers will have to be more creative in their search for organic amendments.

Growing Media - All artificial growing media contain a high proportion of organic materials because they provide many benefits for growing plants in containers (Landis and others 1990).

Organics generate a large proportion of macropores for aeration and micropores for water-holding capacity. Organic material is less subject to compaction than inorganics. All types of organic material have high cation exchange capacities, so they can retain nutrient ions against leaching as well as provide a buffer against rapid changes in pH or salinity.

The amount of organic material used in growing media varies considerably, generally ranging from 25 to 50% (by volume). Joiner and Conover (1965) considered that 40 to 50% organic matter was ideal. For container nurseries that use commercially prepared growing media, such as mixtures of peat moss and vermiculite, the C:N is not an immediate concern. The topic needs to be considered, however, for nurseries that create their own custom growing media and espcially for those who are looking for an organic substitute for peat moss.

In Canada and Scandinavia, where peat bogs are common, forest tree nurseries use a growing media of 100% *Sphagnum* peat moss. *Sphagnum* peat moss has a C:N of around 50:1 (Table 1) and so rapid decomposition with corresponding nitrogen tie-up won't be a problem with normal fertilization. Several forest nurseries in the Pacific Northwest have tried using conifer sawdust in their growing media. Some growers experienced stunting caused by nitrogen deficiency, and therefore decided against using raw sawdust in the media (Justin 2009; Davis 2009). This mosaic stunting pattern is characteristic of nitrogen deficiency due to microbial immobilization (Figure 2). Other nurseries, however, have successfully incorporated sawdust in their

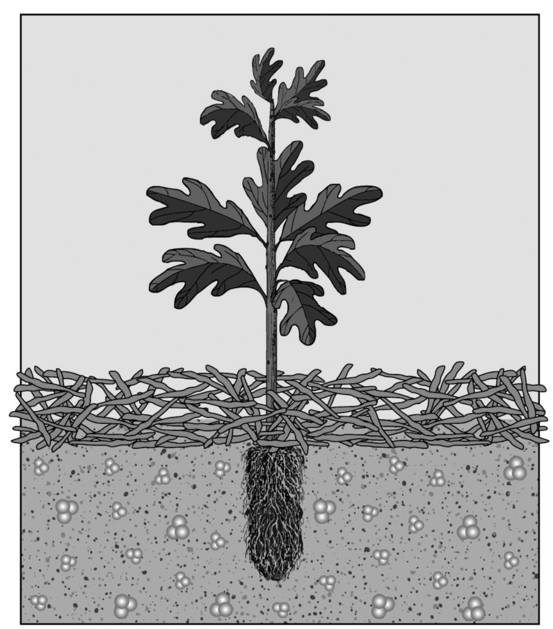

Figure 3 - Nitrogen tie-up is not a serious concern with organic mulches because of the limited contact with the soil.

media. Using a growing medium of 70% peat moss: 30% sawdust, one nursery produced crops as good as a peat-vermiculite growing medium while realizing savings of over 40% (Schaefer 2009). In a research trial comparing a 7 parts peat moss to 3 parts sawdust growing medium with a traditional 1 part peat moss to 1 part vermiculite medium, irrigation and fertilization were carefully controlled. Although seedlings growing in the sawdust mix showed some stunting early in the crop cycle, they were of similar size to the control seedlings by the end of the experiment, presumably because immobilized nitrogen became available later in the growing season. In addition, the sawdust medium required less frequent irrigation (Dumroese 2009).

Other organic materials are also being used in growing media. For example, composted rice hulls have worked out well as a peat moss substitute for another nursery (Lovelace and Kuczmarski 1992). One of the biggest problems with using composts or other organic materials in growing media is the variation from batch to batch, so the initial C:N should be checked regularly. With wood wastes, particle size is a consideration because microorganisms will only decompose the surfaces of larger particles (Handreck and Black 1994). Chipped pine logs (Wright and Browder 2005) and pine tree substrate (Jackson and others 2009), which is a product of whole tree chipping, have successfully been used in growing media for ornamental crop production.

Therefore, sawdust and other organic materials can be used as peat moss substitutes in growing media as long as the C:N of the material is known so that commensurate nitrogen fertilizer can be applied. Crop growth should also be carefully monitored so that, if needed, additional nitrogen can be immediately supplied through fertigation. For the more research-minded, a nitrogen drawdown index can be computed by treating a sample of the organic matter with a known nitrogen source, and incubating it for a few days (Handreck 1992). However, for nurseries that don't want this additional challenge or don't use fertigation, they should stick to traditional growing media.

Take-Home Message

Organic amendments have many beneficial uses in forest, conservation, and native plant nurseries and growers shouldn't shy away from using them because of past experiences. Nitrogen tie-up can be managed by knowing the C:N of the material beforehand, and by being prepared to supply additional nitrogen fertilizer in the proper amount and at the proper time. It's also important to remember that this nitrogen isn't lost but merely converted to an organic form that will serve as a slow-release fertilizer later in the season.

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International Plant Propagators' Society Proceedings Articles

by Thomas D. Landis

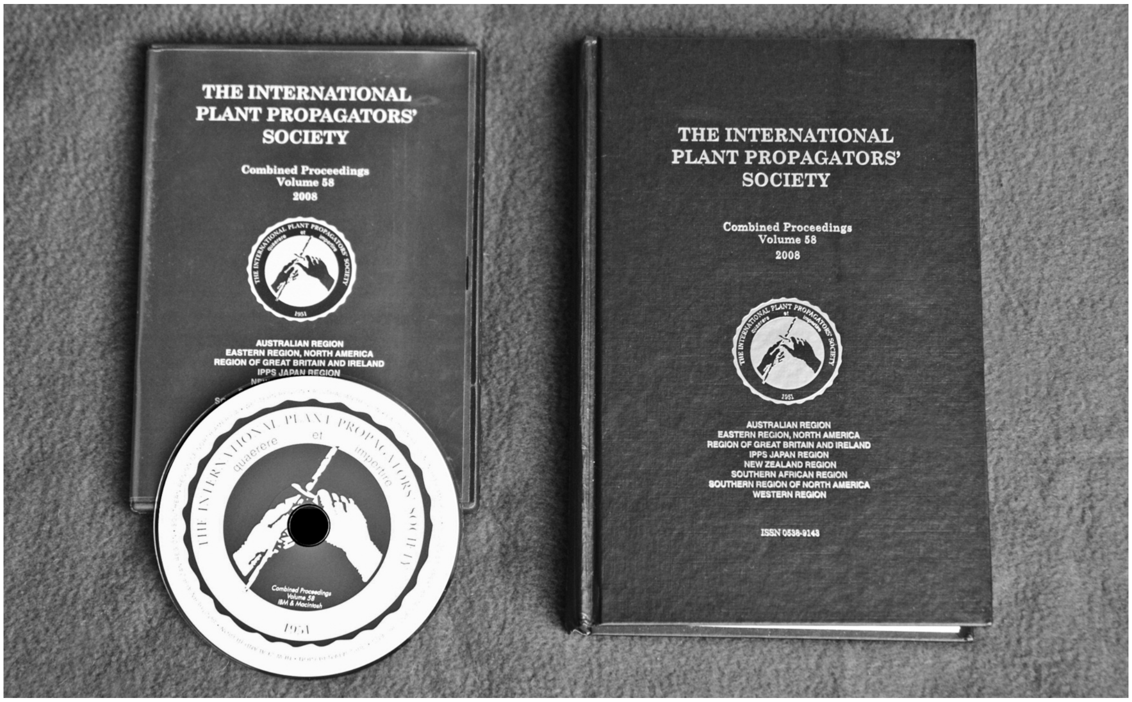

Figure 1. The Proceedings of the International Plant Propagators' Society can be ordered as a hard cover book or a CD in Adobe PDF format.

Several times in the past I have encouraged FNN readers to join **IPPS** because it is an excellent forum for information exchange. Their motto of "To Seed and Share" says it all. I've been a member for almost 30 years and always enjoy attending the annual meetings and receiving the Proceedings, which is available both as a hardbound book and in CD format (Figure 1). I've been reviewing the IPPS proceedings since I became a member in 1983 and always find a wealth of articles for the FNN database. Because the proceedings are copyrighted, all that we can share with you are the title pages and abstracts. For example, in Volume 59 from last year, I found 44 articles that are relevant to our work in forest, conservation, and native plant nurseries. Check out the wide variety of information covered in these articles in the New Nursery Literature section.

Now, there is an even better reason for being an IPPS member. Just recently, they partnered with the International Society for Horticultural Science to scan and upload all the articles from the IPPS Proceedings from Volume 1 (1951) to Volume 56 (2006). Volumes 57, 58, and 59 will be added next year for a total of 60 years of proceedings articles. The website is fully searchable using keywords. For example, my search for "fertilizer" resulted in more than 200 hits.

All IPPS members who purchase the annual Proceedings will be able to download up to ten full papers with no charge through the rest of this year. Renewing your membership in 2011 entitles you to download ten papers in that year, and for every year you maintain your membership. To join IPPS, or just for more information, contact:

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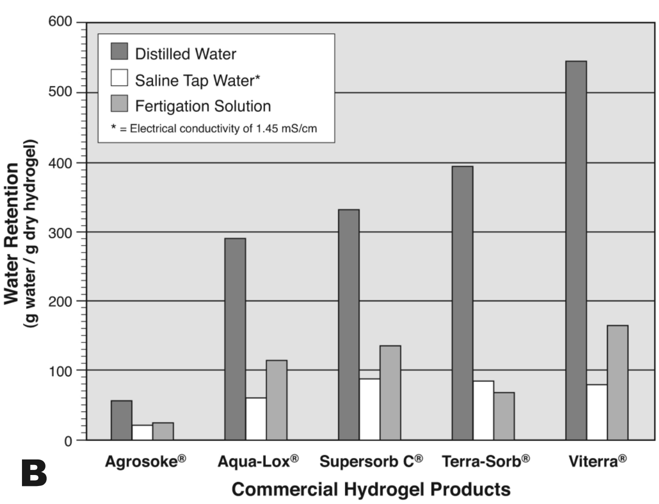
Uses for Hydrogels in the Nursery and During Outplanting

by Thomas D. Landis

Introduction

Hydrophilic gels, or "hydrogels", which are commonly known as superabsorbents, are crosslinked polymers that can absorb 400 to 1500 times their dry weight in water (Figure 1A). Most of the early hydrophilic polymers were destined for non-agricultural uses, most notably baby diapers, but have also found uses in such diverse applications as oil recovery, food processing, water purification, and wound dressings (Peterson 2002).



Hydrophilic polymers can be categorized into three classes (natural, semi-synthetic, synthetic), but can be chemically manipulated to produce products with different characteristics in each class (Mikkelsen 1994).

1. Naturally occurring polymers are starch-based polysaccarides that are made from grain crops such as corn and wheat. Natural polymers are most commonly used in the food industry as thickening agents.

2. Semi-synthetic polymers are derived from cellulose, which is chemically combined with petrochemicals. One of the first hydrogels specifically designed for horticulture was a polyethylene polymer combined with sawdust (Erazo 1987).

3. Synthetic polymers are solely made from petrochemicals. Linear chain polyacrylamides are used for erosion control, canal sealing, and water clarification whereas crosslinked polyacrylamide hydrogels are used in horticulture (Peterson 2002).

The absorptive capability of hydrogels is affected by the chemical composition as well as environmental factors, such as the dissolved salts in the surrounding water solution. Mikkelsen (1994) states that divalent ions, such as calcium (Ca^{++}) and magnesium (Mg^{++}), are more restrictive than monovalent ions, such as ammonium nitrogen (NH_4^+) and potassium (K^+). One research trial soaked commercially available hydrogels in several different solutions including distilled water, moderately saline tap water (electrical conductivity of 1.45 mS/cm), and a dilute fertilizer solution. After soaking, the saturated hydrogels were allowed to drain to determine their absorptive capacity. The optimal absorption is reflected by the weight of water retained in the distilled water treatment, in which the hydrogels varied considerably (Figure 1B). Agrosoke© absorbed and retained considerably less water than the other hydrogels, with Viterra© retaining the most. The effect of dissolved salts of the amount of water that can be absorbed by the various products can be seen in the other two treatments: the saline tap water and the

Figure 1 - Hydrophilic gels, commonly known as hydrogels, are dry crystals that can absorb many times their own weight in water (A). The amount of water that can be retained depends on their chemical composition and environmental factors like the salts dissolved in the surrounding solution (B) (A, courtesy of David Steinfeld; B, modified from Wang and Gregg 1990).

fertigation solution. The tap water reduced the water retention of the commercial hydrogel products substantially, from a 65% decrease in Agrosoke© to almost 85% in Viterra©. Because it contained a variety of fertilizer ions, the water retention for dilute fertilizer treatment was different again (Wang and Gregg 1990). The bottom line is that the laboratory absorption values using distilled water are significantly different than the amount of water that can be absorbed and retained in the nursery or on the outplanting site.

Exactly how hydrogels will benefit plants depends on how they are applied. When incorporated into growing media or soil either at the nursery or on the outplanting site, hydrogels absorb and retain water that would normally be lost to evaporation or leaching. They have also been shown to retain nutrient ions that could be leached out of the root zone (Mikkelsen 1994). When applied as a root dip, hydrogels coat fine roots and protect them against desiccation. One potential benefit that I hadn't considered is that hydrogel dips may function similar to the natural polymeric mucilages produced by healthy roots. One recent study demonstrated that mucilage weakens the drop in water potential at the root-soil interface, increasing the conductivity of the flow path across soil and roots and reducing the energy needed to take up water (Carminati and Moradi 2010). Hydrogel root dips provide the same function, improving root-to-soil contact (Thomas 2008), and filling-in air spaces around transplants or outplanted seedlings (Figure 2).

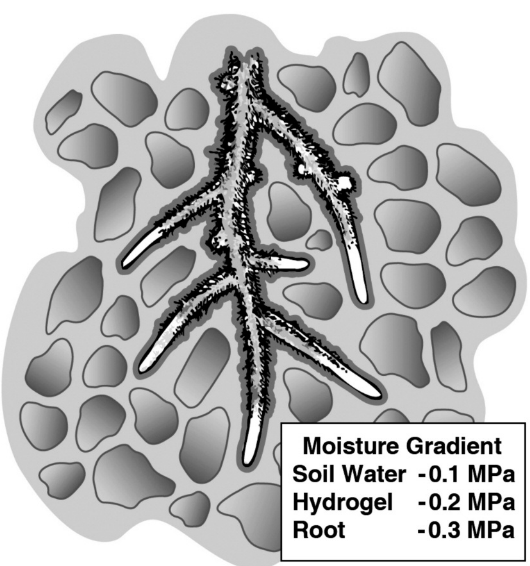


Figure 2 - When hydrogels are applied as root dips, they function like the mucilage naturally produced by healthy roots and improve water uptake by increasing root-to-soil contact and filling-in air spaces.

Application of hydrogels in nurseries, reforestation, and restoration

The main use of hydrogels has been to retain water for plant growth especially when irrigation isn't provided, but new uses are continually being discovered.

1. Gel seeding - This was one of the first applications of hydrogels in horticulture and involves sowing seeds mixed into a hydrogel. The objective is that the hydrogel will retain moisture around the germinating seeds and improve establishment either in a nursery or on an outplanting site. Research trials coating leguminous tree seeds with hydrogels before sowing in a greenhouse or in field soil showed mixed results among plant species; larger-seeded species survived and grew better. One hypothesis was that coating seeds with hydrogels may reduce germination and emergence by reducing aeration around the seeds (Henderson and Hensley 1987). In a more recent test, hydrogels were applied to seeds of Scotch pine (*Pinus sylvestris*) and Austrian pine (*Pinus nigra*) prior to germination tests in the laboratory, greenhouse, and in a bareroot nursery. The hydrogel treatment reduced germination percentage for both species in the laboratory but Scotch pine germinated better than the controls in the greenhouse. In spite of these germination problems, the authors considered that the improved seedling growth after 2 years in the bareroot nursery justified the use of hydrogels in future trials (Sijacic-Nikolic and others 2010). The paucity of other published trials in recent years suggests that gel seeding has little application in forest and native plant nurseries or for direct seeding on project sites.

2. Root dips - The concept of dipping plant roots before transplanting or outplanting has been around for many years because it is intuitively attractive. Roots of nursery plants dry as they are exposed to the atmosphere during harvesting and handling and so it would only make sense to rehydrate them or apply a coating to protect them (Chavasse 1981). Southern nurseries have been dipping the roots of their bareroot stock in a clay slurry for decades, but many have switched to hydrogels in recent years (for example, Bryan 1988). In the western states, the use of root dips is less common but some forestry organizations sell protective root dips as part of their tree distribution programs (for example, Kansas State Forest Service 2010). For a comparison of the various root dip products and their effectiveness, see "Protective root dips: are they effective" (Landis 2006).

John Sloan did a very comprehensive literature review of root dips and concluded that they were detrimental to bareroot stock when applied before storage (Sloan 1994). After outplanting, most of the research at that time showed that hydrogel root dips do not increase survival or growth under very dry conditions and are merely an added expense. One conclusion of this review that I strongly agree with is that, while rootdips can be beneficial in protecting seedlings from exposure to sun and wind, tree planters should not assume that root dipping will restore seedling vigor after improper handling.

Another limitation of comparison trials of root dips is that all too often no appropriate control was included. Many tests were done against no root dip at all but, because all hydrogels are applied in a water slurry, it just makes sense to use a water dip as a control. One recent research study did just that, and tested 3 hydrogel-based root dips against a water dip control (Bates and others 2004). The seedlings of 4 bareroot conifers were dipped into one of 3 commercial root dips or a water control. When evaluated for survival, none of the products showed a significant improvement over the water dip; likewise, the commercial root dips gave no appreciable shoot growth benefit after 2 years (Figure 3).

The vast majority of research has been with bareroot conifer seedlings and, interestingly enough, I could only find one published article on dipping the roots of container plants in hydrogel prior to outplanting. When 2 species of Eucalyptus container seedlings had their root plugs dipped in a hydrogel slurry, mortality at 5 months after outplanting was more that cut in half

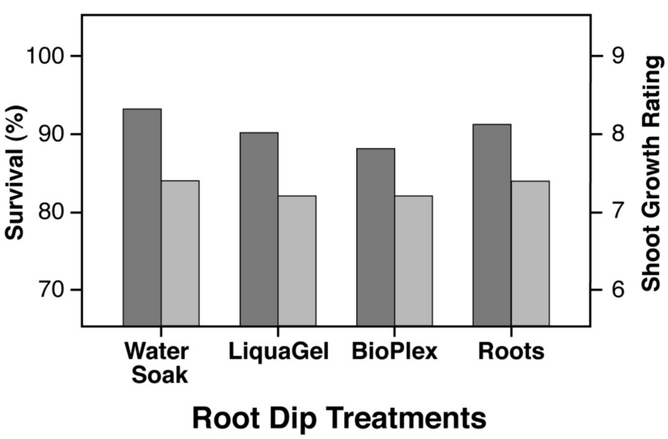


Figure 3 - Compared to a water soak, none of three hydrogel root dips improved survival or shoot growth of four conifer seedlings two years after outplanting (Bates and others 2004).

(Thomas 2008). Likewise, only one study looked at the effects of hydrogel dips on bareroot hardwood seedlings. When the roots of red oak (Quercus rubra L.) seedlings were dipped into a hydrogel slurry, and then subjected to drought stress, the hydrogel-treated seedlings had greater root moisture content and less root membrane leakage than plants without root dipping. These differences were not reflected in increased growth, however (Apostol and others 2009).

Both of these studies stress the importance of using the fine grade of hydrogel when root dipping; using hydrogel with dry particle sizes from 0.2 to 0.3 mm covered roots much better than larger grades which clumped and fell off the roots (Sarvas 2003). Terra-Sorb® is available in 3 particle diameters: coarse (2 to 4 mm), medium (0.75 to 2 mm) and fine (0.10 to 0.75 mm), with the fine grade recommended for root dipping (Plant Health Care 2010).

I also could find only one article on the use of hydrogel dips before transplanting in a bareroot nursery, which I assume would lessen transplant shock. Dipping bareroot Norway spruce (*Picea abies*) seedlings prior to mechanical transplanting increased shoot height and root collar diameter compared to the controls (Sarvas 2003).

3. Amendment to container growing media - Another application that has been widely tested is the incorporation of hydrogels into growing media prior to sowing as a means to hold more water and reduce moisture stress. In addition to increasing water holding capacity, hydrogels have been shown to retain nutrient ions against leaching especially in growing media with low cation exchange capacities. One trial found this to be true for the cations ammonium and potassium, but not for the anionic nitrate which is one of the major causes of nutrient runoff from nurseries (Henderson and Hensley 1985).

Many earlier studies showed that, while hydrogels definitely increased the water holding capacity of the growing medium, this was not always reflected in increased plant growth. When birch seedlings were grown in a hydrogel-amended medium, subsequent growth was actually reduced compared to the control seedlings (Tripepi and others 1991). The authors suggest that the reduced growth could be a result of reduced aeration resulting from less macropore space in the gel-amended media. This observation was supported by reduced root mass in the seedlings from the gel treatment. Another study found that air space in pine bark and pine bark/sand media was reduced in the hydrogel-amended growing media (Fonteno and Bilderback 1993).

In operational practice, I'm not aware of any nurseries who use a growing medium amended with hydrogels, although many such products are available for the non-professional or home gardener (Figure 4). Good growers want complete control of the water-holding capacity of their growing media, which would be lost with hydrogel amendments. Also, the swelling hydrogel particles have to expand somewhere after hydration and undoubtedly reduce the amount of macropores which are so essential for good drainage and air exchange.

4. Soil amendment during outplanting - The final application for hydrogel is to amend soils on the outplanting site, especially on droughty or severely-disturbed sites. The method of application is important and incorporating hydrogels in the rooting zone is much more effective than applying then in a band or layer (Kjelgren and others 1994). When 8 grams of hydrogel was applied per kilogram of 3 different soil textures, the available water content increased 1.8 times that of the unamended control for the clay, 2.2 times for the loam, and 3.2 times for the sandy loam soil (Abedi-Koupai and others 2008). In another study, 2 rates of hydrogel were added to 5 different soil textures ranging from sand to clay and then seedlings of 9 different tree species were planted in pots with both treatments and a control (Agaba and others 2010). The plants were subjected to moisture stress treatments in a greenhouse until some seedling mortality occurred. The percentage of plant available water increased from around 100% in the clay to almost 300% in the sandy soil, and these results were mirrored very closely by the survival of the tree seedlings (Figure 5). As can be seen, hydrogel amendments are most effective on sandy soils and in droughty environments. When a sandy soil was amended with a range of

Figure 4 - Many brands of growing media for the home gardener contain hydrogels.

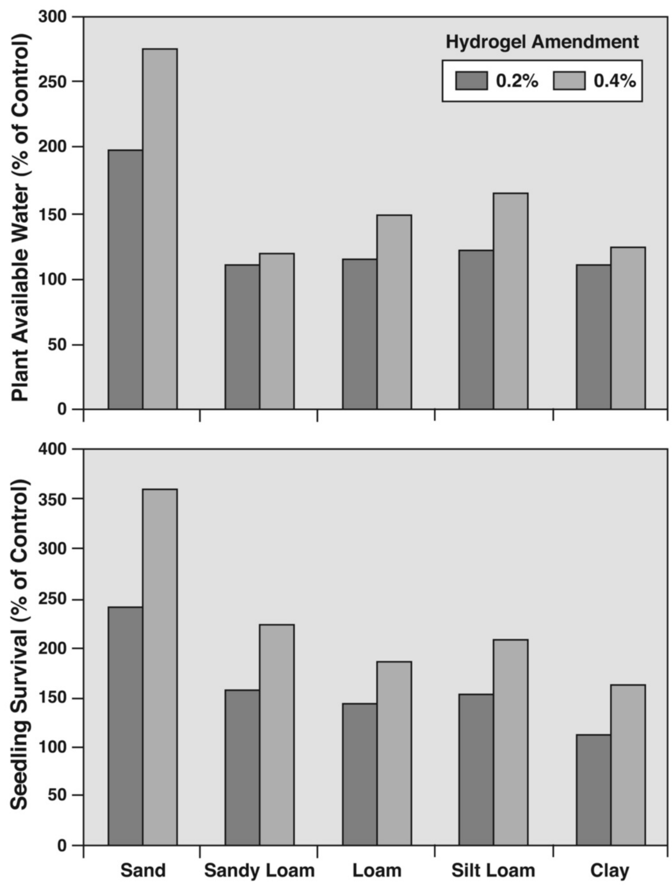


Figure 5 - Hydrogel amendments incorporated into a range of soil textures significantly increased plant available water and seedling survival compared to the controls (modified from Agaba and other 2010).

hydrogel treatments and planted with *Pinus halepensis* seedlings, the water retention of the soil increased exponentially with increasing additions of hydrogel. When the seedlings were subjected to controlled desiccation, the seedlings in soils with the highest amount of hydrogel survived twice as long as in the plants in the control soils. Water potential measurements showed that seedlings in the amended soils had considerably less moisture stress than the controls. Shoot growth and root growth were also significantly increased with the hydrogel amendment (Huttermann and others 1999).

One of the things almost never presented in research studies is cost of the hydrogel treatment. The only reference that I found was for Eucalyptus seedlings where a sandy soil was amended with hydrogel; the cost per plant was increased 17 to 27% while improving survival by a factor of three (Callaghan and others 1989).

Summary

Hydrophilic polymers have been used in agriculture for over 40 years, and a variety of products are available for a wide range of uses both in the nursery and on the outplanting site. When incorporated into growing media or soil either at the nursery or on the outplanting site, hydrogels absorb and retain water that would normally be lost to evaporation or leaching. Hydrogels have also been shown to retain cationic nutrients against leaching. When applied as a root dip, hydrogels protect the roots against desiccation and increase the root-to-soil contact after outplanting. Because of the extreme variation between products and environmental conditions, it is impossible to generalize about whether to use hydrogels or not. As with most things in our business, growers or plant considering the use of hydrogels should conduct small scale trials under their own conditions. For root dips, just giving plants that added measure of care may increase outplanting performance.

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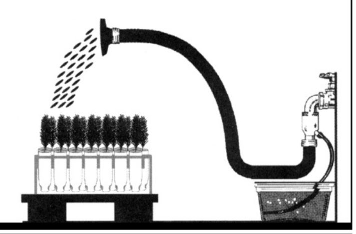

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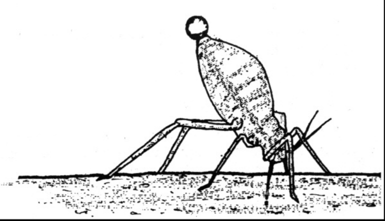

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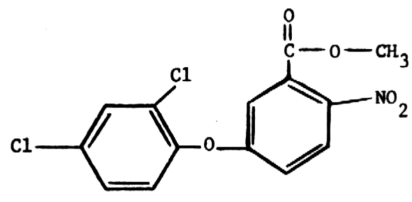

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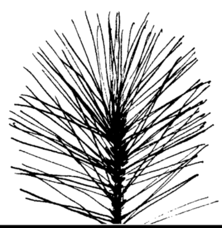

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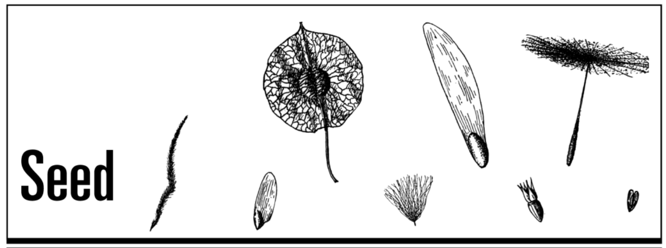

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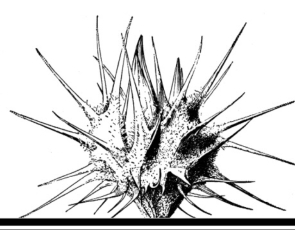

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