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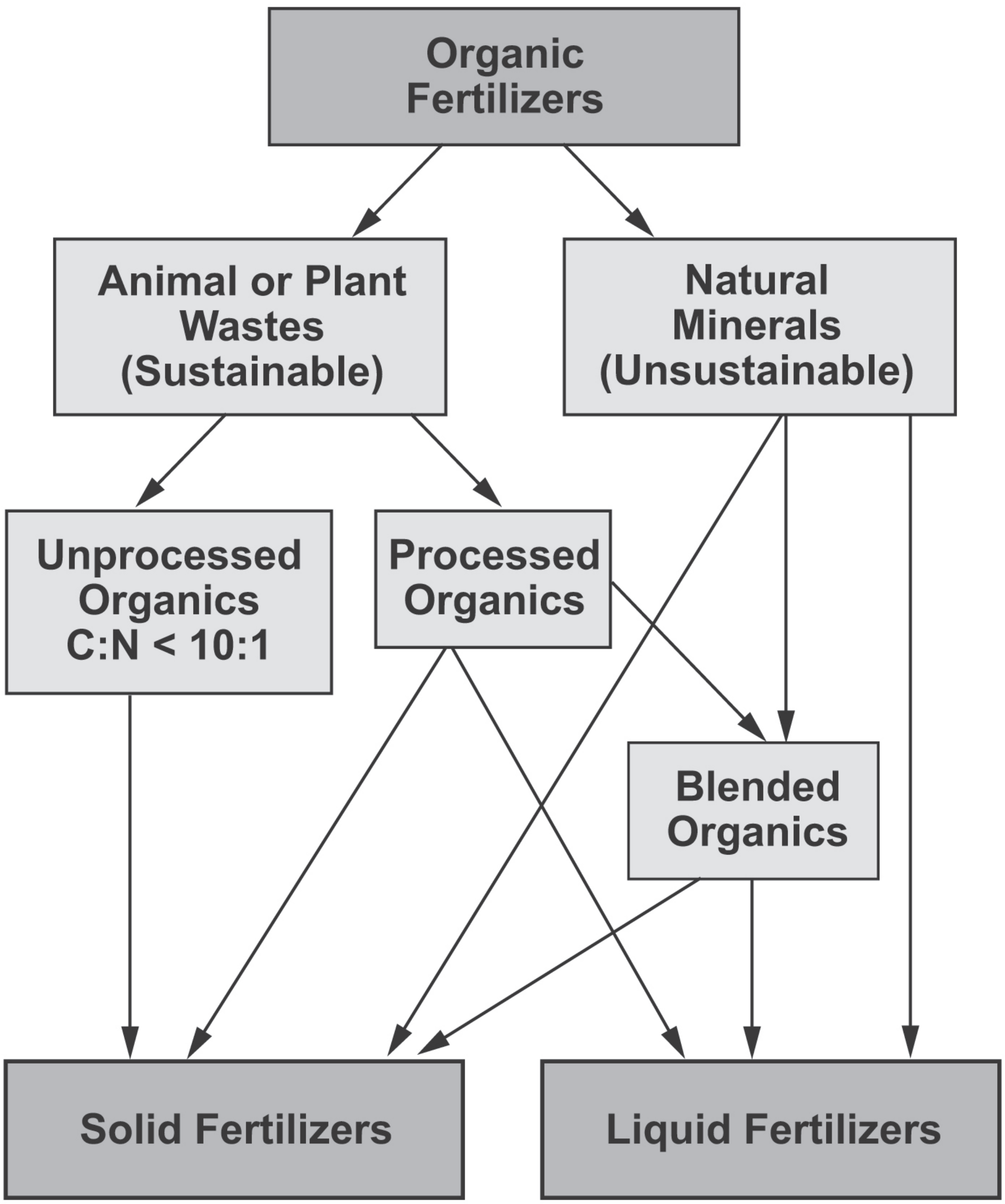
# Forest Nursery Notes

## Summer 2011



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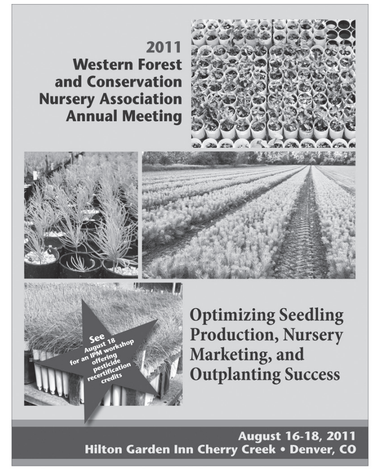
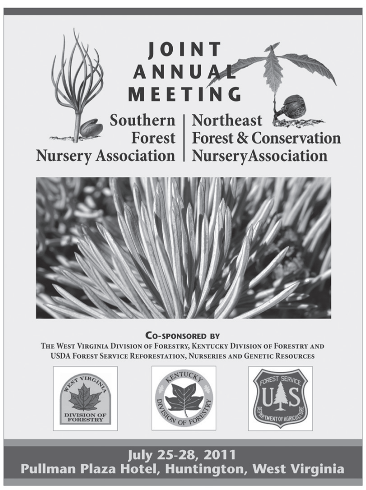
# Nursery Meetings




This year's meeting of the **Western Forest and Conservation Nursery Association** will be held at the Hilton Garden Inn Cherry Creek in Denver, CO on **August 16 to 18, 2011**. The meeting theme will be Optimizing Seedling Production, Nursery Marketing, and Outplanting Success, and two field trips will visit the Denver Botanic Gardens and restoration projects at the Rocky Mountain Arsenal National Wildlife Refuge. The last day will be an IPM workshop on Pest Management in Forest and Conservation Nurseries: Safety, Strategies, and Policies. Pesticide applicator credits will be available for western states. For more information or a copy of the meeting brochure, go to the Western Forestry & Conservation Association website: http://www.westernforestry.org/




**The combined meeting of the Southern Forest Nursery Association & Northeastern Forest and Conservation Nursery Associations** 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 theme for this year's meeting will be forest reclamation and reforestation and will include both presentations and field sessions. Another popular topic will be the latest information on soil fumigation. Two field trips will provide an inside look into nurseries operations and mine site reclamations, and will be followed by an evening BBQ. For more information or a copy of the meeting brochure, go to the Western Forestry & Conservation Association website: http://www.westernforestry.org/

This year's meeting of the **Western Region of the International Plant Propagators' Society** will be held at the Radisson Hotel in Sacramento, CA on **September 21 to 24, 2011**. The technical agenda is still being developed but is always an eclectic mix of interesting information on all aspects of nursery work. A pre-conference tour will explore the Sierra Nevada Mountains with an emphasis on revegetation research and native plant nursery production. Tours will visit Cornflower Farms, Matsuda's, the USDA NRCS Plant Materials Center in Lockeford, and several stops at the University of California at Davis: Foundation Plant Services, the Storer Arboretum, the Robert Mondovi Institute for Wine and Food Science, and the Good Life Garden.

The **40th Atlantic Forest Nursery and Seed Orchard Workshop** is being hosted by the J Frank Gaudet Tree Nursery on Prince Edward Island and will be held on **September 27 to 28, 2011** at Shaw's Hotel in Brackley Beach. One of the agenda items to be discussed is Climate Change as it Relates to Native Species but other topics are also being solicited. For more information, contact Bill Butler at website: wabutler@gov.pe.ca, or FAX: 902.368. 4713.

An **International Union of Forest Research Organizations (IUFRO) symposium on Restoring Forests: Advances in Techniques and Theory** will be held on **September 27 to 29, 2011** in Madrid, SPAIN. The agenda is still being finalized but sessions on Producing Plant Materials to Reduce Stress and Site Preparation for Restoration will be of particular interest to FNN readers. Participants interested in giving a presentation or poster are invited to submit an abstract through the Restoring Forests website (www.restoringforests.net). This website will also be updated regularly with the latest information on agenda topics and registration.

# Preventing Heat Stress

**by Thomas D. Landis**

It's that time of the year when nursery workers are exposed to long hours in the sun, and are therefore at risk to a number of heat-related illnesses. Heat stress is a function of both environmental conditions and personal conditioning. Four environmental factors contribute to heat stress: air temperature, humidity, wind velocity, and radiant heat. People vary in susceptibility to heat with age, gender, weight, physical condition, medical history, and degree of acclimation.

**How the Body Handles Heat.** The human body, being warm blooded, maintains a fairly constant internal temperature, even though it is being exposed to varying environmental temperatures. To keep internal body temperatures within safe limits, the body must get rid of its excess heat, primarily through varying the rate and amount of blood circulation through the skin and the release of fluid onto the skin by the sweat glands. These automatic responses usually occur when the temperature of the blood exceeds 98.6 °F (37 °C) and are kept in balance and controlled by the brain. In this process of lowering internal body temperature, the heart begins to pump more blood, blood vessels expand to accommodate the increased flow, and the microscopic capillaries dissipate heat to the environment. If heat loss from increased blood circulation through the skin is not adequate, the brain senses overheating and signals the sweat glands to emit sweat onto the skin surface. Evaporation of sweat cools the skin, eliminating large quantities of heat from the body (NIOSH 1986).

The effectiveness of sweating greatly depends on atmospheric conditions, especially humidity and wind speed. As atmospheric humidity increases or wind speed decreases, evaporation of sweat from the skin slows until at very high humidities, the body sweats profusely with little beneficial cooling. With so much blood going to the external surface of the body, relatively less goes to the active muscles and the brain, resulting in fatigue and loss of mental acuity. In extreme cases, fainting can result from overheating. Workers who perform precise or detailed work may find their accuracy suffering, and their comprehension and retention of information may diminish.

## Diagnosing Illnesses Caused by Exposure to Heat

Excessive heat exposure can cause a variety of illnesses, which can vary greatly between individuals. The major illnesses are listed by their order of severity (Table 1).

**Heat fatigue** is the least serious heat-related condition, and common symptoms include impaired performance of skilled sensory, mental, or vigilance jobs, and is often due to a lack of acclimatization. Therefore, developing of a program of acclimatization and training for work in hot environments is advisable. There is no treatment for heat fatigue except to get away from the heat stress before a more serious condition develops.

**Heat rashes** are the most common problem in hot work environments. Prickly heat is manifested as red papules and usually appears in areas where the clothing is restrictive or where body parts rub. As sweating increases, these papules give rise to a prickling sensation. Prickly heat occurs in skin that is persistently wetted by unevaporated sweat, and heat rash papules may become infected if they are not treated. In most cases, heat rashes will disappear when the affected individual returns to a cool environment.

**Heat cramps** are usually caused by performing hard physical labor in a hot environment. Cramps are thought to be triggered by an electrolyte imbalance due to excess sweating, but they can be caused by either too much or too little salt. Instead, heat cramps appear to be caused by the lack of water replenishment; excess salt can build up in the body if the water lost through sweating is not replaced. Under extreme conditions, such as working in heavy protective gear, a loss of sodium may occur. Recent studies have shown that drinking carbohydrate-electrolyte replacement liquids is effective in preventing or treating heat cramps.

**Heat exhaustion** is characterized by symptoms such as headache, nausea, vertigo, weakness, thirst, and giddiness. Fortunately, this condition responds readily to prompt treatment. Heat exhaustion should not be dismissed lightly, however, for several reasons. One is that the fainting associated with heat exhaustion can be dangerous under many work conditions. Of greater concern is that the signs and symptoms of heat exhaus-

| Type of Illness | Signs and Symptoms | Treatment |
|---|---|---|
| **Mild Heat Stress** | • Dizziness, fatigue, or irritability with decreased concentration and impaired judgement | • Loosen clothing<br>• Rest in shade<br>• Drink water |
| **Heat Rash** ("Prickly Heat") | • Tiny, blister-like red spots on the skin with prickling or itching. *Common on clothed areas of body | • Wash skin and apply lotion or corn starch<br>• See physician if rash persists |
| **Heat Cramps** | • Heavy sweating; painful spasms of legs, arms, or abdominal muscles; can occur after strenuous work | • Loosen clothing<br>• Drink lightly salted liquids or sports drinks<br>• Massage affected muscles |
| **Heat Exhaustion** | • Profuse sweating, fatigue, headache, dizziness, nausea, chills, fainting<br>• Pale, cool skin; excessive thirst, dry mouth; dark yellow urine<br>• Fast pulse, with body temperature from 99.5 to 101.3°F (38 to 39°C) | • Move patient to shade and make them recline and rest<br>• Loosen and moisten clothing, and fan to cool body<br>• Encourage patient to drink water, *but do not give salt*<br>• *If patient becomes unconscious, treat for heat stroke* |
| **Heat Stroke** ** Life-threatening Emergency ** | • Often develops suddenly<br>• Headache, dizziness, confusion, incoherent speech, irrational or aggressive behavior<br>• Sweating may decrease or even stop<br>• Body temperature of more than 104°F (40°C) | • Move patient to shade and wrap body with wet cloth and fan to cool<br>• Treat for shock by elevating legs<br>• Transport immediately to medical treatment facility<br>• Encourage patient to drink water, *but do not give salt* |

*Table 1 - Heat Stress can be expressed in a variety of different illnesses that can be distinguished by specific signs, symptoms, and treatments.*

tion are similar to those of heat stroke, a medical emergency. Workers suffering from heat exhaustion should be removed from the hot environment and given fluid replacement, and encouraged to get adequate rest.

**Heat stroke** is the most serious condition, which occurs when the body's system of temperature regulation fails and body temperature rises to critical levels. Heat stroke is caused by a combination of highly variable factors, and its occurrence varies greatly between individuals. Heat stroke is a medical emergency, so if a worker shows signs of possible heat stroke, professional medical treatment should be obtained immediately. The primary symptoms of heat stroke are confusion, irrational behavior, loss of consciousness, convulsions, and a hot, dry skin. The most diagnostic symptom is an abnormally high body temperature — a rectal temperature of 106 °F (41°C). In such extreme cases, death can result. The elevated metabolic temperatures caused by a combination of work load and environmental heat load, both of which contribute to heat stroke, are also highly variable and difficult to predict. The worker should be placed in a shady area and the outer clothing should be removed. The worker's skin should be wetted and air movement around the worker should be increased to improve evaporative cooling until professional methods of cooling are initiated and the seriousness of the condition can be assessed. Fluids should be replaced as soon as possible. The medical outcome of an episode of heat stroke depends on the victim's physical fitness and the timing and effectiveness of first aid treatment. Regardless of their protests, no employee suspected of being ill from heat stroke should be left unattended or sent home until examined by a physician.

## Managing Heat-Related Problems

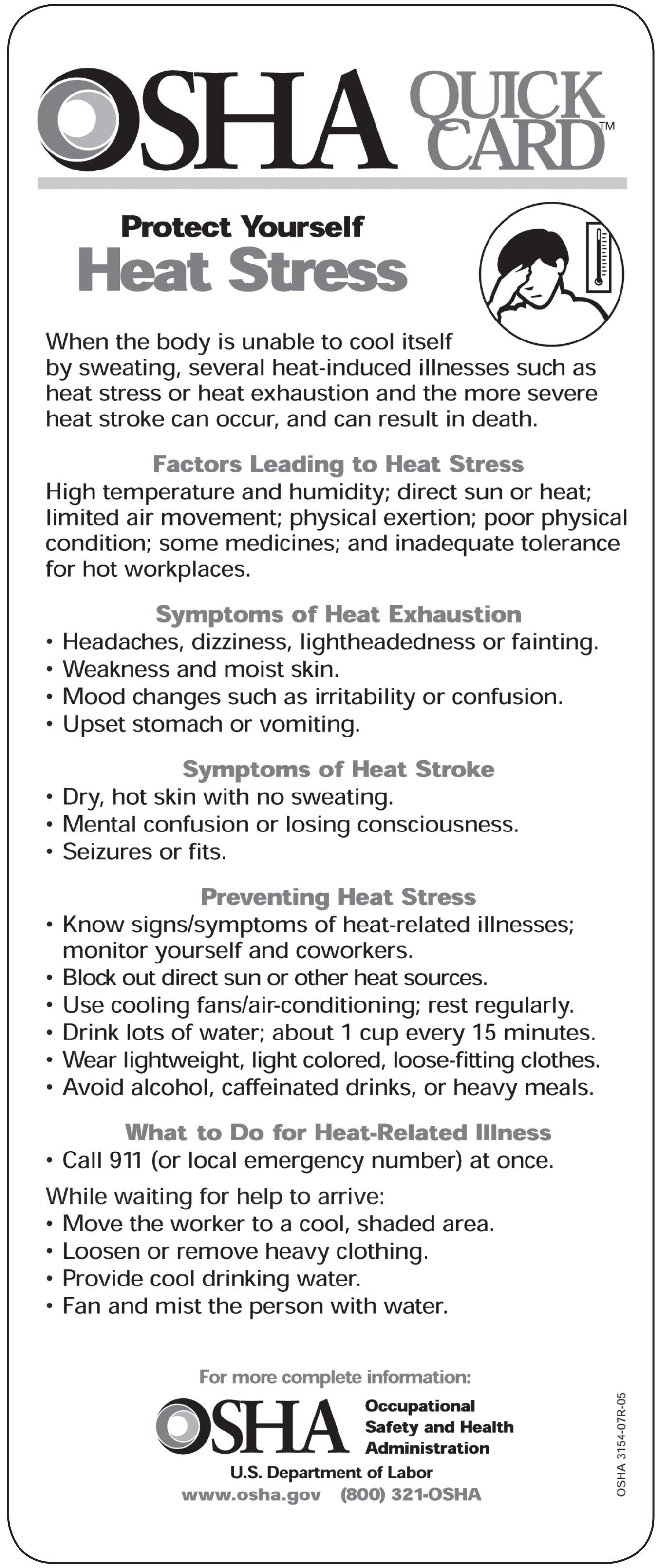
Avoiding heat stress is the common responsibility of the nursery manager and the workers, so regular training is essential. A comprehensive heat safety program should consist of six steps:

**Assign responsibility** - Make sure that someone takes the lead in the program. Ideally, one field worker should be appointed a safety coordinator and receive special training, but everyone should be taught to look out for each other.

**Hold seasonal training** - All new workers, and especially supervisors, should be trained in the recognition, prevention, and treatment of heat-related problems. Refresher courses should be given at the beginning of each season and work crews should be reminded with periodic tail-gate sessions and posters. A wide variety of training aids and posters are available from the Occupational Health and Safety Administration (OSHA) of the US Department of Labor (Figure 1). Many other training aids are available on the internet in both English and Spanish. One particularly good resource for tailgate training is Heat Hazards in Agriculture (Teran 2008).

**Acclimatize workers** - The human body needs time to adapt to working in the sun and heat, and this is particularly important for new employees. Acclimatization is a physiological process where the body adapts to the type of work and ambient heat levels, improving the circulation system and salt balance. It usually takes about two weeks, although individuals acclimatize at different rates. Everyone, regardless of their age or physical condition needs time to acclimate to heat, so don't assume that someone in good physical shape will naturally be more heat tolerant.

**Adjust for weather conditions and type of work** - Work assignments should take into account weather, workload, the physical condition of the worker, and if special protective clothing will be worn. Watch weather forecasts and monitor conditions at the work site, and then adjust the job accordingly. Assign tasks based on ability, acclimatization, and general health. Schedule work during cooler hours of the morning and evening, and postpone strenuous jobs during unseasonably hot weather. Because pesticide application requires protective clothing that can rapidly create heat stress, schedule this work for early in the morning or late in the evening. Schedule frequent water and rest breaks and provide shade.



OSHA QUICK CARD™

Protect Yourself
**Heat Stress**

When the body is unable to cool itself by sweating, several heat-induced illnesses such as heat stress or heat exhaustion and the more severe heat stroke can occur, and can result in death.

**Factors Leading to Heat Stress**

High temperature and humidity; direct sun or heat; limited air movement; physical exertion; poor physical condition; some medicines; and inadequate tolerance for hot workplaces.

**Symptoms of Heat Exhaustion**

- Headaches, dizziness, lightheadedness or fainting.
- Weakness and moist skin.
- Mood changes such as irritability or confusion.
- Upset stomach or vomiting.

**Symptoms of Heat Stroke**

- Dry, hot skin with no sweating.
- Mental confusion or losing consciousness.
- Seizures or fits.

**Preventing Heat Stress**

- Know signs/symptoms of heat-related illnesses; monitor yourself and coworkers.
- Block out direct sun or other heat sources.
- Use cooling fans/air-conditioning; rest regularly.
- Drink lots of water; about 1 cup every 15 minutes.
- Wear lightweight, light colored, loose-fitting clothes.
- Avoid alcohol, caffeinated drinks, or heavy meals.

**What to Do for Heat-Related Illness**

- Call 911 (or local emergency number) at once.

While waiting for help to arrive:

- Move the worker to a cool, shaded area.
- Loosen or remove heavy clothing.
- Provide cool drinking water.
- Fan and mist the person with water.

For more complete information:
OSHA Occupational Safety and Health Administration
U.S. Department of Labor
www.osha.gov (800) 321-OSHA

OSHA 3154-07R-05

*Figure 1 - A wide variety of training aids and posters are available from the Occupational Health and Safety Administration (OSHA) of the US Department of Labor.*

**Establish a drinking water program** - Dehydration is the primary cause of heat-related illnesses, so replacing water loss through sweating is the single most important factor of a heat safety program. The human body contains about 5 quarts (4.7 l) of blood (mostly water), which helps cool the body by conducting heat produced by the muscles to the skin surface. The amount of water that is needed to prevent dehydration varies between individuals, and is affected by temperature, humidity, and the type of work. An average person requires 6 to 10 quarts (5.7 to 9.5 l) of water on a hot summer day. Because the feeling of being thirsty always lags behind actual dehydration, workers should be trained to drink some water before starting the job, and then drink more "by the clock". That's at least one cup (about 0.25 l) of water every 30 minutes under average conditions, and more when temperatures increase (Figure 2). Chugging water to quench an intense thirst makes no more sense than pouring water on an already wilted plant. Water temperature should be cool but not cold, and plain water is generally preferable to other types of liquid, including sports drinks.

Salt tablets should not be taken with water. The average American diet contains sufficient salt for acclimatized workers even when sweat production is high. If, for some reason, salt replacement is required, the best way to compensate for the loss is to add a little extra salt during meals (NIOSH 1986)

**Make proper clothing a condition of employment** - Heavy clothes trap heat near the body and dark colors absorb the most sunlight so encourage workers to wear light-colored, loose-weave cotton garments. Hats or visors should be required when working outdoors.

# References and Sources of Additional Information

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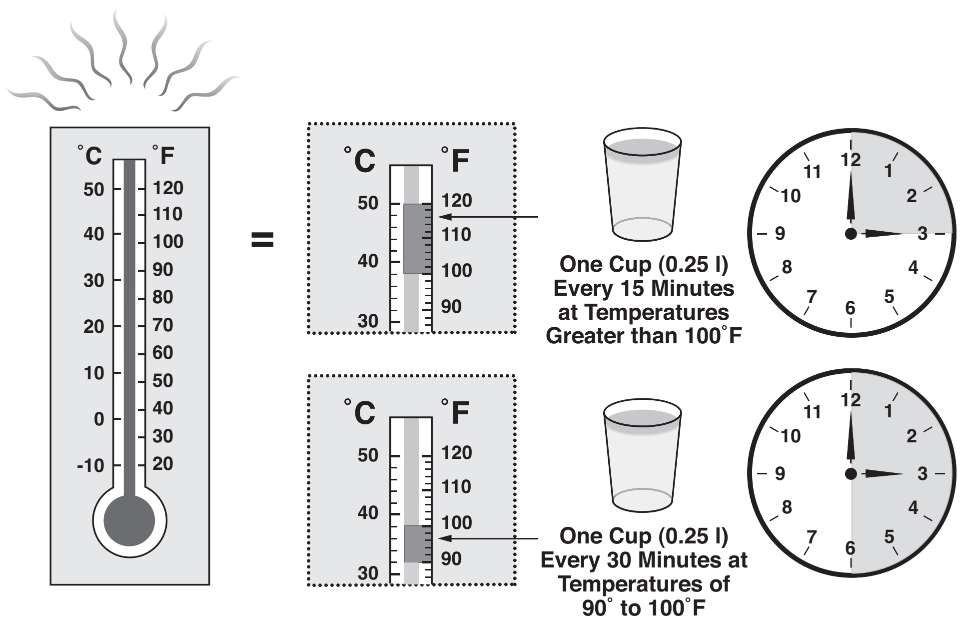


*Figure 2 - Workers should be trained to drink some water before starting the job, and then drink more "by the clock". That's at least one cup (0.25 l) of water every 30 minutes under average conditions, and more when temperatures increase.*

# Using Organic Fertilizers in Forest and Native Plant Nurseries

**by Thomas D. Landis**

Most fertilizers were organic until the early 20th century when the Haber Process allowed conversion of the abundant nitrogen gas in our atmosphere into ammonia, which can then be chemically converted into a vast array of synthetic fertilizers (Wikipedia 2011a). Organics such as animal manure and compost were the primary fertilizers mentioned in the first USDA Forest Service nursery manual (Tillotson 1917) but, after the Second World War, the new manmade fertilizers became predominant. Statistics show that, in the early 1900s, 91% of nitrogen fertilizers were organic but, by the 1950s, that percentage had dropped to 3% (Jones 1982). In recent decades, however, organic farming continues to increase in popularity and many new organic fertilizers have become available. Most forest and native plant nurseries haven't used organic fertilizers recently so I wanted to make sure that you were aware of their potential.

## What is an Organic Fertilizer?

When I started to gather information for this project, I just assumed that someone in agriculture or horticulture had already addressed this subject and that I could just modify their information for our purposes. Not really. In fact, standard references such as Fertilizers and Soil Fertility (Jones 1982) or the Western Fertilizer Handbook (California Plant Health Association 2002), offered no practical definition for organic fertilizers and only contained a couple of paragraphs on organic amendments After spending days researching the topic I think that I know why: organic fertilizers are a very complicated and confusing subject.

Part of the confusion comes from terminology. As you probably remember from college chemistry, an "organic" compound is one that contains carbon but this really doesn't have anything to do with organic fertilizers. When dealing with food production, the term organic has a legal definition and a private, non-profit organization known as the Organic Materials Review Institute evaluates fertilizers for certified organic food production (OMRI 2011). Because we are not growing edible plants, however, forest and native plant nurseries are not bound by these regulations. So, let's discuss modern organic fertilizers and evaluate how they might be used to grow forest and native plant crops.

## Types of Organic Fertilizers

For the purposes of our discussion, organic fertilizers are materials that are both naturally-occurring and have not been synthesized. I have divided organic fertilizers into two general categories: animal or plant wastes, and natural minerals (Figure 1).

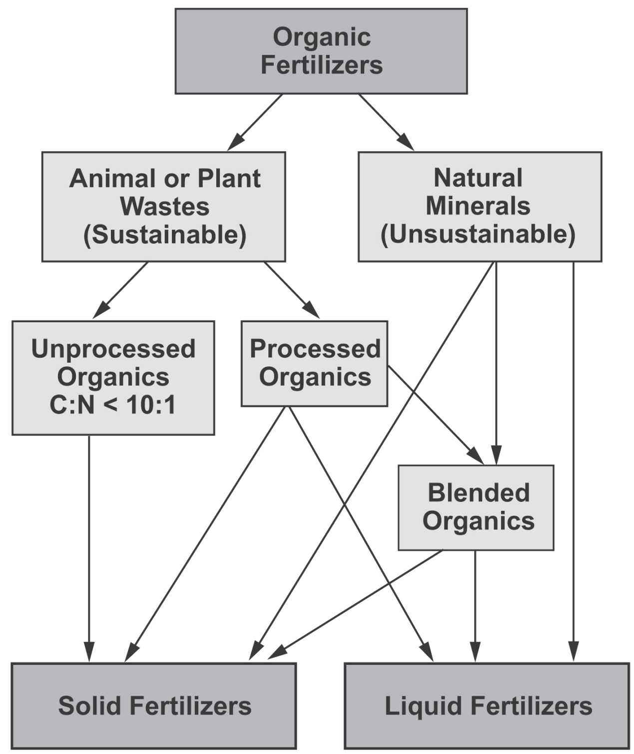


*Figure 1 - The terminology of organic fertilizers is complicated and the various types can best be illustrated with a flow chart.*

**Animal or Plant Wastes.** These are the materials that most people consider organic fertilizers and can be applied to crops directly or developed into a wide variety of other processed fertilizers. One of the real attractions of these types of organic fertilizers is their use is sustainable and has a positive environmental impact.

**Unprocessed Organics**. This category is by far the largest and most complicated because many types of organic matter have been used as fertilizers, including animal manure, sewage sludge, peat moss, hopwaste,

*Figure 2 - Unprocessed organic matter, like this mushroom compost, is the most familiar type of organic fertilizer. Any organic material with a carbon-to-nitrogen ratio of less than 10:1 is considered a fertilizer.*

and a myriad of composts (Figure 2). If you'll remember from the article on carbon-to-nitrogen ratios in the last Forest Nursery Notes issue (Landis 2011), organic materials with a C:N less than 10:1 are considered to be fertilizers. Evaluating the fertilizer benefits of unprocessed organics is extremely difficult because these materials have many other beneficial effects on crop growth besides simple nutrition (Benzian 1965). For example, animal manure can be a source of all the essential plant nutrients but organic matter also improves the tilth, aeration, and water-holding capacity of the soil, and also stimulates beneficial soil microorganisms. Composted manure is not recommended for organic vegetable crops due to concerns about leaching of high levels of phosphorus, one of the leading causes of water eutrophication (Sharpley and others 1994). Although raw organic materials such as manure and compost were considered the "most useful fertilizers" in historical times, they are not common in contemporary forest nurseries (Armson and Sadreika 1979; van den Driessche 1984). Green manure crops, which have been used for centuries to capture mineral nutrients, are also not recommended for forest nurseries because of concerns about disease pathogens (McGuire and Hannaway 1984). For those interested in more information on using raw organic materials in bareroot nurseries, a wealth of published information is available (Chaney and others 1992; Rose and others 1995; Card and others 2009; Colorado State University Extension 2011).

**Processed Organics**. This category includes any organic material that has been processed in some manner before used as a solid or liquid fertilizer (Figure 1). Solid fertilizers include many types of composts, bloodmeal, bone meal, sewage sludge, and other more exotic materials like feather meal and kelp extracts. From a sustainability standpoint, almost any waste organic matter can be composted and the composting process was discussed in the Summer 2008 issue of Forest Nursery Notes (Landis and Khadduri 2008). Although processed organic fertilizers are common in organic farming, they haven't been widely used in forest or native plant nurseries. However, many new brands of processed organic fertilizers are now available. Major horticultural supply firms such as A.H. Hummert (www.hummert.com) carry the line of Bradfield Organics® fertilizers, which are marketed for specific crops such as lawns or vegetables. For example, their Luscious Lawn Corn Gluten (9-0-0) Organic Fertilizer is made from the wet milling processing of corn and comes in an easy-to-apply granular formulation. Interestingly enough, corn gluten has also been shown to have preemergent herbicidal effects on some grasses (Christians 2011).

**Natural Mineral Fertilizers.** This second major category of organic fertilizers includes minerals and some organic materials that come directly from the earth. Like all types of mining, obtaining these fertilizers is an extractive process and unsustainable in the long term (Figure 1). Still, we consider them as organic fertilizers in this article since they are not chemically synthesized and are components in many blended organic fertilizers. Because mining is not a sustainable process, the use of these fertilizers is restricted in some types of organic farming (Wikipedia 2011a).

**Guano** - Guano is the accumulated excrement of seabirds or bats and has been used as a fertilizer since the Incas collected it along the coast of Peru hundreds of years ago. It is an excellent fertilizer due to high levels of phosphorus and nitrogen and does not have any noticeable odor. The best guano deposits are found in very dry climates because rainwater leaches out the nitrogen, and therefore desert coastal areas or islands are ideal. Large populations of seabirds use these locations as their land base for resting and breeding so, after many centuries, guano deposits can exceed several meters in depth. Before the development of synthetic fertilizers, guano was one of the primary sources of fertilizer and wars have even been fought to control the supply (Wikipedia 2011b). One of the largest mining operations occurred on the small South Pacific island of Nauru where centuries of deposition by seabirds created vast reserves of guano. Although very profitable, the mining operation had a relatively short lifespan, which has had severe economic consequences on the local population. Following its independence in 1968, Nauru possessed the highest GDP per capita in the world but, due to poor financial management, the country now is economically dependent on Australia (US CIA 2011).

**Rock phosphate** - Natural deposits of fluoroapatite are the raw material of most phosphate fertilizers and are currently mined in North Africa, the former Soviet Union, and in the several states in the US including Florida, Idaho, Montana, Utah, and Tennessee. The raw ore contains from 14 to 35% $P_2O_5$, and is processed by grinding and washing into a fine granular fertilizer. Rock phosphate is very insoluble in water so isn't used in soluble formulations, but does made a decent slow-release granular fertilizer (California Plant Health Association 2002). Because of its low solubility, rock phosphate has been recommended as an ideal phosphorus fertilizer to encourage mycorrhizal development (Amaranthus 2011).

**Sodium nitrate** - This is a naturally occurring salt ($NaNO_3$), which is commonly known as Chilean or Peruvian saltpeter due to the large caliche mineral deposits found in both countries. It was first introduced as a fertilizer in Europe in the early 1800s although its primary use was for munitions. Later that century, sodium nitrate became so valuable that a war was waged between Chile, Peru, and Bolivia to control the most valuable deposits (Wikipedia 2011c). In the early 1900s, sodium nitrate was one of the few mineral fertilizers mentioned for forest nursery crops (Tillotson 1917), and a top dressing of sodium nitrate was found to stimulate slow-growing species such as Engelmann spruce (*Picea engelmannii*) at the Savenac Nursery in Montana (Wahlenberg 1930). Organic farmers have long favored sodium nitrate as the fastest acting organic fertilizer for top dressing during the growing season (Hartz and Johnstone 2006). Although this fertilizer has been used in organic farming for many years, several organic certifying agencies conclude that mined mineral fertilizers conflict with basic organic principles. For example, the USDA National Organic Program currently restricts use of sodium nitrate to no more than 20% of total annual nitrogen and requires that growers phase out its use over time (Gaskell and Smith 2007).

**Magnesium sulfate** - Another naturally occurring mineral is the well known Epsom salts or Kieserite. Although more widely used for medicinal purposes, magnesium sulfate ($MgSO_4$) is a very soluble source of

A

B

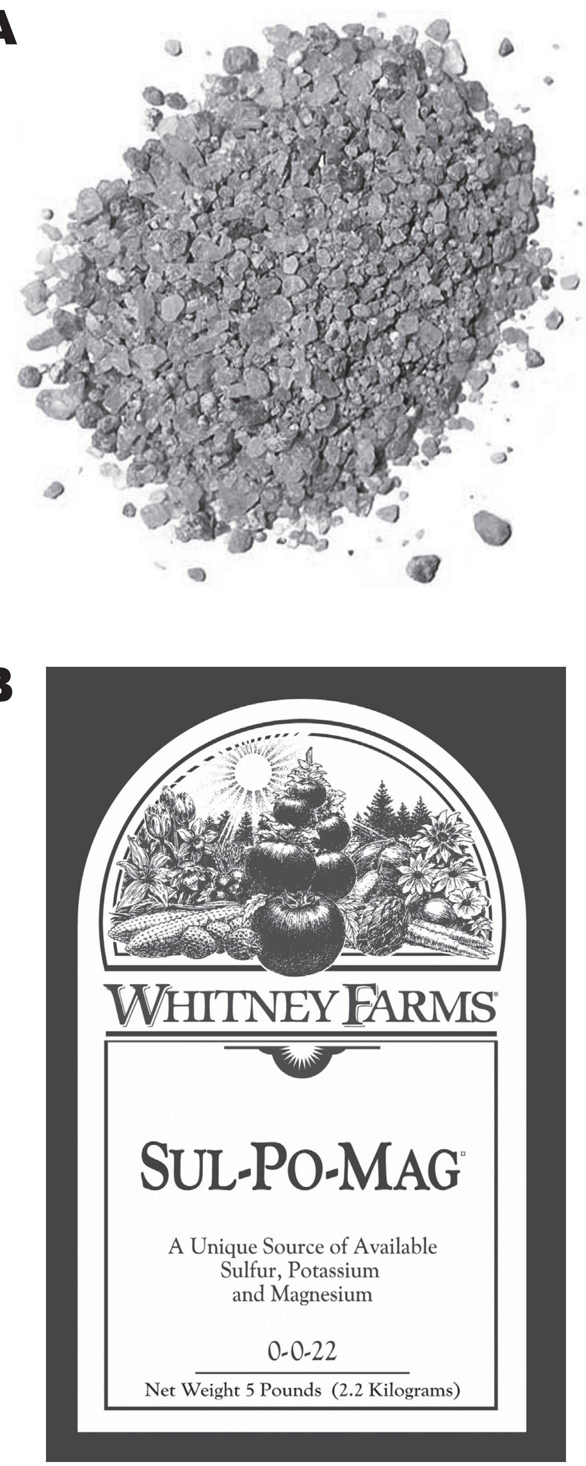


*Figure 3 - Natural minerals, such as sulfate of potash-magnesia (A), are mined from the earth and are marketed as organic fertilizers (B) because they are naturally occurring and not synthesized by humans.*

the secondary macronutrients magnesium and sulfur and has been used in the formulation of liquid fertilizers for container tree nursery crops (Landis and others

1989).

**Sul-Po-Mag** - This naturally occurring mineral is technically known as sulfate of potash-magnesia or langbeinite (Figure 3A), and is mined from marine evaporite deposits (California Plant Health Association 2002). It was originally discovered in Germany and contains soluble nutrients in the following ratio: 22% potassium, 22% sulfur and 11% magnesium (Figure 3B). Another common trade name is K-Mag Natural and this product is ideal for supply potassium and sulfur without any accompanying nitrogen. Sul-Po-Mag is a common component in many blended organic fertilizers.

A


B

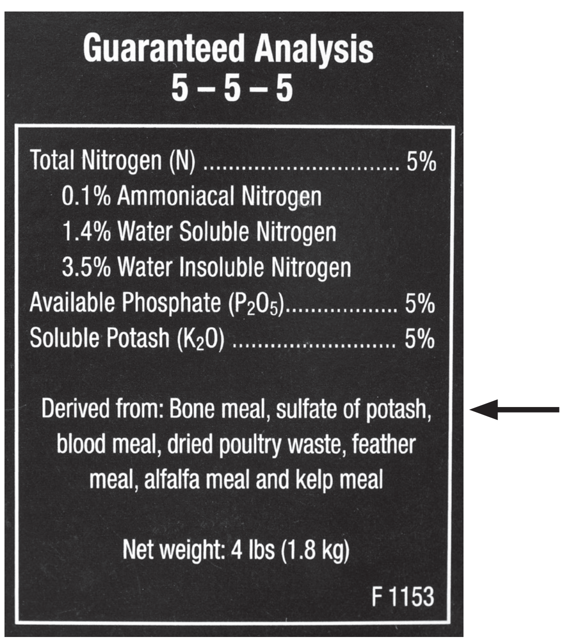


*Figure 4 - Blended organic fertilizers (A) contain both processed organics and natural minerals, such as sulfate of potash (B).*

**Blended Organics.** This is the newest category of organic fertilizers, and products contain a mixture of processed organic plant or animal wastes supplemented with natural minerals (Figure 1). Blended organics aren't discussed in any fertilizer publication that I could find, so I created this category myself. Therefore you won't find this term in the literature, but you can identify blended organics by checking fertilizer labels. The best source of information on all type of organics is the internet. Many horticultural suppliers, such as Black Gold® (www.blackgold.bz/), are getting into the organic fertilizer market. For example, they offer an all-purpose organic fertilizer (5-5-5), which contains processed organics including bone and blood meal but also potassium sulfate, which is a natural mineral (Figure 4A). Be sure to read the label of ingredients before purchasing a blended organic fertilizer because they can vary considerably between products. If you want an organic fertilizer made from sustainable materials, be aware that many products contain natural minerals (Figure 4B).

**Solid Fertilizers.** Powdered or granular fertilizers can be derived from unprocessed organics, processed organics, natural minerals, or blended organics (Figure 1). Due to these highly variable sources, it's best to just discuss a couple of examples. Milorganite© (www.milorganite.com), which is manufactured from processed sewage sludge from Milwaukee, WI. This granular fertilizer was used in several USDA Forest Service nurseries in the past with good success, and the pros and cons of using Milorganite© at Wind River Nursery in Washington State are well documented (Dutton 1977). Biosol® (6-1-3) is a blended organic fertilizer developed from the fermentation of soybean and cottonseed meal, and is a by-product of the pharmaceutical manufacture of pencillin. To balance the nutrient content, Biosol® is supplemented with Sul-Po-Mag. Although it has never been used in forest or native plant nurseries to my knowledge, Biosol has been successfully used as a fertilizer in native plant restoration projects (Claassen and Carey 2007).

**Liquid Fertilizers.** This category of organic fertilizers can be derived from processed organics, natural minerals, or blended organics (Figure 1). One of the first mentions of liquid organic fertilizers was the use of a solution of sodium nitrate as a top dressing to stimulate conifer seedling growth in a forest nursery (Wahlenberg 1930). Again, most of these products are so new that they aren't discussed in standard fertilizer texts, and the best and most current information on liquid organic fertilizers can be found on-line. Grow-Organic (www.groworganic.com/) lists liquid organic fertilizers that are developed from a variety of sources including processed fish waste, soybean meal, kelp, and even recycled foodstuffs. Many products are targeted to specific crops but other are more general. For example, Earth Juice Grow (2-1-1) is derived from bat guano, kelp, sulfate of potash, feather meal, oat bran, blood meal, and steamed bone meal (www.groworganic.com/fertilizers). I could find no published information on growing forest or native plant crops with liquid organic fertilizers, but some work has been published on vegetable crops (Gaskell and Smith 2007). They conclude that liquid organic fertilizers typically lack uniformity because they are subject to settling and microbial breakdown. The nutrient composition reported for the liquid organic fertilizers includes organic material in suspension that should be filtered to avoid plugging in fertigation systems. Because of this variability and the fact that application rates are typically given as simple dilutions, it would be almost impossible to conduct systematic research trials.

# Comparison of Organic vs. Synthetic Fertilizers

Because of the variability involved, it's difficult to compare organic and synthetic fertilizers but some generalizations can be made (Table 1):

| Factor | Organic | Synthetic |
|---|---|---|
| Mineral Nutrient Analysis | Low | High |
| Range of Mineral Nutrients | All | One to many |
| Nutrient Release Rate | Slower | Faster |
| Compatibility with Beneficial Microorganisms | Yes | At low levels |
| Cost | More | Less |
| Handling | Bulkier | More concentrated |
| Ecological Sustainability | Yes | No |
| Water Pollution Risk | Low | High |
| Other Benefits | Improves soil texture, encourages soil microbes | Better for research |

*Table 1 - Comparison of attributes of organic and synthetic fertilizers.*

**Mineral Nutrient Analysis**. Fertilizer analysis means the N-P-K percentages that must be listed on the label. Almost all organic fertilizers have relatively low analysis (Figure 4B) and the nitrogen percentage is rarely above 15% and more typically in the range of 5 to 10%. Higher analysis products are often supplemented with natural minerals such as sodium nitrate.

**Range of Mineral Nutrients**. On the other hand, one of the major benefits of organic fertilizers is that they contain a full complement of all 13 mineral nutrients. Most synthetic fertilizers, on the other hand, contain one or only a few mineral nutrients, which makes it easier to correct specific mineral deficiencies. Some of the newest synthetic fertilizers have been specially formulated to contain the full range of mineral nutrients.

**Nutrient Release Rate**. Plants take up mineral nutrients from applied fertilizers in a two-step process. First, the substance must be dissolved in water in the soil solution. This is much easier and faster for synthetic fertilizers, many of which are formulated to be soluble. Unprocessed organic fertilizers, such as manure, must first be broken down into smaller particles by soil microorganisms and then converted to a soluble form. Processed organics, such as compost, must still undergo microbial decomposition before their nutrients are available to plants. Some of the newer, highly processed organics are already soluble.

The second step in plant uptake is when the dissolved ions are absorbed into the plant roots. Most plant nutrients are taken up from the soil solution as ions, which have either a positive electrical charge (cations), or are negatively charged (anions). Some exceptions occur. Boron is taken up as a entire molecule (boric acid) and some metal micronutrients, such as iron and manganese, can be taken up as organic complexes known as chelates (Roy and others 2006). One of the advantages of organic fertilizers is that micronutrients are already organically chelated. Considerable research has been directed as to determine whether organic nitrogen molecules can be taken up by plants directly, and limited uptake of organic nitrogen does occur. A recent comprehensive literature review states that, although labeled amino acids have proven that plants can take up organic nitrogen, direct evidence that this constitutes significantly to plant nutrition is lacking (Nasholm and others 2009).

A recent research trial provides a good illustration of the differences in nutrient uptake between organic and synthetic fertilizers (Claassen and Carey 2007). The

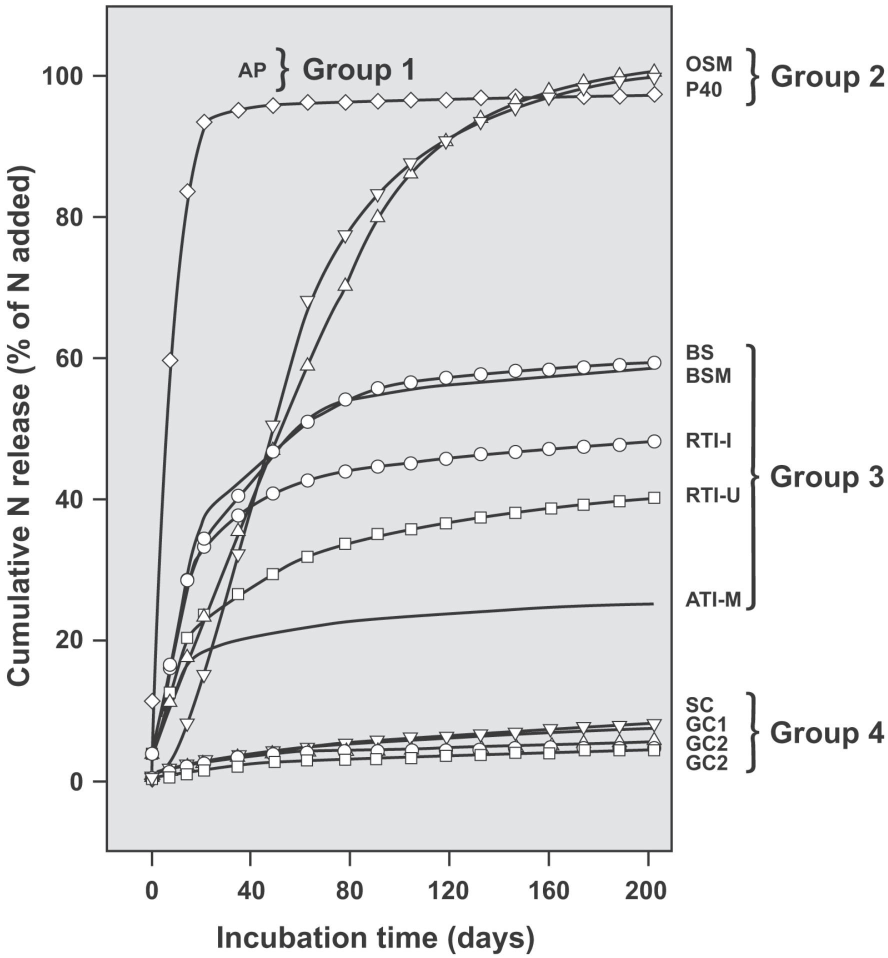


*Figure 5 - Nutrient release rate is one of the most important considerations when comparing fertilizers.*

*This test shows that soluble synthetic fertilizers (Group 1) have the most rapid release of nitrogen, controlled release synthetic fertilizers (Group 2) release nitrogen slower but both synthetics have similar final release rates.*

*The nitrogen release rates of organic fertilizers (Groups 3&4) are extremely variable with the municipal composts (Group 4) being the slowest with less than 10% nitrogen released by the end of the trial (modified from Claassen and Carey 2007).*

| Code | Fertilizer Type | Nitrogen % | Source |
|---|---|---|---|
| | **Synthetic Fertilizers** | | |
| AMP | Ammonium phosphate | 16.0 | Soluble 16-20-0 fertilizer |
| OSM | Osmocote® | 18.0 | Resin coated controlled release fertilizer |
| P40 | Polyon PCU 40® | 40.0 | Polyurethane coated controlled release fertilizer |
| | **Organic Fertilizers** | | |
| BSM | Biosol Mix® | 6.5 | Fungal & bacterial pharmaceutical waste |
| BS | Biosol® | 7.0 | Fungal pharmaceutical waste |
| GC1 | Gilton Compost #1 | 1.2 | Yard waste compost |
| GC2 | Gilton Compost #23 | 1.3 | Yard waste compost |
| GC3 | Gilton Compost #3 | 1.2 | Yard waste compost |
| RTI+ I | RTI Nova Organics™ + IBDU | 7.7 | Composted biosolids + IBDU mixture |
| RTI+M | RTI Nova Organics™ + melamine | 8.0 | Composted biosolids + melamine mixture |
| RTI+U | RTI Nova Organics™ + ureaformaldehyde | 8.0 | Composted biosolids + ureaformaldehyde mixture |
| SC | Sacramento Municipal Compost | 1.5 | Yard waste compost |

*Table 2 - Nitrogen release rates of some common synthetic and processed organic fertilizers (modified from Claassen and Carey 2007).*

nitrogen release rates of a variety of organic fertilizers was compared to a synthetic granular fertilizer, ammonium phosphate, and two plastic-coated controlled release fertilizers (Figure 5). The organics were different brands of processed organic wastes, which had been composted or otherwise processed and are commercially available as fertilizers (Table 2). These fertilizer treatments were aerobically incubated in artificial media in laboratory chambers and in field soil at a revegetation site for 200 days. At the end of the trial, the nitrogen release rates naturally separated into 4 groups. The synthetic granular ammonium phosphate had by far the faster release rate, whereas the two controlled release synthetic fertilizers constituted the second group. These 3 synthetic fertilizers released more than 95% of their nitrogen by the end of the trial. The nitrogen release rates of the organic fertilizers varied considerably among products but all were significantly slower than the synthetic fertilizers. At the end of the test period, the final release percentages for the organics ranged from less than 10% to around 60%. These results emphasize the critical importance of knowing the nutrient release rates of any fertilizer that you are using because they will have a major effect on crop growth and development.

**Compatibility with Beneficial Microorganisms**. One of the most underappreciated benefits of organic fertilizers is that they promote the growth of beneficial soil microorganisms including mycorrhizal fungi and nitrogen-fixing bacteria. A wealth of published research has shown that high levels of synthetic fertilizers, especially nitrogen and phosphorus, inhibit the establishment and development of mycorrhizal fungi. This is particularly serious in the soilless growing media of container seedlings where high levels of soluble synthetic fertilizers are the norm (Castellano and Molina 1989). Conversely, because organic fertilizers release nutrients more slowly and also improve soil conditions, they favor beneficial microorganisms.

**Cost**. Organic fertilizers are typically several times more expensive per nutrient compared to synthetic products. For example, the cost per unit of nitrogen for organic fertilizers was found to be higher than synthetic nitrogen fertilizers, such as urea or ammonium nitrate (Gaskell and Smith 2007). A mathematical comparison of fertilizer costs is difficult because each contains different percentages of nutrients and values must be expressed on a per weight or per volume basis. In one study, feather meal, blood meal, and guano were found to be one-fourth the cost of fish-based organic fertilizer (Hartz and Johnstone 2006). Although they are more expensive strictly on a per nutrient basis, both processed and unprocessed organic fertilizers provide many other benefits that are hard to valuate, including adding organic matter and stimulating soil microorganisms. Synthetic fertilizers also have hidden costs, such as the carbon emissions during their manufacture and the ecological impacts of increased water pollution. In the final analysis, however, fertilizers are only a very small percentage of the cost of producing nursery stock so price should not be a deciding factor on whether to use organic fertilizers.

**Handling and Application**. Due to their bulkiness and low nutrient analysis, unprocessed organics are more expensive to ship, store, and apply compared to high analysis synthetic fertilizers. This is particularly true of manure and other plant and animal wastes. Conversely, synthetic fertilizers are more uniform in quality, have a high nutrient analysis per unit weight and are much easier to apply to crops. This is particularly true of container nurseries; for example, there's no good way to apply unprocessed organics to container nursery crops.

**Ecological Sustainability and Water Pollution**. One of the real benefits of organic fertilizers is that they are kind to the environment and many can be obtained from recycled materials — compost and municipal sludge are prime examples. Not only can nurseries recycle cull seedlings, weeds, and other organic materials through composting, but they can serve as places for municipalities to recycle leaves, yard clippings, and other such wastes that would otherwise go to landfills (Morgenson 1994). Because nursery crops are not consumables, they can accept sewage sludge and even some industrials wastes. Nurseries can generate cooperative agreements with municipalities or industries to reduce their composting costs while generating an environmentally beneficial source of plant nutrients (Rose and others 1995).

Another environmental advantage of organic fertilizers is that their nutrients are much less susceptible to leaching than those from synthetic fertilizers. Although this doesn't apply to natural minerals, both processed and unprocessed organic fertilizers release their nutrients slowly and in a form that remains in the soil profile. Synthetic fertilizers often release their nutrients much faster than plants can use them and the excess nutrients leach into groundwater, resulting in water pollution. This is especially serious with fertilizers containing the anions nitrate and phosphate, which are not adsorbed on the cation exchange sites in the soil and

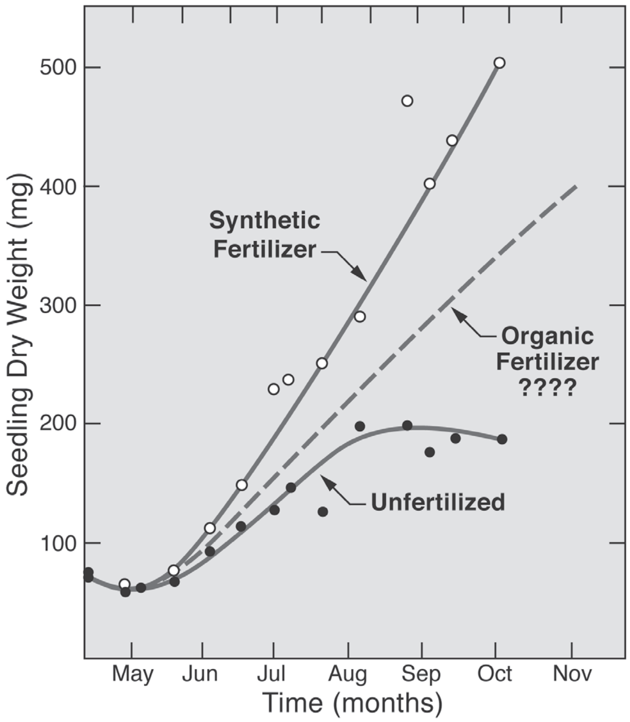


*Figure 6 - The growth benefits of synthetic fertilizers have been well established (solid lines) but it would be interesting to conduct growth trials between organic and synthetic fertilizers (modified from Armson and Sadreika 1979).*

rapidly leach down to pollute groundwater (Landis and others 1992). Sewage sludge is one organic fertilizer that can cause water pollution is sewage sludge when it is improperly applied. To minimize this risk, guidelines on sludge application in bareroot forest nurseries have been developed (Rose and others 1995).

**Applications in Forest & Native Plant Nurseries.** Now that we have evaluated the pros and cons of organic fertilizers and compared them to synthetic fertilizers, let's review how they can be used in forest and native plant nurseries. Growers need to have ethical or ecological reasons for wanting to use organic fertilizers because quality crops of forest trees and other native plants have been grown for half a century using only synthetic fertilizers.

Because no formal research has been conducted on the use of organic fertilizers with forest and nursery crops, it is difficult to make comparisons with synthetic fertilizers. Of all the various methods used to evaluate the effects of fertilizers, plant growth rates and quality are the true test. With the increased interest in organic farming, numerous examples exist showing that organic fertilizers can be used effectively. The benefit of synthetic fertilizers to the growth of forest tree seedlings has been well established, but it would be interesting to see direct comparisons between organic fertilizers and synthetics (Figure 6).

**Using organic fertilizers in bareroot nurseries** - Because plants are grown in large volumes of field soil, bareroot nurseries have the greatest potential for using all types of organic fertilizers. In particular, unprocessed materials like manure and sewage sludge can provide both a base level of mineral nutrients and a source of valuable organic matter to maintain soil tilth. Bulk organics should be applied as soon after crops are harvested to allow time for decomposition. Application rates vary between the different materials and should be determined by operation trial due to differences in soil type and nursery climate; specific rates for Milorganite®, sewage and fish sludge have been reported for forest nurseries (Dutton 1977; Rose and others 1995). Due to the slow release rates of most organic fertilizers, it may make sense to institute a combination of both organic and synthetic fertilizers. The organics could provide a base level of nutrients and then synthetics could be applied during the season based on crop growth and development.

**Using organic fertilizers in container nurseries -** Because container plants are typically grown in artificial growing media, it would be difficult to incorporate either processed or unprocessed organic fertilizers. This is particularly true for smaller volume containers but organics could be used in large ones. Composts could be incorporated into growing media but they must be fully mature to prevent any incidental toxicity. Many container plants are grown with only soluble fertilizers and natural mineral fertilizers are already being used in the formulation of soluble fertilizers. One of the challenges for converting to organics would be to achieve the high soluble nitrogen levels that are used to achieve the rapid growth rates in greenhouse crops. Although the number of highly soluble organic fertilizers are very limited, sodium nitrate would be suitable and Sul-Po-Mag and Epsom salts would provide other macronutrients. In a recent test with a grass test crop, 3 brands of liquid organic fertilizers produced growth similar to conventional synthetic fertilizers. The authors concluded that their rapid nitrogen availability was much faster than other organic fertilizers but the solutions may have to be filtered before use in fertigation systems (Hartz and others 2010).

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# The Importance of Crop Growth Monitoring

**by Thomas D. Landis**

Coaxing plants to grow the way we want them to grow is the essence of nursery culture, and growth records from past seasons are one of a grower's best tools to accomplish this goal. Unfortunately, many nurseries only measure their crops during the annual inventory and before harvest. While absolutely necessary to good nursery management, inventory measurements don't give any hints about how the plants reached that size. The only way to really know how your crops perform is to monitor their growth during the season. However, in a survey of bareroot nurseries from the 1980s, less than one-third kept crop growth records (Royce 1984).

I don't know how many times I've been asked for my opinion about why a crop isn't growing up to expectations, but when I ask the nursery manager for some growth records, they don't have any. Growth records are like a road map — if you don't have a reliable map, you probably won't get where you want to go. So, I thought it might be a good idea to review how plants grow and what type of measurements a prudent nursery manager should be taking.

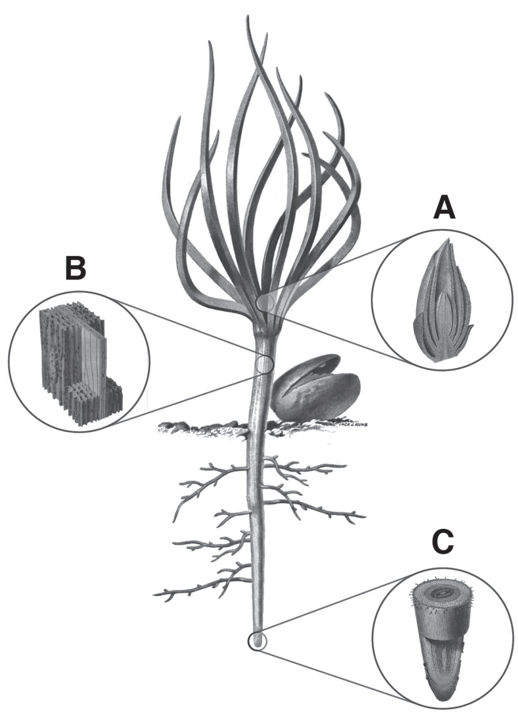


*Figure 1 - Woody plants grow in size from 3 different meristems: shoot grow in height from the terminal meristem (A), woody stems and roots grow in diameter from the lateral meristem (B), and roots grow outward from the root tips (C).*

## How Plants Grow

Woody plants grow from 3 different meristems: the terminal bud, the lateral meristem, and the tips of the roots (Figure 1). By comparison, grasses grow from basal or intercalary meristems, which are found at the base of the plant. For the rest of this discussion, however, we'll be discussing shoot growth of woody plants. We'll cover root growth in the next issue.

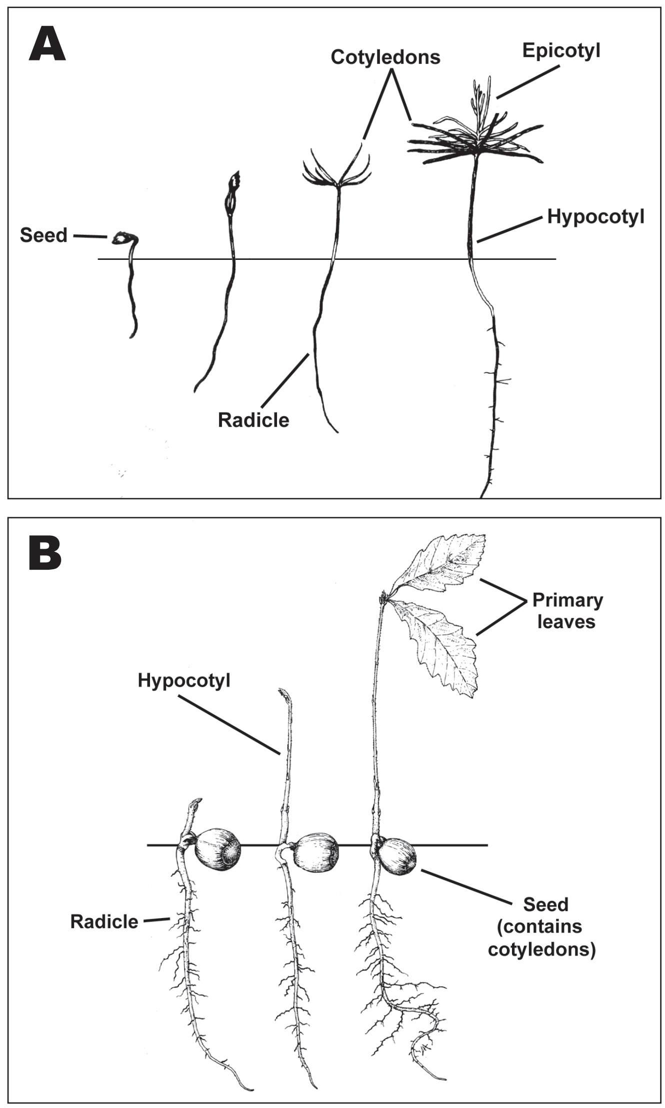


*Figure 2 - In epigeous germination (A), the cotyledons carry the seedcoat above the surface of the soil or growing medium whereas, in hypogeous germination (B), both the cotyledon and seedcoat remain below the surface (modified from Schopmeyer 1974).*

**Seed germination and emergence**. During seed germination, the root system begins growth first, when the radicle penetrates the seed coat and begins to extend downward under the influence of gravity (geotropism). After the radicle becomes established in the growing medium, the seedling follows either of two patterns of seed germination (Kozlowski 1971). Most conifers and some broadleafed species exhibit epigeous germination, in which the cotyledons ("seed leaves") are pushed above the surface of the growing medium by the expanding hypocotyl (Figure 2A). Conifer cotyledons carry the seedcoat on their tips to form a "birdcage." Other broadleaved species, such as oaks (*Quercus* spp.), exhibit hypogeous germination in which the cotyledons remain underground while the epicotyl ("shoot") elongates upward and produces primary leaves above the surface of the growing medium (Figure 2B). Some genera, such as *Prunus* spp., contain some species that have epigeous germination and others with hypogeous germination (Grisez and others 2008).

## Shoot Growth Patterns

The shoots of nursery plants grow in two different ways (Powell 1982). Preformed ("predetermined") growth is a result of the expansion of preexisting structures, either those preformed in the embryo for first year shoots or those in terminal and lateral buds in subsequent years. Neoformed ("free") growth, on the other hand, does not depend on any preformed structures and shoots grow directly from the meristems (Figure 3). Some species exhibit both preformed and neoformed shoot growth in a given year, whereas other plant shoots grow either one way or the other. This growth form is genetically determined and cannot be changed by cultural means (MacDonald 1998).

The presence or absence of buds also affects shoot terminology (Kozlowski 1971). The shoots of many temperate zone species, including spruces (*Picea* spp.), form buds at the end of the growing season (determinate shoots) whereas other species, such as junipers (*Juniperus* spp.), do not (indeterminate shoots).

**First Season Shoot Development**. Seedling growth and development is different during the first growing season than in subsequent years because all species exhibit both preformed and neoformed growth (Figure 4). In the first season, the amount of preformed growth is determined by the size of the embryo (which is preformed in the seed), the stored energy in the seed, and the germination environment.

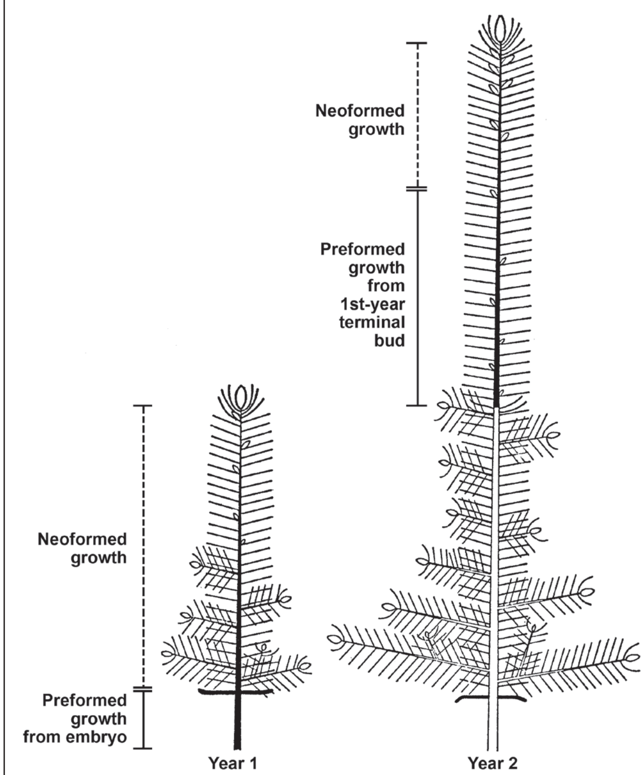


*Figure 3 - Shoot growth can be divided into two categories: one that expands from preexisting structures ("preformed") and one that develops freely during the growing season (neoformed") (modified from Powell 1982).*

Seedlings may or may not develop typical buds at the end of the first growing season. The shoots of determinate species, such as pines (*Pinus* spp.), cease growth and form ("set") terminal buds (Figure 4A&D). Other indeterminate species, such as junipers, never do form true dormant buds (Figure 4B&C). The shoots of pine seedlings, in particular, can look remarkably different during the first growing season, depending on species and growth environment. At least 4 variations in shoot development have been documented with pines (Powell 1982; Thompson 1989). Some pines produce only awl-shaped primary foliage and instead of a true bud form a rosette of needles at the end of the first growing season (Figure 4C). Other pines produce fascicled secondary needles in the axils of the primary needles and form a typical resting bud (Figure 4D). In some temperate zone pines, the time of budset is under strong genetic control and the shoot will not continue to extend even under the ideal growing conditions in a fully controlled greenhouse (Thompson 1989). For example, ponderosa pine (*Pinus ponderosa*) seedlings typically set a firm

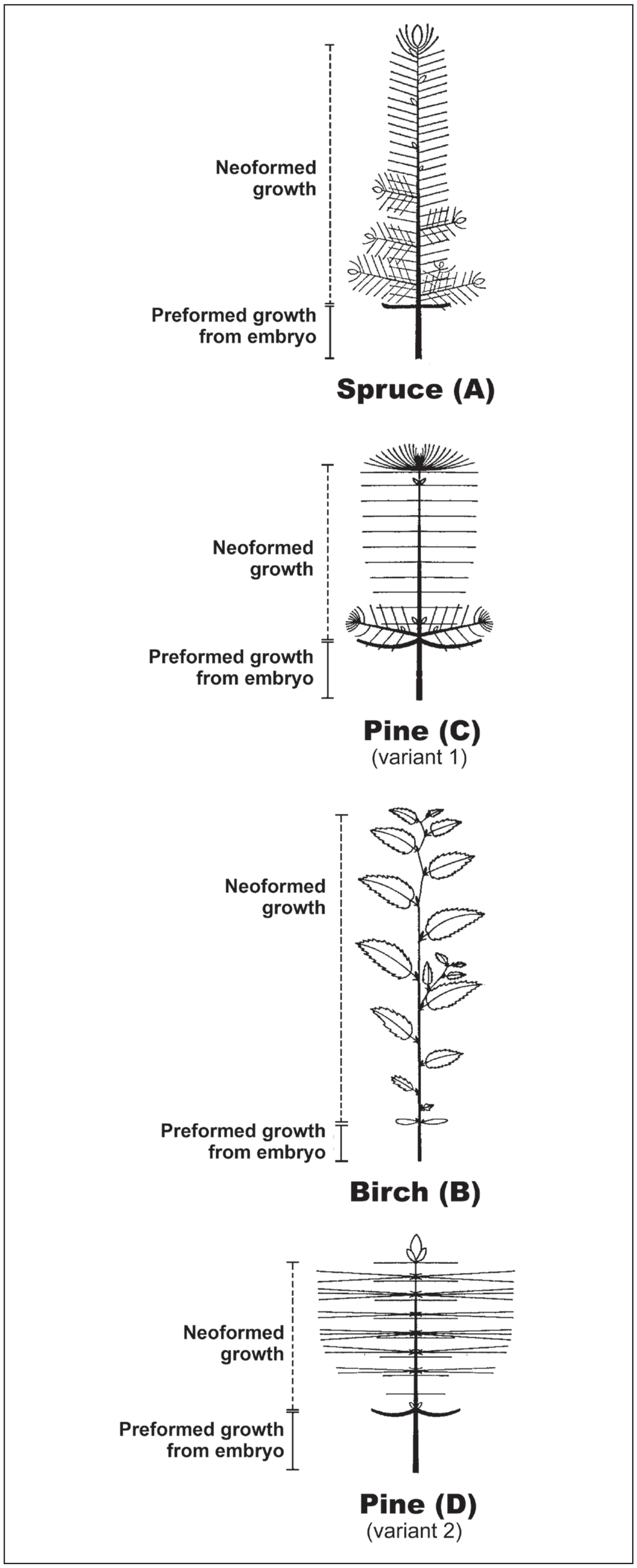


*Figure 4 - First-year seedlings exhibit several different shoot growth patterns in nurseries, depending on the species, propagation environment, and daylength (modified from Powell 1982).*

terminal bud in early July even though they are growing in a greenhouse under long-day photoperiod and high fertilization. In other species, such as blue spruce *(Picea pungens*), shoot growth will continue for over a year under ideal growing conditions before forming a bud (Young and Hanover 1978). Growers must induce budset in these species by radically changing the propagation environment. Ecotypes from northern latitudes are particularly prone to free growth during the long days of summer, and growers need to use extraordinary cultural measures, such as blackout curtains, to promote budset and dormancy. Bud development is particularly important because the presence and size of buds are considered by many customers to be a sign of seedling quality.

The shoot growth of broadleaved species is also variable under nursery conditions. In oaks, a temporary resting bud with scales may form between several growth spurts and a firm dormant bud is only formed at the end of the season. Leaf size and shape will also change between these growth spurts, with those formed later being larger and more deeply lobed (Powell 1982). In other indeterminate species such as birch (*Betula* spp.) and elm (*Ulmus* spp.), however, a true terminal bud never forms (Figure 4C). Instead, the shoot tip aborts at the end of the season and a lateral bud functions as the new terminal bud (Kozlowski 1991).

**Second Season Shoot Development**. If woody plants are held for a second growing season, some species will produce only preformed or neoformed shoot growth, whereas others will produce both types in sequence (Figure 3). Determinate species, such as pines, exhibit preformed growth as their entire second-season shoot extension comes from either preformed stem units in the dormant bud, resting rosettes, or long-shoot buds (Powell 1982). Shoot growth in other indeterminate species including junipers and birches does not depend on preformed structures from the first growing season but consists of only neoformed growth. Spruces and basswood (*Tilia* spp.) seedlings exhibit both preformed and neoformed growth, with the amount of neoformed growth strongly controlled by ecotype (Von Wuehlisch and Muhs 1991).

## Measuring Woody Plant Growth

For nursery purposes, the following morphological attributes are measured (Armson and Sadreika 1979):

**Shoot height** is the vertical distance from the surface of the soil or growing media to the tip of the terminal leader, and is easily measured with a ruler. Although shoot height is easy to measure in the nursery bed or container, it is more challenging to measure on harvested stock because you are no longer sure of the original ground line. One way to determine this is to scrape the outer back and notice where the color of the inner bark changes from white to green, but this is slow and destructive (Mexal and Landis 1990). Other useful techniques are to measure height either 1 cm above the uppermost lateral root (Hodgson and Donald 1980), or approximately halfway between the uppermost lateral root and the cotyledon scar. The top of the seedling shoot can also be difficult to determine, particularly when the seedling is actively growing or with indeterminant species such as cedar (*Thuja* spp.) or juniper. If no obvious terminal bud is present, the measurement should be taken from the slightly swollen part of the shoot tip indicating the position of the terminal meristem.

**Stem diameter**, also called root collar diameter or caliper, is the diameter of the main stem of the seedling just above the ground line and is measured with calipers. Because the stem diameter can change significantly in this area, measurements should be made at a standardized location. Some nurseries specify that stem diameter be measured at the cotyledon scar or 1 cm above the first lateral root (Mexal and Landis 1990). Experience has shown that repeated measurements of stem diameter on the same plant causes stem thickening just due to the additional flexing during the measurement process. Therefore, it's better to measure a sample of plants and calculate an average stem diameter.

**Dry weight** represents the net gain between photosynthesis and respiration and, when monitored over time, gives an excellent index of how fast a plant is growing (Armson and Sadreika 1979). Although dry weight is commonly used for research purposes, the fact that it is time consuming and destructive makes it unpopular in nurseries. In addition, dry weight gain does not distinguish between the type of tissue. Two seedlings could have the same dry weight of roots but one could have a few large woody roots and the other more desirable mix of medium and fine roots.

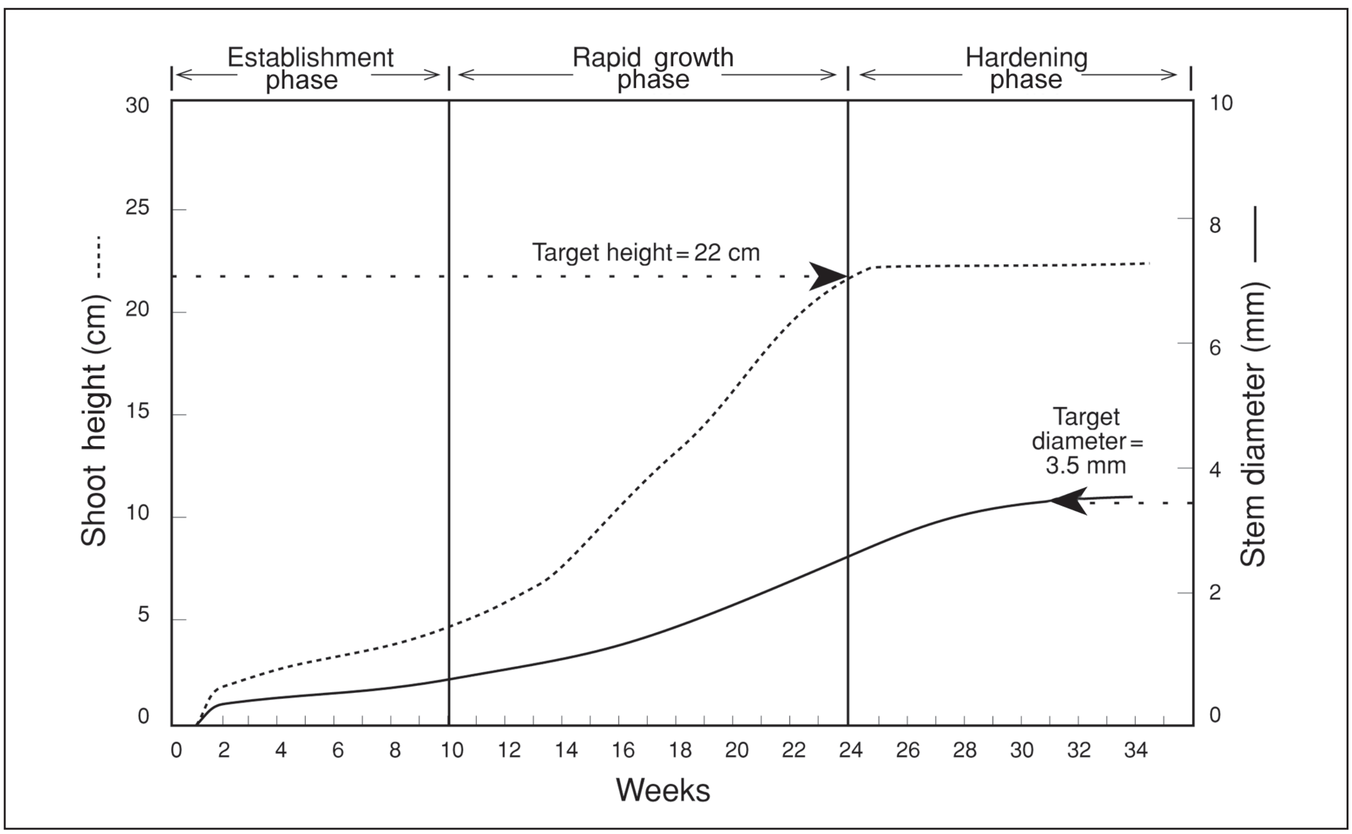


*Figure 5 - The cumulative growth curve for height and stem diameter shows how a crop is progressing compared to target specifications.*

## Analyzing Plant Growth Patterns

The best way to utilize plant growth data is to record it in graphic form as you collect it. This can be as simple as a pencil and graph paper or a complicated as a spreadsheet, which will generate graphs.

Plant growth cycles can be plotted in 2 different ways: cumulative growth and incremental growth. The cumulative growth curve is the most commonly used graphing method and shows seedling dimensions plotted against time throughout the growing season (Figure 5). Total growth curves are useful for showing seedling growth progression relative to the target specifications of shoot height and stem diameter. The relative growth rate is illustrated by the slope of the line—the steeper the slope of the curve, the faster the seedling is growing.

The other, less-common type of growth curve is the incremental growth curve, which plots growth rate, rather than total growth. Incremental growth curves are useful because they reveal growth periodicity patterns during the growing season (Figure 6). Shoot growth of first year crops begins with emergence or with spring bud break for older stock. Stem diameter growth in newly germinated seedlings begins after the vascular cambium develops and starts producing wood cells at about 4 to 6 weeks of age (MacDonald 1998). In older seedlings, stem diameter growth begins early in the spring, slowly increases until it peaks after terminal bud set, and then gradually tapers off until cold weather induces dormancy. Note that competition occurs between the shoot and root for photosynthate, and so an increase in shoot growth causes a relative decrease in root and cambial growth. All woody plants follow this same general pattern, although the growth rate varies between different species.

Growth curves are also useful for detecting problems or for scheduling changes in cultural practices. After several seasons of growth records have been accumulated, nursery managers can compare the current shoot and stem diameter growth to a computed average or target growth curves (Figure 7).

One added benefit of monitoring crop growth is that it forces you to get out in the nursery on a regular basis, and you can use this time to scout for insects and diseases or notice other growth problems.

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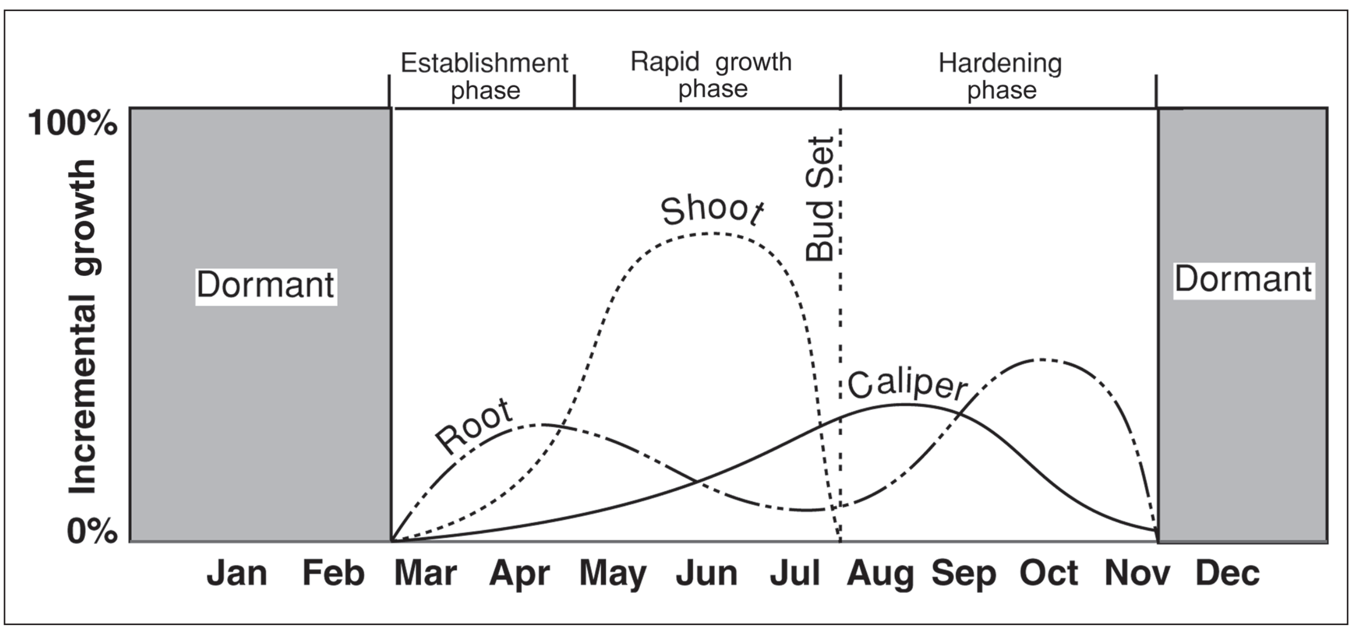


*Figure 6 - Although less common, incremental growth curves show growth rate changes over time and give a good view of when growth of shoots, roots, and stem stem diameter occur during the season.*

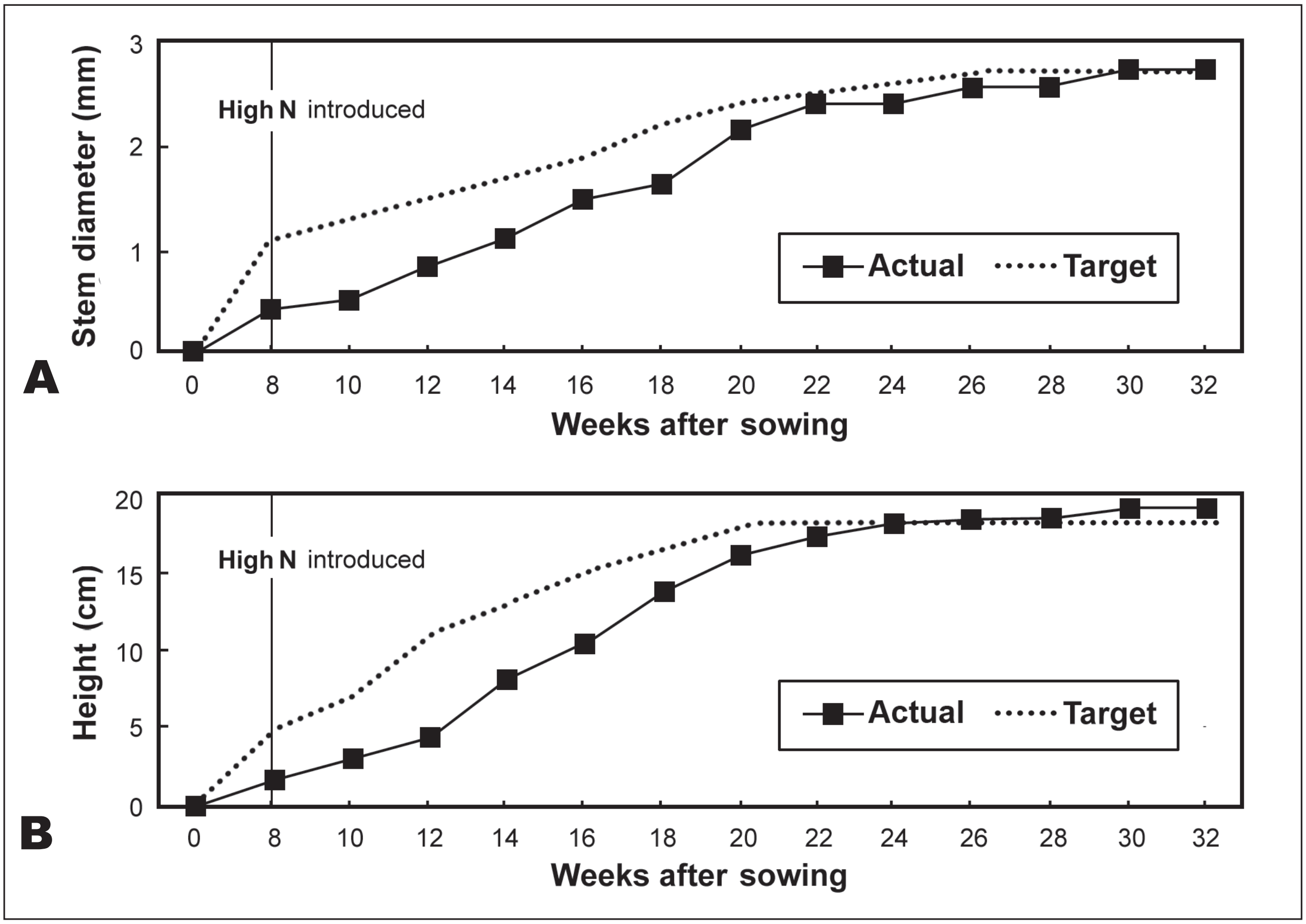


*Figure 7 - One of the most useful applications for growth data is for diagnosing problems and scheduling cultural adjustments. In this example, these Colorado blue spruce (Picea pungens) container seedlings were growing much slower than expected so a high nitrogen (N) fertigation was started at week 8 and both stem diameter and height met the targets by the end of the season.*


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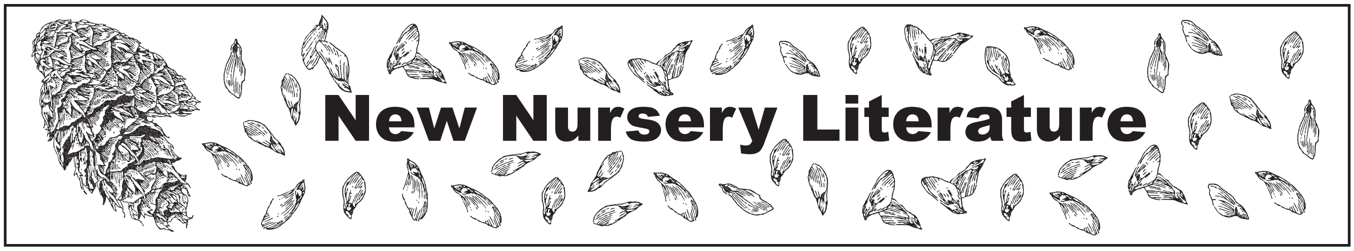

# New Nursery Literature

## Special Order Publications

**Tree Planter's Notes** has been completely revised and upgraded with a full-color layout. The articles from the latest volume 54, number 1 are included in the following list of new literature. If you have received TPN in the past, you MUST renew your subscription online at http://www.rngr.net/subscribe to continue to receive your free copy. Please consider subscribing to the electronic version of TPN, helping us save paper and printing costs. If you have difficulty with the online subscription or need to request a special subscription (e.g., more than one copy), please contact Rae Watson at rewatson@ fs.fed.us or Diane Haase at dlhaase@fs.fed.us.

Riley LE, Pinto JR, Dumroese RK, tech. coords. 2010. **National Proceedings: Forest and Conservation Nursery Associations—2009**. Proc. RMRS-P-62. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 101 p.

These proceedings are a compilation of 20 papers that were presented at the regional meetings of the Intertribal Nursery Council (INC) and the forest and conservation nursery associations in the United States in 2009. The INC meeting was held in Moscow, Idaho, on July 14, 2009. Subject matter for the technical sessions included resource protection, collaborative research efforts, cultural use of native species, and native species programs. The Joint Meeting of the Western Forest and Conservation Nursery Association and Intermountain Container Seedling Growers' Association was held in Moscow, Idaho, on July 15 to 16, 2009. Subject matter for the technical sessions included seedling nutrition, pest management, nursery research and new technology, and general nursery topics. The Northeastern Forest and Conservation Nursery Association meeting was held in Grand Rapids, Michigan, on July 20 to 23, 2009. Subject matter for the technical sessions included tree improvement programs, nursery culture and management, fumigation updates, and insect and disease management.

***Order a Copy of RMRS-P-62, National Proceedings: Forest and Conservation Nursery Associations–2009 from:***

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Roy RN, Finck A, Blair GJ, Tandon HLS. 2006. **Plant nutrition for food security: a guide for integrated nutrient management**. FAO Fertilizer and Plant Nutrition Bulletin 16. Rome: Food and Agriculture Organization of the United Nations. 366 p.

This is an update of one of the classic texts on fertilizers and plant nutrition. Although it primarily deals with agronomic crops around the world, there are excellent sections on Plant nutrients and basics of plant nutrition, Soil fertility and crop production, Sources of plant nutrients and soil amendments, as well as the important topic; Plant nutrition and environmental issues.

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## Container Production

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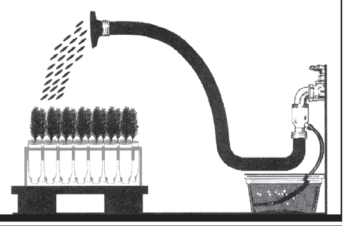

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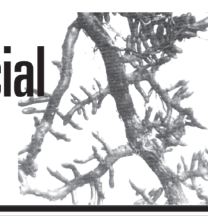
## Mycorrhizae & Beneficial Microorganisms



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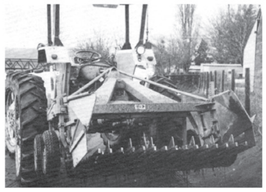

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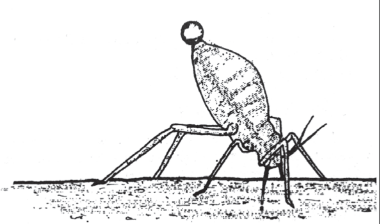

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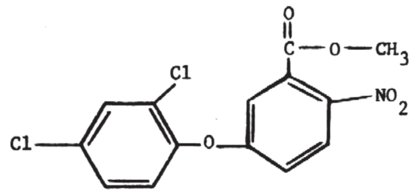

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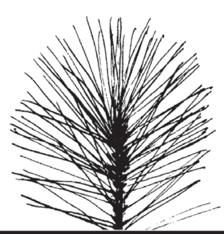

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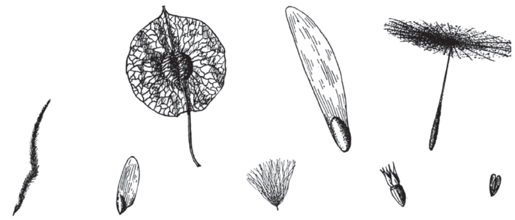

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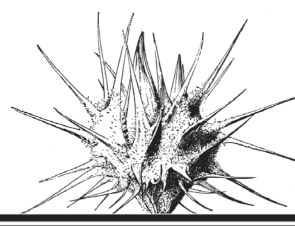
# Weed Control



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