Using Organic Fertilizers in Forest and Native Plant Nurseries

Thomas D Landis and R Kasten Dumroese

Thomas D Landis is Retired Nursery Specialist, USDA Forest Service, and currently Consultant, 3248 Sycamore Way, Medford, OR 97504; Tel: 541.858.6166; E-mail: nurseries@aol.com. **R Kasten Dumroese** is Research Plant Physiologist, USDA Forest Service, Rocky Mountain Research Station, 1221 South Main Street, Moscow, ID 83843; Tel: 208.883.2328; E-mail: kdumroese@fs.fed.us

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Abstract: Since World War II, synthetic fertilizers have been used almost exclusively to grow forest and native plant nursery crops because they are quickly soluble and readily taken up by crops, producing the rapid growth rates that are necessary in nursery culture. In recent years, however, a wide variety of new organic fertilizers have become available. We divided these organics into three categories: 1) animal and plant wastes that are sustainable, and can further be separated into unprocessed and processed materials; 2) natural minerals that are unsustainable, with their use regulated in strict organic farming; and 3) a blend of waste material supplemented with natural minerals. Mineral nutrients are released more slowly by organic fertilizers and crops will therefore take longer to reach commercial size. This slow nutrient release rate has other benefits, however, such as less chance of water pollution and better establishment of beneficial microorganisms. In the final analysis, high quality nursery crops can be grown with organic fertilizers, but production schedules will have to be adjusted.

Keywords: nutrient release rate, nutrient uptake, nutrient analysis, pollution, mycorrhizae

Introduction

Until the early 20th century, nearly all fertilizers used in agriculture, including nurseries, were organic. Animal manure and compost were the primary fertilizers mentioned in the first USDA Forest Service nursery manual (Tillotson 1917). Prior to World Wars I and II, Chilean nitrate was the main source of organic nitrogen; demand for nitrogen that was essential for the manufacture of munitions, however, quickly outpaced availability (Wikipedia 2011b). This led to development of the Haber-Bosch Process that converts the abundant nitrogen gas in our atmosphere into ammonia; this ammonia can then be chemically converted into a vast array of synthetic fertilizers (Meister 2011). After World War II, these synthetic, ammonia-based fertilizers became cheap and readily available, and use of organic fertilizers dropped from 91% in the early 1900s to 3% by the 1950s (Jones 1982). In recent decades, organic farming has seen a resurgence due to changes in public values and greater availability of new types of organic fertilizers. We therefore believe it is time to take a second look at how organic fertilizers could be utilized in forest and native plant nurseries.

What is an Organic Fertilizer?

Standard agriculture or horticulture fertilizer references, such as Jones (1982) or the California Plant Health Association (2002), offer no practical definition for organic fertilizers and only contain a couple of paragraphs on organic amendments. After spending a considerable amount of time researching the topic, we found that the lack of information is due to the fact that organic fertilizers are a very complicated and confusing subject.

Part of the confusion is the result of terminology. In chemistry, an “organic” compound is one that contains carbon; this really doesn’t have anything to do with organic fertilizers. When dealing with food production, the term organic has a legal definition; 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, forest and native plant nurseries are not bound by these regulations.

Organic Fertilizers Types

For the purposes of our discussion, organic fertilizers can be defined as materials that are naturally occurring and have not been synthesized. We divided organic fertilizers into three general categories: 1) animal or plant wastes; 2) natural minerals; and 3) blended wastes supplemented with natural minerals (Figure 1).

Animal or Plant Wastes

Animal and plant wastes are the materials that most people consider to be organic fertilizers. These materials 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 that they are sustainable and widely available; on the other hand, heavy use of animal manures poses a potential source of water pollution (Moral and others 2009).

Unprocessed Organic Wastes

Unprocessed organic wastes are by far the largest and most complicated; almost any type of organic matter has been used as a fertilizer, including animal manure, sewage sludge, peat moss, hopwaste, and a myriad of composts. The best criteria for determining what types of organic matter can be considered fertilizers is their carbon-to-nitrogen (C:N) ratio (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 and yield besides simple nutrition (Benzian 1965). For example, animal manure can be a source of all essential plant nutrients, but its organic matter also improves the tilth, aeration, and water-holding capacity of the soil, and stimulates beneficial soil microorganisms. Unprocessed organic wastes can be challenging to use because of their high potential for water pollution. When growing organic vegetable crops, composted manure is not recommended because of potential leaching of high levels of phosphorus, one of the leading causes of water eutrophication (Sharpley and others 1994).

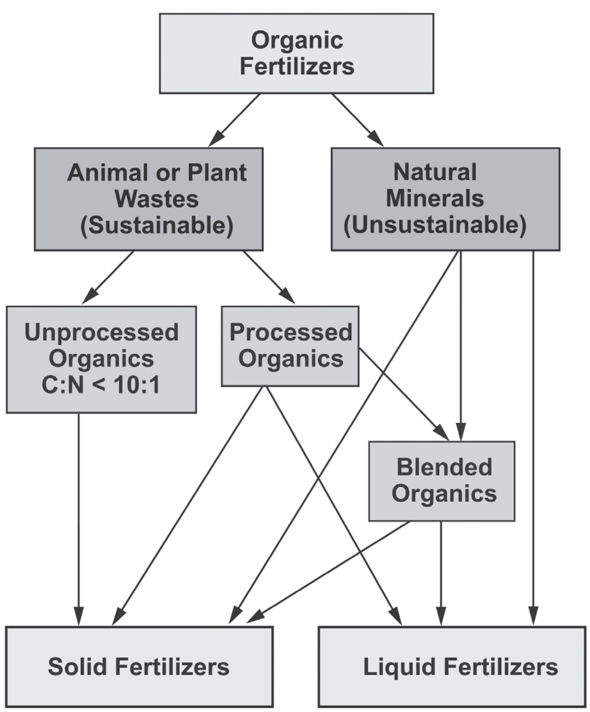

Figure 1. The terminology of organic fertilizers is complicated, and the various types can best be illustrated with a flow chart.

Although raw organic materials, such as manure and compost, were considered the "most useful fertilizers" in historical times, they are not commonly used in contemporary forest nurseries (Armson and Sadreika 1979; van den Driessche 1984). Green manure crops that have been used for centuries to capture mineral nutrients are also not recommended for forest nurseries because of concerns about disease pathogens (McGuire and Hannaway1984). 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).

Processed Organic Wastes

Processed organic wastes are considered to be any organic material that has been processed in some manner before being used as a solid or liquid fertilizer (Figure 1), including composts, bloodmeal, bone meal, sewage sludge, as well as more exotic materials such as feather meal and kelp extracts. Almost any waste organic matter can be composted, and the composting process has been well documented (Landis and Khadduri 2008).

Although processed organic fertilizers are common in organic farming, they have not been widely used in forest or native plant nurseries. Many new processed organic fertilizers, however, are now available from horticultural supply firms. For example, Bradfield Organics® fertilizers (available through Hummert™ International, Earth City, MO) are marketed for specific crops, such as lawns or vegetables. Their Luscious Lawn Corn Gluten ($9N:0P_2O_5:0K_2O$) 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 pre-emergent herbicidal effects on some grasses (Christians 2011).

Natural Mineral Fertilizers

Natural mineral fertilizers are a second major category of organic fertilizers. They include minerals and other materials that come directly from the earth, and are components in many blended organic fertilizers (Figure 1). Many commercial products in this category are widely marketed as organic fertilizers because they are not chemically synthesized. Like all types of mining, however, obtaining these fertilizers is an extractive process and unsustainable in the long term. The use of natural mineral fertilizers is restricted in some types of organic farming, and the Organic Materials Review Institute rejects their use for certified organic food production (OMRI 2011). Other countries and some states, however, have their own organic certification process and permit the use of natural mineral fertilizers.

Guano

Guano is the accumulated excrement of seabirds or bats. It has been used as a fertilizer for hundreds of years since the Incas collected it along the coast of Peru. It is an excellent fertilizer due to high levels of phosphorus and nitrogen, and does not have any noticeable odor. Because rainwater leaches soluble nitrogen out of guano, the best guano deposits are found in very dry climates; desert coastal areas or islands are ideal guano collection sites. Large populations of seabirds use these locations as their land base for resting and breeding. 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 2011a). 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 that had severe economic consequences on the local population (US CIA 2011).

Rock Phosphate

Natural deposits of fluoroapatite are the raw material of most phosphate fertilizers. Deposits are currently mined in North Africa, the former Soviet Union, and in Florida, Idaho, Montana, Utah, and Tennessee. The raw ore contains 14% to 35% phosphate (P_2O_5), and is processed by grinding and washing into a fine granular fertilizer. Rock phosphate is very insoluble in water, and is not used in soluble formulations; it does make an effective 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 the development of mycorrhizal fungi (Amaranthus 2011).

Sodium Nitrate

Sodium nitrate ($NaNO_3$) 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 2011b). In the early 1900s, sodium nitrate was one of the few mineral fertilizers mentioned for forest nursery crops (Tillotson 1917). Although this fertilizer has been used in organic farming for many years, several organic certifying agencies have concluded that mined mineral fertilizers conflict with basic organic principles. For example, the USDA National Organic Program currently restricts use of sodium nitrate to less than 20% of total annual applied nitrogen and requires that growers phase out its use over time (Gaskell and Smith 2007).

Magnesium Sulfate

Magnesium sulfate ($MgSO_4$) is better known as Epsom salts or Kieserite. Although more widely used for medicinal purposes, magnesium sulfate is a very soluble source of 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

Technically known as sulfate of potash-magnesia or langbeinite (Figure 2A), Sul-Po-Mag 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 2B). K-Mag Natural is a common trade name; this product is ideal for supplying potassium and sulfur without any accompanying nitrogen. Sul-Po-Mag is a common component in many blended organic fertilizers.

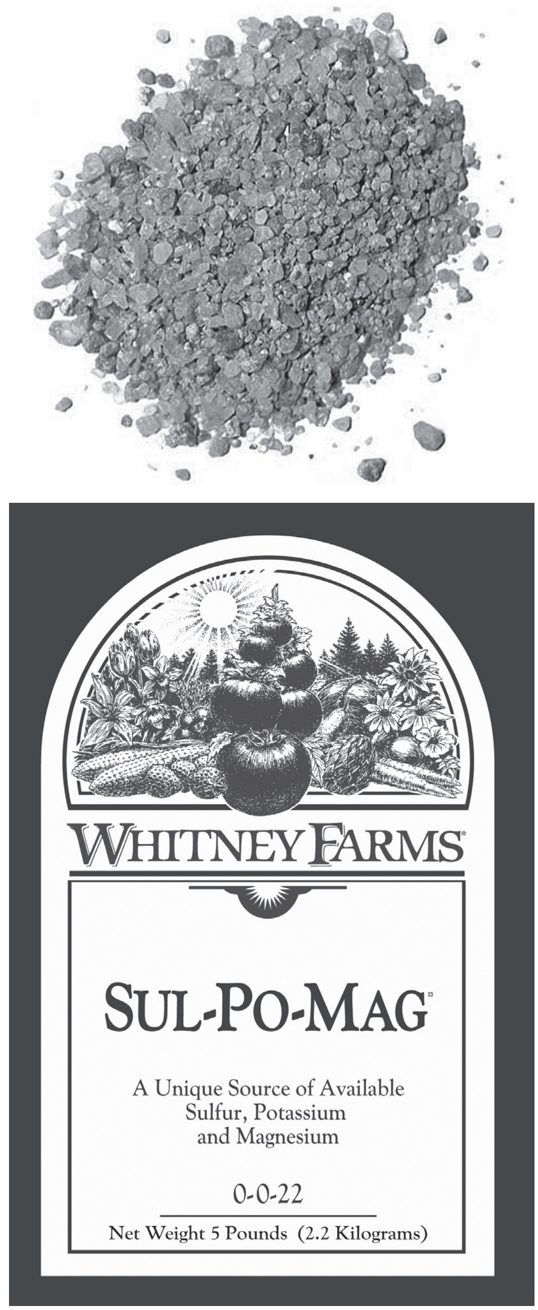

Figure 2. Mineral fertilizers, such as Sul-Po-Mag, are mined from the earth and are considered organics because they are naturally occurring and not synthesized by humans.

Blended Organics

Blended organics are the newest category of organic fertilizers; 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 we could find, so we created this category. It is easy to identify blended organic fertilizers by checking the ingredients on their labels, and a wide variety of products can be found on the internet. Many horticultural suppliers, such as Black Gold® (Bellvue, WA), are entering the organic fertilizer market. For example, they offer an all-purpose organic fertilizer ($5N:5P_2O_5:5K_2O$) that contains processed organics, including bone and blood meal, blended with the natural mineral potassium sulfate (Figure 3A). If you want an organic fertilizer that is made from sustainable materials, that is not mined or synthetically made, be aware that many blended organic fertilizers contain natural minerals (Figure 3B).

Organic Fertilizer Forms

Solid Organic Fertilizers

Powdered or granular fertilizers can be derived from unprocessed organics, processed organics, natural minerals, or blended organics (Figure 1). Solid organic fertilizers have not been widely used in forest or native plant nurseries, or their use has not been documented in the published literature. Milorganite® (Milwaukee,

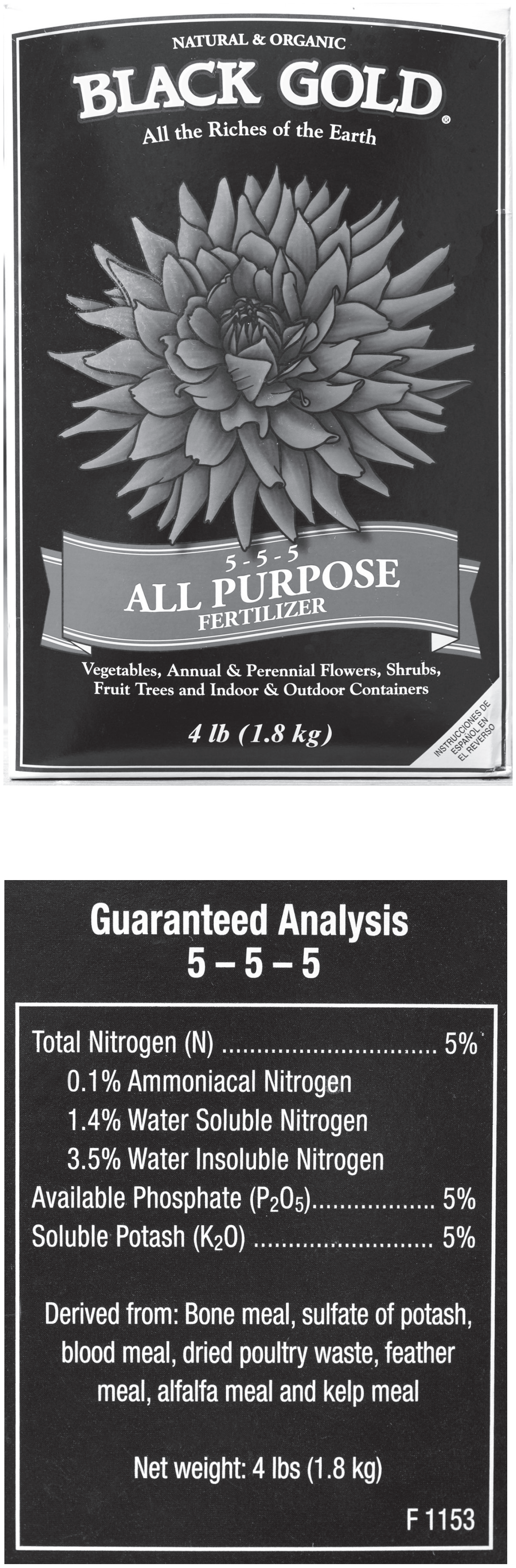

Figure 3. Blended organic fertilizers (A) contain processed organics and natural minerals, such as sulfate of potash (B).

WI) is one example that is produced from processed sewage sludge. This granular fertilizer was used in several USDA Forest Service nurseries with good success, and Dutton (1977) documented the pros and cons of using Milorganite® at USDA Forest Service Wind River Nursery (Carson, WA). Biosol® (6N:1P_2O_5:3K_2O), another solid organic fertilizer, was developed from the fermentation of soybean and cottonseed meal, and is a by-product of the pharmaceutical manufacture of penicillin. Biosol® is supplemented with Sul-Po-Mag to balance the nutrient content. Although it has never been used in forest or native plant nurseries to our knowledge, Biosol® has been successfully used as a fertilizer in native plant restoration projects (Claassen and Carey 2007; Steinfeld and others 2007).

Liquid Organic Fertilizers

Liquid organic fertilizers can be derived from processed organics, natural minerals, or blended organics (Figure 1). Again, most of these products are so new that they are not discussed in traditional fertilizer texts, and the best and most current information on liquid organic fertilizers can be found on-line. GrowOrganic (Grass Valley, CA: URL: http://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 others are for more general use. For example, Earth Juice Grow (2N:1P_2O_5:1K_2O) is derived from bat guano, kelp, sulfate of potash, feather meal, oat bran, blood meal, and steamed bone meal. Liquid organic fertilizers can present some operational difficulties. In a review article on the production of organic vegetable crops, Gaskell and Smith (2007) conclude that liquid organic fertilizers lack uniformity because they are subject to settling and microbial breakdown. In addition, many liquid organic fertilizers include organic material in suspension and must be filtered or continually agitated during fertigation to prevent the material from plugging nozzles.

Very little formal research has been published on growing forest or native plant crops with liquid organic fertilizer. Unfortunately, most published research was not properly designed, so the results are confounded, making them difficult to properly interpret. In one study, Norway spruce (*Picea abies* [L.] Karst.) seedlings were grown in either 100% Sphagnum peat moss or peat moss amended with forest organic matter, including pine bark. They were grown for 2 years in a nursery with either conventional synthetic fertilizers or a liquid organic fertilizer made from composted chicken manure. The seedlings grown with synthetic fertilizer were significantly taller at the end of nursery culture but, after 3 years in the field, the organically grown seedlings had faster growth rates (Vaario and others 2009).

Comparison of Organic versus Synthetic Fertilizers

Because of the variability involved, it is difficult to compare organic and synthetic fertilizers. Some generalizations, however, can be made (Table 1).

Mineral Nutrient Analysis

By law, all fertilizers must list their chemical analysis (%N:%P_2O_5:%K_2O) on the label. Almost all organic fertilizers have relatively low analyses. The nitrogen percentage is rarely above 15%, and more typically in the range of 5% to 10% (Figure 4). Higher analysis products are usually supplemented with natural minerals, such as sodium nitrate.

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

Factor	Organic	Synthetic
Mineral Nutrient Analysis	Low	High
Range of Mineral Nutrients	All	One to Many
Nutrient Release Rate	Slower	Faster
Nutrient Uptake	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

Range of Mineral Nutrients

One major benefit of organic fertilizers is that they contain a full complement of all 13 mineral nutrients. Some synthetic fertilizers, on the other hand, contain one or only a few mineral nutrients. Some of the newest synthetic fertilizers have been specially formulated to contain the full range of mineral nutrients.

Nutrient Release Rate

One of the major differences between organic and synthetic fertilizers is how fast their nutrients become available to plants. The first step in mineral nutrient uptake is dissolution in water, and this process is much easier and faster for synthetic fertilizers. Synthetic fertilizers are formulated as salts that are very 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. Even processed organics contain a large percentage of insoluble nitrogen that must undergo microbial decomposition before being available for plant uptake (Figure 4). Liquid organic fertilizers have the benefit of being already in solution, or at least in aqueous suspension.

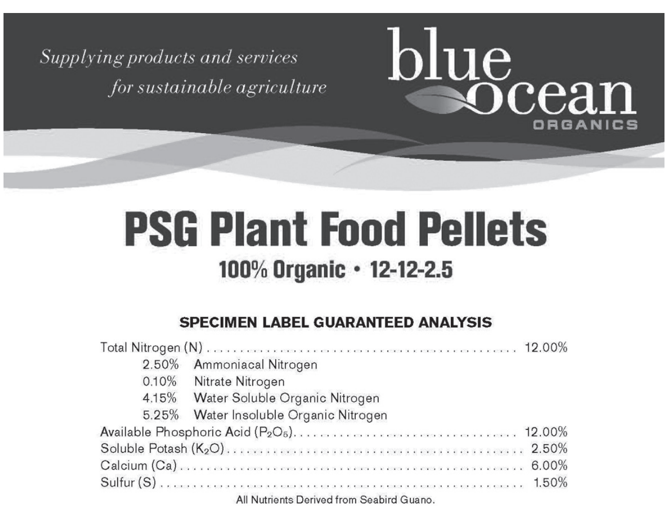

Figure 4. Organic fertilizers have relatively low nutrient analysis compared to synthetic fertilizers, and much of the nitrogen is insoluble.

A recent research trial provides a good illustration of the differences in nutrient release rates among a variety of organic and synthetic fertilizers. Claassen and Carey (2007) found that nearly all (95%) of the nitrogen in synthetically produced ammonium phosphate was released within a few days of application; two formulations of synthetically produced controlled-release fertilizers took about 150 days to release 95% of their nitrogen. In contrast, the nitrogen release of two types of organic fertilizers was much slower. Commercially processed organic wastes released from 20% to 60% of their nitrogen after 200 days; municipal composts released only about 10% of their initial nitrogen in the same period.

Nutrient Uptake

Most plant nutrients enter plants as electrically charged ions from the soil solution. Nutritional research has established that organic nitrogen molecules can be taken up by nursery plants directly as amino acids. For example, the growth of Scots pine (*Pinus sylvestris*) seedlings was similar whether they were fertilized with inorganic nitrogen or supplied with amino acids (Ohlund and Nasholm 2001). Metcalfe and others (2011) found that, although seedlings of two conifers, Sitka spruce (*Picea sitchensis*) and Douglas-fir (*Pseudotsuga menziesii*), and two shrubs, oval-leaf blueberry (*Vaccinium ovalifolium*) and salmonberry (*Rubus spectabilis*), readily took up nitrogen as organic amino acids, all four species grew significantly larger when grown with ammonium and nitrate fertilizers (Figure 5). This finding is supported by a recent, comprehensive literature review that concludes organic nitrogen can be taken up by plants, but direct evidence that this constitutes significantly to plant nutrition is lacking. Nursery trials comparing synthetic and organic fertilizers are very difficult to design; organic fertilizers contain numerous nutrients so it is impossible to isolate the effects of just one nutrient.

Compatibility with Beneficial Microorganisms

Perhaps 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. Much research has shown that high levels of synthetic fertilizers, especially nitrogen and phosphorus, inhibit the establishment and development of mycorrhizal fungi. This is particularly evident in the soilless growing media of container seedlings where applications of high levels of soluble, synthetic fertilizers are common (Castellano and Molina 1989). Conversely, beneficial microorganisms are favored by organic fertilizers because nutrients are released at a slower rate and the organic component improves soil conditions. A recent survey of ectomycorrhizal fungal species in Polish bareroot nurseries found that ascomycetes were more common when compost was used as fertilizer (Trocha and others 2006).

Cost

Organic fertilizers are typically several times more expensive per nutrient compared to synthetic products. For example, the cost per unit of nitrogen, as urea or ammonium nitrate, for organic fertilizers was higher than that of synthetic nitrogen fertilizers (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. 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 evaluate, including adding organic matter and stimulating

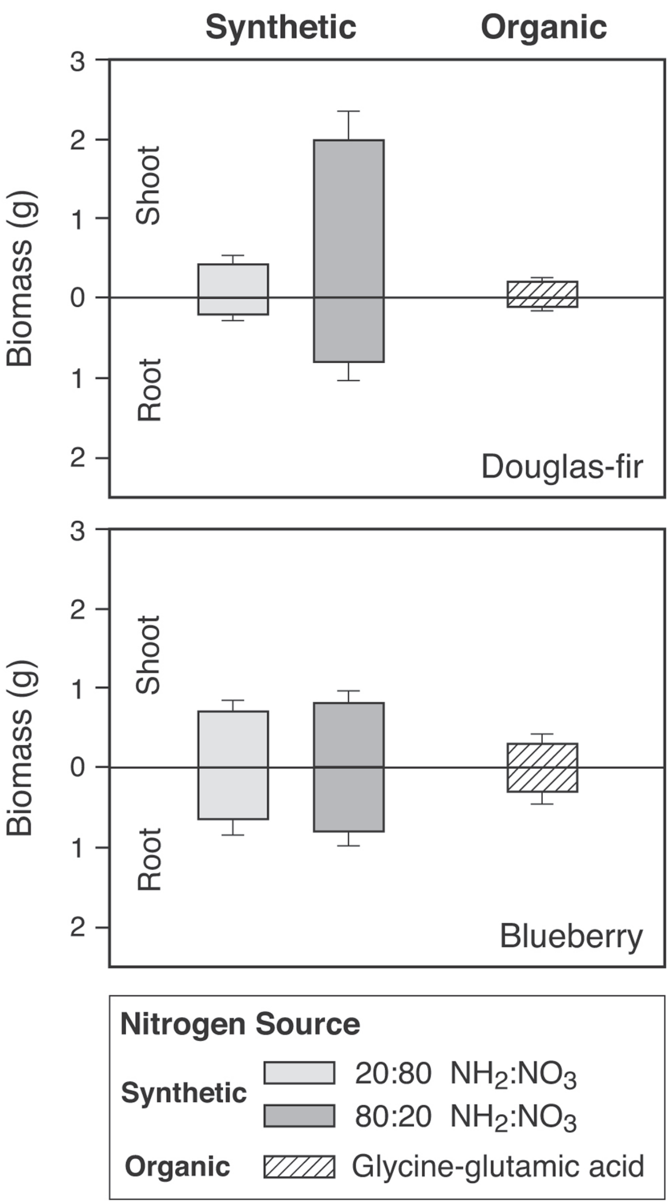

Figure 5. Douglas-fir (*Pseudotsuga menziesii*) and oval-leaf blueberry (*Vaccinium ovalifolium*) seedlings grown with two different synthetic nitrogen fertilizers were significantly larger than those grown with organic nitrogen (Metcalfe and others 2011).

soil microorganisms (Table 1). Synthetic fertilizers also have hidden costs, such as carbon emissions during their manufacture and the ecological impacts of increased potential for water pollution. In the final analysis, because fertilizers represent only a very small percentage of the cost of producing nursery stock, price may not be a deciding factor on whether to use organic fertilizers.

Handling and Application

Because of their bulkiness and low nutrient analysis, unprocessed organics are more expensive to ship, store, and apply compared with 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 for container nurseries, because no good method yet exists for applying 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, for example, compost and municipal sludge. 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, sewage sludge and even some industrial wastes can be used as fertilizers. 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).

Nutrients in organic fertilizers are much less susceptible to leaching than those in 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, with the excess nutrients potentially entering surface or ground water, resulting in pollution. This is especially serious with fertilizers containing the anions nitrate and phosphate that are not adsorbed on the cation exchange sites and therefore easily leached (Landis and others 1992). Although sewage sludge is one organic fertilizer that can cause water pollution when applied improperly, guidelines for proper application in bareroot forest nurseries have been developed (Rose and others 1995).

Applications 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. Although the higher cost of organics is often given as a reason to use synthetics, fertilizers are a small portion of total production costs and organic fertilizers have many other benefits.

As previously mentioned, it is difficult to make direct comparisons between organic and synthetic fertilizers in nursery trials. Of all the various methods used to evaluate the effects of fertilizers, plant growth rates and quality are the true tests. 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 of the growth rate between crops grown with organic and synthetic fertilizers applied at the same nitrogen rate.

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 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 trials because of differences in soil type and nursery climate; specific rates for Milorganite® and sewage and fish sludge have been reported for forest nurseries (Dutton 1977; Rose and others 1995). Because of the slow release rates of most organic fertilizers, it may be prudent to use organic fertilizer to provide a base level of nutrients and synthetic fertilizer to respond to crop growth and development during the season.

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, particularly in smaller volume containers. Organic fertilizer could be used in containers larger than 1 l (60 in3). Composts could be incorporated into growing media, but they must be fully mature to prevent fertilizer burn from excess ammonia. Fertigation is the preferred fertilization method in many forest and native plant container nurseries, and growers could incorporate the more soluble natural mineral organics into their mixes. One of the challenges of completely converting to organic fertilizers is how to achieve the high soluble nitrogen levels that are used to promote the rapid growth rates in greenhouse crops. Although the number of highly soluble organic fertilizers is very limited, sodium nitrate could be used to provide nitrogen, and Sul-Po-Mag and Epsom salts could provide other macronutrients. Many newer blended organic fertilizers contain a full complement of macro- and micronutrients. In a recent trial with a grass test crop, 3 brands of liquid organic fertilizers produced growth similar to conventional synthetic fertilizers. The authors concluded that the nitrogen availability of the synthetics was much faster than the organic fertilizers and that the organic solutions should be filtered before their use in fertigation systems (Hartz and others 2010).

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