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).

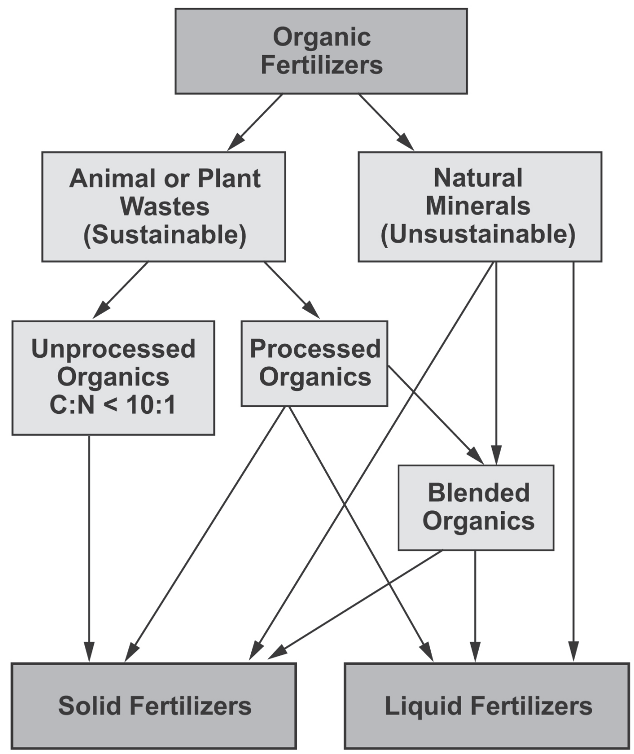

Figure 1 - The terminology of organic fertilizers is complicated and the various types can best be illustrated with a flow chart.

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 pre-emergent 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

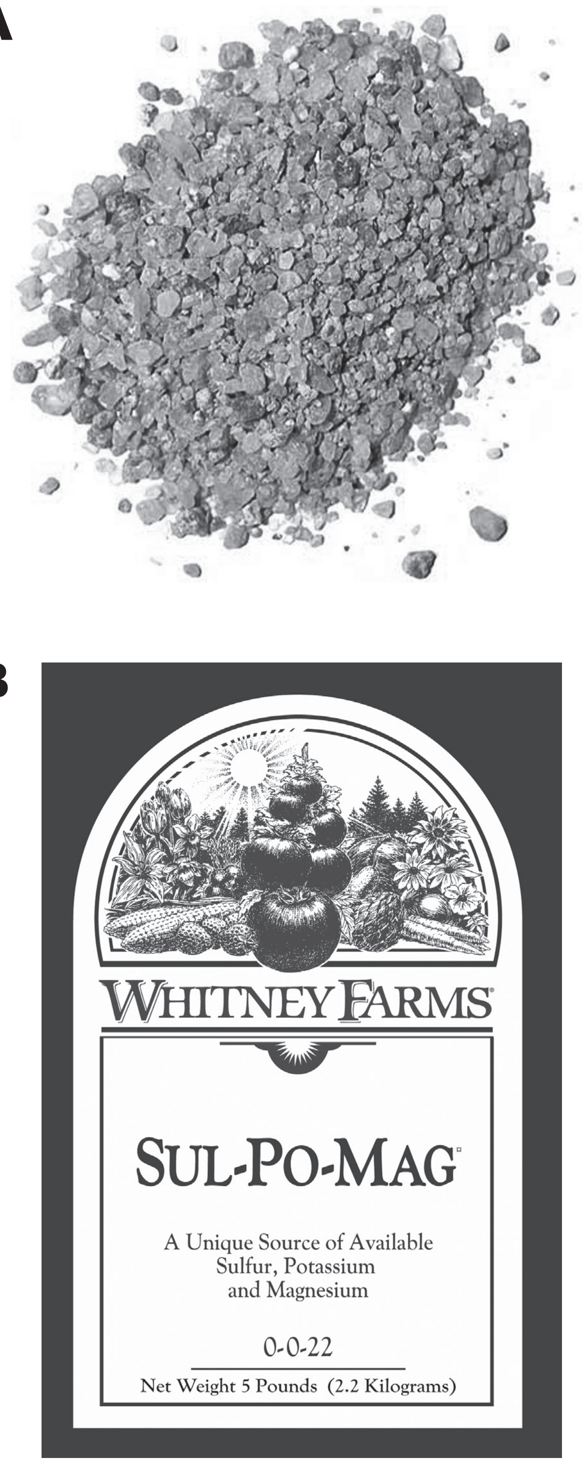

Figure 3 - Natural minerals, such as sulfate of potash-magnesia (A), are mined from the earth and are marketed as organic fertilizers (B) because they are naturally occurring and not synthesized by humans.

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

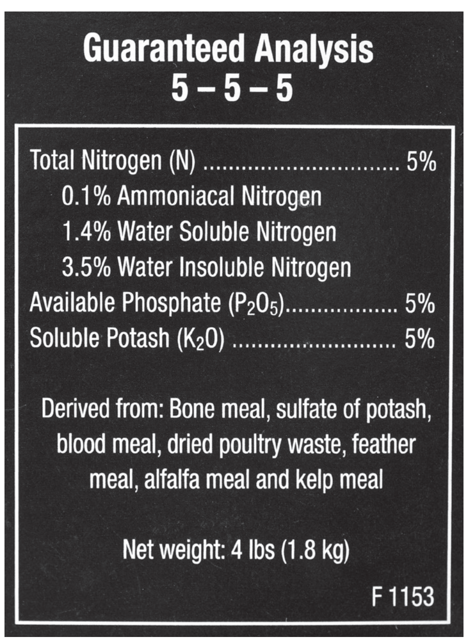

Figure 4 - Blended organic fertilizers (A) contain both processed organics and natural minerals, such as sulfate of potash (B).

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

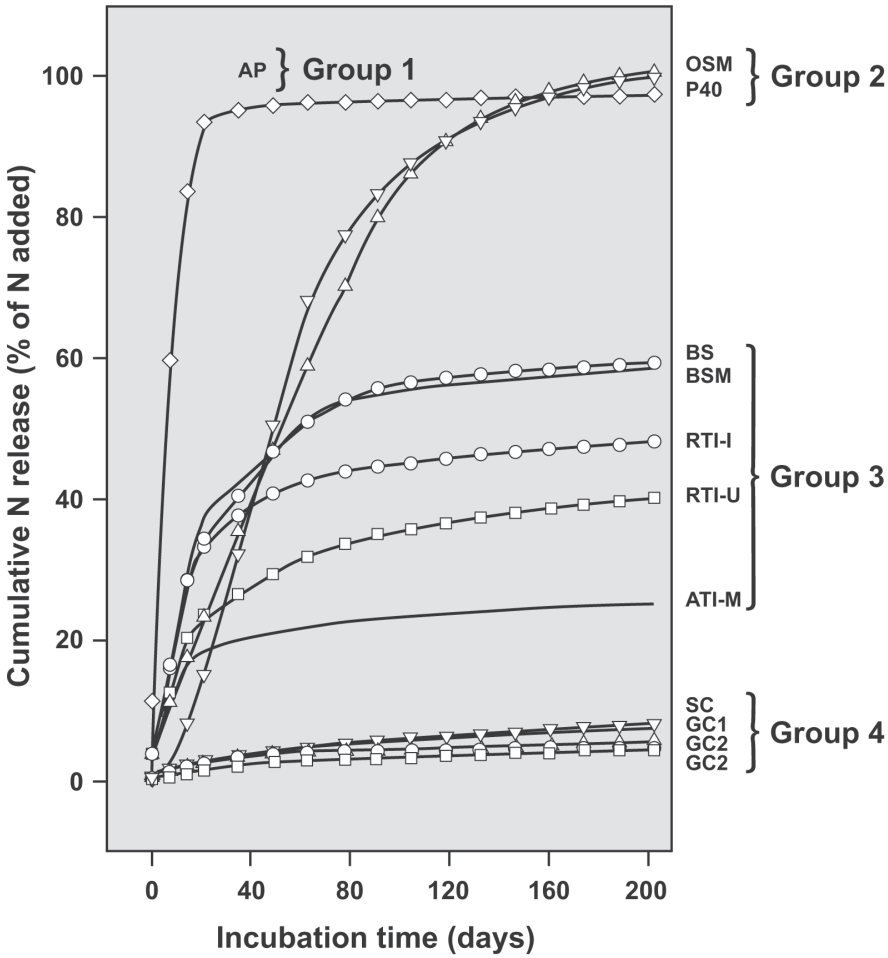

Figure 5 - Nutrient release rate is one of the most important considerations when comparing fertilizers.

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

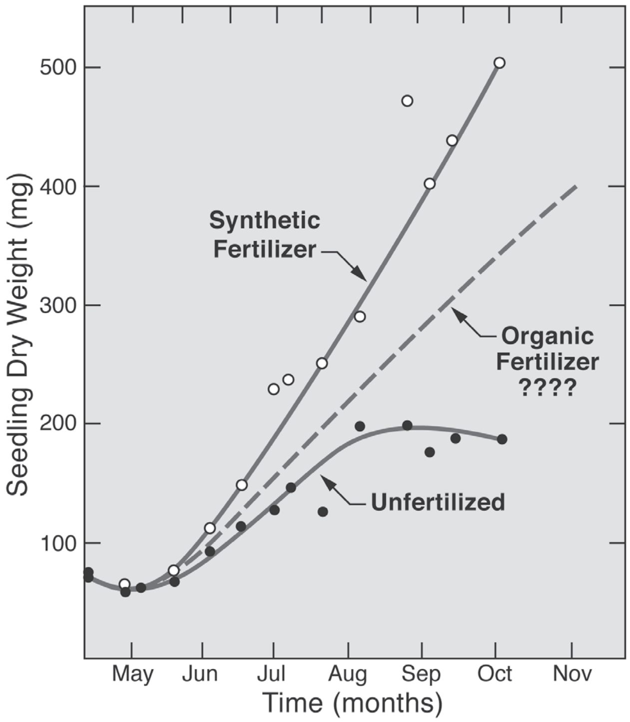

Figure 6 - The growth benefits of synthetic fertilizers have been well established (solid lines) but it would be interesting to conduct growth trials between organic and synthetic fertilizers (modified from Armson and Sadreika 1979).

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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