Chapter 9

Nursery Soil Organic Matter: Management and Importance

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Abstract

Organic matter is important in nursery management because of its favorable effects on the physical, chemical, and biological properties of the soil. Organic matter may be added by incorporating into the soil either cover or green manure crops grown on the site or organic amendments brought from elsewhere. Some constituents of organic matter decompose very quickly and others much more slowly, but both types are important in maintaining favorable soil conditions and productivity.

9.1 Introduction

"Now *here*, you see, it takes all the running *you* can do to keep in the same place. If you want to get somewhere else, you must run at least twice as fast as that."

—The Queen to Alice in *Through the Looking Glass* [7], Chapter 2, by Lewis Carroll (1832-1898)

To paraphrase the Queen, we could easily state: "Now *here*, in the nursery, you see, it takes all the running *you* can do to maintain your soil organic matter level. If you want to increase it, you must run at least twice as fast as that."

With very few exceptions, nursery managers are faced with a constant struggle in keeping their soil organic matter content at an appropriate level. In this regard, they differ from many other tillers of the soil. Basically, forest-nursery management is a mining operation with respect to organic matter. Most management activities accelerate the decomposition of organic matter: further, during harvest (lifting), the entire plant, including roots with adhering soil and organic matter, is removed. It is no wonder, then, that the soil must be replenished frequently.

There are really only two fundamental ways in which organic material can be added to the soil. The first way is to grow a crop on the land and incorporate it into the soil. Such crops may be referred to as **catch crops** if they are grown principally for catching and holding nutrients on the site, **cover crops** if they are grown principally for erosion control, or **green manure crops** if they are grown principally as organic amendments for the soil [13] (see also chapter 10, this volume). In this chapter, I discuss mainly green manure crops. The second way is to transport organic matter from another place to the nursery and incorporate that into the soil. Both of these approaches are employed frequently in the Northwest, as shown clearly by the OSU Nursery Survey.

Following a brief look at the current status of soil organic matter levels and management in Northwest nurseries, we will explore organic matter dynamics, types, and sources. The importance of organic matter to the physical, chemical, and biological properties of the soil will be stressed, and these properties will be related to the growth and harvesting of forest-tree seedlings and transplants.

9.2 Nursery Survey Results

The results of the OSU Nursery Survey (see chapter 1, this volume) showed that most managers (86%) felt that their soil organic matter level was not as high as it should be. They reported current levels ranging from 1 to 7% (average 3.6%) but estimated that levels should range from 2 to 10% (average 5.0%). When asked to list their five major nursery-management problems in order of importance, 62% included soil organic matter maintenance among their top five, and 14% regarded it as their greatest problem.

Of the eight nurseries not including organic matter maintenance among their top five problems, three reported adding sawdust, manure, or both and growing green manure crops. Two felt that their organic matter levels were near optimum and used green manure crops to maintain those levels. One nursery reported being so pushed for production that it had no opportunity to include a green manure crop in the rotation, though both manure and sawdust were applied, and one was so new that it had not evolved to the point of needing to enhance its organic matter. Finally, one had so many other major problems that organic matter maintenance did not make the top five; however, in attempts to deal with some of its other problems (e.g., soil compaction, poor drainage, and crusting), that nursery stressed the use of organic amendments and green manure crops.

Of the 17 nurseries (81 %) that reported adding organic matter other than green manure crops, 12 added sawdust or

In Duryea. Mary L., and Thomas D. Landis (eds.). 1984. Forest Nursery Manual: Production of Bareroot Seedlings. Martinus Nijhoff/Dr W. Junk Publishers. The Hague/Boston/Lancaster, for Forest Research Laboratory, Oregon State University . Corvallis. 386 p.

bark, six added peat, two added manure, and one added sludge. Obviously, several reported using more than one source. The really disturbing fact is that 90% of the managers said that they foresaw a shortage of such materials in the future. Those fortunate managers that did not expect shortages reported ample local supplies of either peat or manure.

Although composting offers several advantages—weed and pest control as well as stabilization of organic matter through lowering of the carbon to nitrogen (CA) ratio and elimination of toxic decomposition products—it also is an inconvenience. Thus, despite the fact that several managers said they were interested in using composts, only 14% said they actually did.

Cover or green manure crops were included in the management of 76% of the nurseries, and 71% used them in every rotation. Peas [some cowpeas, *Vigna sinensis* (L.) Endl.; some field peas, *Pisum sativum* var. *arvense (L.)* Poir.; some not specified] were listed most frequently. They were followed in order of decreasing frequency by oats (*Avena sativa* L.), sudangrass [*Sorghum bicolor* (L.) Moench], and lupines (*Lupinus* L. spp.). Several other crops were reported used, each in a separate nursery. Exactly half (8 of 16) of the nursery managers said they used cover or green manure crops to increase the soil organic matter level; two were less optimistic, hoping only to maintain the present level; and others cited different reasons, including improving soil structure, controlling weeds, preventing erosion, and conserving nutrients.

9.3 Organic Matter Dynamics

Soil organic matter has been variously defined. This is not surprising, however, because it results from a complex and dynamic system comprising three principal segments: (1) organic residues (plant, animal, and microbial) in various stages of decomposition, (2) true humic materials, and (3) live organisms, principally microbes. The turnover rate in this mostly biochemical system is determined by the nature of the organic residues added to the soil and the physical and chemical nature of the soil. These all affect the microbial species populations and their rates of biological activity.

In forest nurseries, most of the organic residues added to the soil are of plant origin. They are composed principally of carbohydrates, primarily cellulose, and lignin but include varying amounts of other constituents. Though microorganisms degrade these materials at various rates, eventually, most of the carbon is either returned to the atmosphere as respiratory carbon dioxide (CO_2) or resynthesized into the bodies of microbes. The final true humus is dark colored, predominantly aromatic material of high molecular weight. Its rate of decomposition is very slow.

The early stages of the breakdown of organic residues are quite rapid, especially if the residue is an immature green manure crop. The process is slower when materials such as sawdust or bark are added to the soil. Peat represents material which has already undergone the initial stages of humificatiom thus, its breakdown is slow. Any plant residue incorporated with the soil undergoes continuous decomposition, the rate of which decreases with time as the remaining compounds become increasingly resistant to decay. Much of any added material will be gone in weeks or months, and nearly all of it will be gone in a few years. But some will remain, in a highly altered form, even after several centuries.

Summarizing the studies of several workers in a new text on humus chemistry, Stevenson [22] reported trends in organic matter system dynamics. Long-term crop rotations have generally resulted in a slow decrease in organic matter content, leading to a steady state in 50 to 100 years. Yet in a study where barley (*Hordeum vulgare* L.) was grown continuously and manure applied annually, the soil organic matter content kept increasing and still had not reached equilibrium when the experiment was terminated after 94 years.

Though the exact age of soil organic matter cannot be determined, its mean residence time (MRT) can be by ^{14}C dating. In his summary, Stevenson [22] found that MRT varied from 250 to 1,900 years. In a virgin prairie soil, MRT was almost 1,200 years. But continuous clean cultivation had resulted in the accelerated loss of the younger fractions such that its MRT had increased to 1,900 years. Conversely, where considerable manure had been added, MRT had decreased to less than 900 years.

9.3.1 Optimum soil organic matter levels

The question can very legitimately be asked by any nursery manager: "What is the optimum soil organic matter level?" Unfortunately, there is no simple, single answer. However, the factors affecting the answer are sufficiently well understood that an answer can be given for a specific site.

The organic matter level represents a dynamic equilibrium among those factors favoring organic matter accumulation and those dedicated to its decomposition. The most important soil variables are moisture, temperature, fertility, and texture. A long, moist, **cool** growing season and fertile soil favor the accumulation of organic matter through the growth of vegetation such as a green manure crop. However, a long, moist, **warm** growing season and fertile soil favor the action of saprophytic microbes that decompose organic matter. Clay and humified organic matter tend to be closely associated in the soil, which reduces the surface area available for attack by saprophytic organisms. Thus, fine-textured soils tend to have higher organic matter contents than coarse-textured soils.

Assessing all of the above variables together, we can arrive at some reasonable ranges for desired soil organic matter content in forest nurseries. Areas where Sitka spruce *[Picea sitchensis* (*Bong.*) *Carr.]* predominates and soils that have a moderate amount of clay provide the ultimate mix of climatic and soil conditions favoring organic matter accumulation. In those soils, 7 to 10% organic matter would be desirable. Where coastal Douglas-fir *[Pseudotsuga menziesii (Mirb.*) Franco var. *menziesii]* predominates, summers are slightly warmer and drier; in those soils, 5 to 8% organic matter would be desirable. At higher elevations and in inland areas well beyond any coastal influence, growing seasons tend to be decidedly shorter, hotter, and drier; in those soils, 3 to 6% organic matter would be desirable. In contrast, in the typical sandy nursery soil of the U.S. Southeast coastal plain-with its long, hot, moist summers and moist, mild winters-saprophytes are active nearly year round and decomposition dominates. In those soils, managers must be content with 1 to 2% organic matter.

9.3.2 Methods for determining soil organic matter content

Basically, three different methods can be used to determine soil organic matter content: loss on ignition, wet oxidation by acid hydrolysis, and wet oxidation by alkaline hydrolysis.

Loss on ignition might seem the simplest, but it tends to yield values that are too high. It removes all of the organic matter, including charcoal and other inert, nonreactive materials. Additionally, at certain temperatures, it actually begins to destroy some of the mineral matter. Thus, except in the case of peats, mucks, and other soils that are mostly organic matter, this method is seldom used.

Wet oxidation by acid hydrolysis, by far the most common method, is intended to determine the "active" soil organic matter only. Chromic acid is used to oxidize organic matter so that the amount of reactive carbon in the soil can be determined. The resulting value is then multiplied by a factor used to convert carbon content to organic matter content. (This method is assumed in all of the equilibrium organic matter contents given in 9.3.1.)

Despite its popularity, wet oxidation by acid hydrolysis has certain problems. First, some laboratories heat the flask in which the reaction takes place, which results in elevated values. Second, not all laboratories use the same multiplication factor to convert carbon to organic matter, which has a variable effect on the results. Third, a significant amount of chromium leaves the laboratory in its wastewater; for this reason, state environmental protection agencies have required some soil-testing laboratories to cease using this method.

A few labs, especially those that have been required to abandon the chromic acid method, have adopted wet oxidation by alkaline hydrolysis. Sodium hydroxide is used to determine organic matter that is partly humified. Because this method detects neither inert carbonaceous materials such as charcoal nor fresh nonhumified organic matter, it tends to give lower values than the chromic acid method. Experience with nursery soils that frequently receive fresh sawdust or green manure crops has indicated that organic matter contents determined with alkaline hydrolysis range from 1/2 to 2/3 of those determined with the chromic acid method.

One final word on methodology is warranted. Essentially all soil-testing laboratories sieve soil samples before they are analyzed. Thus, any large fragments of residue such as green manure crop stems or roots or fresh sawdust or bark will be removed and not included in the analysis. As a result, some soil amendments may take more than a year to appear in the organic matter test. This is much more likely with sawdust or bark than it is with more easily decomposable or finely divided materials.

9.4 The Two Organic Matters

Fresh organic material added to soil begins a continuum of reactions that are of ever-decreasing rates and that eventually terminate only when the last atom of carbon reenters the atmosphere as CO_2 many years later. Nonetheless, it is convenient to divide organic matter into two basic types: (1) highly reactive, recently added fresh organic materials and (2) much less reactive, more nearly stable materials of the later stages of humification. Both types serve important functions in the soil, and each deserves separate discussion.

9.4.1 Highly reactive organic materials

Fresh organic residues, especially green manure crops, contain a wide variety of compounds. These vary from water-soluble substances (such as sugars, amino acids, and some starches) to less soluble materials (such as pectins, proteins, and more complex starches) to insoluble celluloses and lignin. In addition, there are varying amounts of fats, oils, waxes, and extractives such as resins and terpenes.

Most of the water-soluble substances are immediately available to microbes and are metabolized quickly unless they are physically inaccessible because of location within large fragments. The pectins, proteins, and starches also are readily metabolized. The hemicelluloses, alphacelluloses, and lignins are increasingly difficult to decompose. Although fats, waxes, oils, resins, and terpenes were once thought to be quite resistant to decomposition, we now know that most of them are readily metabolized by specific microbes.

During the rapid decomposition phase, several important functions are performed, principally by bacteria and some "sugar fungi" [15]. The bacteria produce many polysaccharide gums that improve soil structure. The metabolic rate in the soil results in the suppression of various pathogens through (1) nonspecific reactions, such as the production of a high level of CO_2 in the soil atmosphere which is fungistatic to *Rhizoctonia solani* Kühn [18]; (2) competition for specific nutrients; (3) parasitism by some facultative organisms of pathogens; and (4) production of specific antibiotics and other antimetabolites in the soil. Small amounts of nitrogen may be fixed by free-living bacteria, principally in the genera *Clostridium* and *Bacillus*, and nutrients may be mineralized during this phase. The major carbon-containing constituents, cellulose and lignin, are attacked only slightly. Thus, the C/N ratio is narrowed only a small amount.

The period of very high microbial activity lasts from 1 to a few weeks. Most of the organisms involved can respond quickly to the presence of readily available food, grow rapidly, and produce resting structures, principally spores. These microbes are generally poor competitors and have low tolerance of antibiotics. Thus, their chief advantage is speed.

During the very early stages of rapid decomposition, soil oxygen often becomes temporarily limiting. This results in the incomplete metabolism of some constituents and the production of certain volatile organic compounds and some organic acids with low molecular weight which are toxic to germinating seeds and young plants. However, this plant-toxic period is short lived, nearly always less than 2 weeks and usually less than 1 [17], and toxic substances are easily metabolized as soon as the oxygen level permits. The important point for nursery managers is that it is frequently unwise to plant seeds of trees or green manure crops in soil less than a week after crop residue or other easily decomposed material has been added to the soil. This is not, however, a problem with compost or peat because both have passed this stage of decomposition [13]. Fresh sawdust or bark, at high rates of application, may cause some minor toxicity problems, but weathered bark or sawdust generally does not.

9.4.2 Less reactive organic materials

As the initial burst of microbial activity begins to diminish, a different group of microbes, composed principally of fungi and some actinomycetes, becomes dominant. This group can utilize the celluloses and eventually the lignins. The period of their activity is measured in months or years.

Again, several important changes—chiefly physical and chemical ones—take place in the soil. As organic matter particles break down, the macropore volume of the soil increases, which increases water infiltration and gaseous exchange. In fine-textured soils, surface crusting is reduced.

During this more leisurely phase of decomposition, the nitrogen in the system is passed efficiently from one crop of microorganisms to the next, as a significant amount of carbon is lost through respiration as CO_2. The result is a lowering of the C/N ratio. The general course of biological activity is to transform organic debris from identifiable particles composed of identifiable compounds to humified materials whose origin is impossible to detect and whose chemical composition is highly altered from the original. Early concepts of humus formation held that humus represented biochemically altered lignin [24]. But we now know that humic substances are resynthesized by microbes and are not simply degraded lignin [22].

Humic substances affect the soil in many ways:

- They are brown or black, which facilitates soil warming.
- They readily retain water and thus are particularly important in sandy soils.
- They combine with clays to stabilize soil structure.
- They are highly buffered and so help stabilize the soil reaction (pH).
- They have very high cation exchange capacities (CEC) -some exceed 1,000 milliequivalents per 100 grams of soil-and thus increase the soil's CEC and hence its ability to hold cations against leaching.

- They slowly mineralize and provide plant-available sources of nitrogen, phosphorus, and sulfur.
- They readily combine with many organic molecules such as pesticides and thereby affect the application rate needed for effective pest control.

The turnover rate of organic matter may seem difficult to determine because some fractions are metabolized in a few hours whereas others may require centuries. However, in many soils, added organic matter decomposes at rates which metabolize about 2/3 of the material in 1 year and 4/5 of it in 2 years.

One possible complication can arise in assessing the effect of added organic residues on soil organic matter. Once soil microorganisms become stimulated ("primed") because of the added organic matter, they are likely to metabolize any organic material in the soil, including native organic matter. This was demonstrated clearly with a soil-incorporated sudangrass cover crop that was ^{13}C-labeled [5]. The fraction of ^{13}C-label in the respiratory CO_2 was related to the breakdown rate of both the sudangrass and the native organic matter in the soil. After the sudangrass was incorporated, the oxidation rate of the native organic matter more than tripled. Indeed, because of the priming action of the microorganisms, it is possible to add easily decomposable organic material to the soil and, following its normal decomposition, reach a soil organic matter level actually lower than if the material had not been added. This condition is restricted almost exclusively to easily decomposable materials such as immature green manure crops. It does, however, help us understand why increasing soil organic matter content with such crops is, at best, difficult.

One recent, interesting study [23] suggested that soil organic matter in Georgia might be maintained between 1.4 and 1.6% with green manure crops. The organic matter level increased soon after the various tested crops were turned under at the end of the first summer. However, this level did not change again, despite cover crops the succeeding winter and summer. A crop of 1+0 pine (*Pinus* spp.) was then grown in the nursery and soil organic matter content decreased to the pretreatment level during that growing season [pers. commun., 21]. Thus, the net flux for the 3-year rotation of green manure crops and tree seedlings was zero. The green manure crops had served a valuable purpose in the soil, but the gain in soil organic matter content lasted less than 1 year.

9.5 Sources of Organic Matter

As stated earlier, only two general sources of organic matter are available for nurseries: that which is grown as a cover, catch, or green manure crop on the soil into which it will be incorporated, and that which is brought to the site from elsewhere and incorporated into the soil (organic soil amendment).

9.5.1 Cover and green manure crops

Cover and green manure crops are important in the soil physically, chemically, and biologically and should be included in all nursery rotations (see chapter 10, this volume, for details). However, their potentially positive or negative influence on the succeeding tree crop needs more investigation.

For example, a periodically recurring outbreak of a *Fusarium* root rot in the Saratoga Nursery, New York, was traced to the use of buckwheat (*Fagopyrum sagittatum* Gilib.) as a green manure crop preceding the tree crop [8]. The problem was corrected by eliminating buckwheat as a green manure crop in that nursery. Green manure and cover crops also can be associated with beneficial microorganisms. Preliminary results indicate that the preceding green manure crop stimulated both mycorrhiza formation and seedling growth on endomycorrhizal hardwood seedlings in Virginia [unpubl. data, 20].

9.5.2 Organic soil amendments

Traditional organic soil amendments include sawdust, bark, peat, and manure. Because some of these are locally scarce or because other organic residues are locally abundant, a wide variety of other materials has been used on nursery soils with varying levels of success.

Briefly, this list includes: hammermilled cones from seed extractories; leaves collected from city streets; spoiled hay, straw, and other agricultural wastes; organic sludges including sewage, paper mill, fish, and mint; commercially processed and dried sewage sludge; brewery and cannery wastes; and spent mushroom compost. The *Western Fertilizer Handbook* [6] provides the nitrogen, phosphate, potash, and organic matter contents of a range of such materials. On an absolute scale, these amendments carry only limited amounts of mineral nutrients, but on a relative scale they vary greatly (Table 1).

It is difficult to generalize about such a diverse group of substances, but many have high ON ratios and thus require that extra nitrogen be added to the soil to avoid immobilization of soil nitrogen during the early stages of decomposition. The amount of nitrogen needed depends more on the ease of decomposition of the material than on its ON ratio. For example, sawdust from red alder (*Alnus rubra* Bong.) has a C:N ratio of 134, that from Douglas-fir a ratio of 623, and that from western hemlock *[Tsuga heterophylla* (Raf.) Sarg.] a ratio of 1,244 [2]. Even though it contains the most nitrogen per unit of carbon, red alder decomposes so readily that it required more supplementary nitrogen when added to soil than either of the other two species [3, 4]. As a general guideline for using Douglas-fir sawdust, Bollen and Lu [4] recommended applying from 5 to 10 pounds of actual nitrogen per ton of sawdust applied in the first year, with amounts halved in each of the following 2 years.

Table 1. Average analysis of organic materials (adapted from [6]).

Material	N	P_2O_5	K_2O	Organic matter
Bulky organics				
Pine sawdust	0.1	0.01	0.05	98
Steer manure[1]	2.0	0.54	1.92	60
Horse manure	0.7	0.34	0.52	60
Hog manure	1.0	0.75	0.85	30
Sheep manure	2.0	1.00	2.50	60
Poultry manure	1.6	1.25	0.90	50
Poultry droppings[2]	4.0	3.20	1.90	74
Seaweed (kelp)	0.2	0.10	0.60	80
Alfalfa hay	2.5	0.50	2.10	85
Grain straw	0.6	0.20	1.10	80
Organic concentrates				
Dried blood	13.0	1.50	……	80
Fish meal	10.4	5.90	……	80
Sewage sludge				
Digested	2.0	3.01	……	50
Activated	6.5	3.40	0.30	80
Castor pomace	6.0	2.75	0.50	80

[1]All manures include some bedding material.

[2]Droppings are bedding-free.

9.5.2.1 Sludge

The several sludges that are available vary widely in their composition. Thus, before any sludge is used, its chemical composition should be determined. This is especially true of sewage sludges. For example, in a study of the sludges produced in the Tualatin Basin of Oregon [19], Portland sludge was found to contain a higher concentration of lead, cadmium, nickel, and zinc than sludges from Forest Grove, Hillsboro, Oregon City, or Aloha, whereas Hillsboro sludge contained the most copper.

One difficulty in using sludges is knowing how much of any of these potentially toxic elements the soil can tolerate. A useful guide has been provided by Hausenbuiller [16] who stated that the tolerance level varies with the soil CEC. For each milliequivalent of CEC per 100 grams of soil, no more than 100 kg/ha (or lb/acre) of lead, 50 of zinc, 25 of copper, 10 of nickel, or 1 of cadmium should be allowed to accumulate in soil.

Most sludges have very high (close to 99%) water contents and consequently may be quite expensive to transport and spread. Even dewatered sludge cake, which must be handled and spread as a solid, is still at least 50% water.

Several cities thoroughly dry their digested sewage sludge and market it as a soil amendment. Such products are generally excellent soil amendments but are rather expensive to use. As a group, they tend to contain ample nitrogen and phosphorus but very little potassium. Some 25 U.S. cities are now using a new method of composting sewage sludge which provides a solid, easily handled, nearly odorless, weed-and-disease-free end product which may be particularly useful in forest nurseries [1].

9.5.2.2 Composts

Various composts can be used advantageously in nurseries. Generally, they are prepared by combining carbonaceous wastes such as sawdust with nitrogen and other nutrients contained in manures [14], sewage sludges [1], or chemicals [9, 11]. Such materials are placed in a suitable physical environment for several weeks. The end product, stabilized and pest-free, can be applied to soil immediately ahead of a seedling crop. The advantages of using composts are obvious. The disadvantages are that their preparation requires much prior planning and considerable handling of bulky materials. Costs vary tremendously, depending on the availability of the constituents.

Some unexpected benefits have resulted from using sawdust composts. Applying 40 yd^3/acre to a sandy soil increased the number of mycorrhizal roots of pine seedlings 50%, even though the compost itself contained no detectable mycorrhizal inoculum [unpubl. data, 10]. However, using spent mushroom compost as an organic amendment was disappointing. At reasonable application rates, excessive amounts of soluble salts can become a problem [unpubl. data, 12].

9.5.2.3 Application rates

Application rates of organic soil amendments are difficult to express. Volume (cubic yards per acre, cubic meters per hectare, or depth) is frequently mentioned, but compaction can vary greatly. Thus, the actual amount applied at the same apparent rate can vary considerably. Likewise, expressions of weight are quite arbitrary because of great variation in water content, especially for peat, which can easily hold several times its own weight in water. The only completely nonambiguous rate is oven-dry weight per unit of area; though fine for research, measuring oven-dry weight is seldom operationally practical. Application rates should probably be expressed in terms of volume, with the organic amendments moist but not saturated and not compacted.

In the OSU Nursery Survey, five groups of nonaqueous materials were listed: (1) sawdust and bark, (2) peat, (3) compost, (4) manure, and (5) sludge. Application rates were given principally in terms of volume (cubic yards per acre or cubic meters per hectare). Cubic yards per acre doubled approximately equals cubic meters per hectare. Thus, some comparisons can be made with all rates converted to the cubic yards per acre equivalent (Table 2).

Table 2. Application rates of organic soil amendments.

Amendment	Application rate: Range	Typical
	yd^3/acre	
Sawdust and bark	90-270	100
Peat	100-270	100
Compost	40-270	50
Manure	30-100	50
Sludge	80-100	80

Suppose, for example, we apply Douglas-fir sawdust at 100 yd^3/acre per rotation. In addition to assumptions noted earlier, we will assume that the oven-dry weight of a cubic yard of the sawdust is 500 lb and that the soil down to the bottom of the rooting depth weighs 2,000,000 lb/acre. Finally, because of the length of a typical rotation in Northwest nurseries, approximately 90% of the added sawdust will be gone by the time we are ready to add more at the beginning of the next rotation. We can then calculate the immediate effect on soil organic matter content, the effect at the end of 1 year, and the effect at the end of the rotation:

Immediate effect

100 yd^3 of sawdust at 500 lb dry weight/yd^3 = 50,000 Ib/acre of sawdust; 50,000 lb of sawdust added to 2,000,000 lb/acre of soil represents an immediate increase of 2.5% in soil organic matter content.

At end of 1 year

Research has shown that, generally, 2/3 of the sawdust will decompose during the first year and 1/3 remain in the soil; 1/3 of the immediate 2.5% gain represents a 0.8% gain in soil organic matter content at the end of the first year.

At end of rotation

Though 90% of the sawdust decomposes during the rotation, 10% remains in the soil; 10% of the 2.5% immediate gain represents a 0.25% gain in the nearly stable fraction of the soil organic matter content.

This may seem like a small victory, but it is solid progress nonetheless and is much better than can be done with cover or green manure crops.

9.6 Conclusions and Future Outlook

In sum, organic matter is good for the trees, good for the soil, and perhaps even good for the soul. Some sources of organic matter, like green manure crops, can be home grown; others, like sawdust, peat, or manure, must be imported. Some organic matter is dynamic and highly reactive. It decomposes rapidly but favorably affects soil biology and, to some extent, physical and chemical soil properties. Some is more stable and less reactive. It decomposes slowly, its rate decreasing with time. But eventually, it is fully resynthesized into true humic materials and only many years later is totally metabolized and eliminated from the soil. During all this time, perhaps over centuries, it favorably affects physical and chemical soil properties and, to some extent, soil biology.

Nearly all nursery managers see soil organic matter maintenance as an important step in the production of quality trees. Actual management strategy among nurseries varies considerably, though, primarily because of soil properties, climate, and local availability of organic amendments.

The best information currently available suggests that a shortage of the traditional organic amendments is likely in the foreseeable future. Therefore, we need to devote some time and resources to studies of catch, cover, and green manure crops; to alternative sources of organic amendments; and to changes in rotation schedules. Certainly, we now grow fewer transplants than we did only a few years ago. The proportion of 2+0 and plug + 1 stock has increased considerably. Each of these changes offers the opportunity to use more green manure crops and add more organic amendments to the soil over any number of years.

We can be cautiously optimistic about the future. Organic matter is as essential as nutrients and water to producing quality trees. Fortunately, we have more time to make appropriate additions to the soil. Unfortunately, this has lulled some nursery managers into a false sense of security, and they have let their soils become depleted. A whole litany of physical, chemical, and biological problems can then ensue, and it may not be immediately apparent that loss of organic matter is the cause of them all.

The road back to soil and tree health is long and difficult. Thus, prudent nursery managers will not neglect soil organic matter. Rather, they will determine the appropriate level for the existing soil and climate and design a steady, deliberate management program to reach and maintain that level.

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