ORGANIC MATTER MAINTENANCE IN SOUTHERN PINE NURSERY SOILS

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ABSTRACT

Ever since organic matter (OM) was shown to have decided effects on plant growth, its maintenance has carried a position of prominence in soil management. The problems associated with OM maintenance are nowhere more appreciated than in soil-based nursery systems. The moist but well-aerated soils and frequent nutrient additions in most nurseries produce ideal conditions for microbial oxidation of organic residues. OM has stable and dynamic components; it is the stable fraction we attempt to maintain, and do so by manipulating the dynamic fraction. As forestry operations, of which nurseries are a part, face tightening economic constraints, nursery managers must evaluate the cost:benefit ratio of OM maintenance practices. OM maintenance is costly, whether accomplished with cover crops or imported materials. One must take into account the cost of production or material acquisition, along with residence time in the soil and relative value of the material as OM. Also, the opportunity costs of various OM management programs must be considered. Quantitative information is still lacking on the benefits of OM to a seedling crop. This is the result of 1) lack of a clear measure of seedling quality, and 2) lack of a sustained OM research program. This information gap must be filled by a cooperative and sustained effort by researchers and nursery personnel.

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INTRODUCTION

A chronological sequence of investigators, including Bacon, Van Helmont, Boyle, Glauber, Mayow, Woodward, de Saussure, Liebig, and Lawes and Gilbert, conducted trials and observations which eventually demonstrated the great influence of soil organic matter (OM) on plant growth and development (Russell 1973). Technological advances in recent decades have brought about a more precise characterization of OM. Excellent review of the formation, composition, function and fate of soil OM is provided by Waksman (1938), Kononova (1961), Schnitzer and Khan (1972, 1978), and Allison (1973).

Ever since OM was shown to have decided effects on plant growth, its maintenance has carried a position of prominence in soil management. Because of decomposition, the task of maintaining a given level of OM is never accomplished. Several investigators have demonstrated the rapid decomposition rates of agronomic crop residues and green manures. For example, Parker (1962) showed a 65% loss of cornstalk residue when buried in the soil for 20 weeks. Brown and Dickey (1970) reported losses of 50% in 3 months and 93% in 18 months for wheat straw buried in soil. Sain and Broadbent (1977) showed a 40% loss of buried wheat straw between November and April. More substantive reviews of the decomposition of agronomic crop residues have been provided by Russell (1973) and Allison (1973).

The problems associated with OM maintenance are nowhere more appreciated than in soil-based nursery systems which produce ornamental or forest tree seedlings. The moist but well-aerated soils and frequent nutrient additions in most nurseries produce ideal conditions for microbial oxidation of organic residues. The problem is further accentuated by complete crop removal, as opposed to most agricultural crops where much of the plant remains in the field after harvest. Organic matter maintenance programs in the nursery have ranged from non-existent to excessive. Each nursery must form a program based on climate, soil conditions, cropping sequence, economics and availability of appropriate organic materials. This paper briefly reviews the benefits of OM, then discusses the costs of OM, and finally offers a few suggestions for future direction. The intent is to stimulate thought, and perhaps re-assessment of our current OM maintenance strategies.

WHAT ARE WE TRYING TO MANAGE?

In order to manage soil OM, we must understand what OM is. There are three components of soil OM: 1) living microbial cells and plant and animal tissues, 2) remnants of microbes, plants and animals in different stages of decomposition, and 3) humic substances (Davey and Krause 1980). It is fairly easy to develop a visual image of the first two types of OM, but the third is less clear. Humic substances (humus) are the result, or end-product, of microbial breakdown and re-synthesis of relatively simple compounds (item #2 above) into more complex and stable compounds of high molecular weight. Humus can be subdivided into humin, humic acids and fulvic acids (Flaig and others 1975). Humus accounts for the majority of the exchange capacity in light-textured nursery soils.

For the purpose of management, it is convenient to consider OM as consisting of two fractions: stable and dynamic. In the preceding paragraph, the first two OM components can be considered dynamic, while humus can be considered stable. Stable is a relative term; humus is subject to slow decomposition and thus to maintain a given level requires input of "raw materials." It is this stable fraction we attempt to maintain, and do so by manipulating the dynamic fraction.

Davey and Krause (1980) note that the stable OM fraction has an equilibrium level which varies with geographic location. For example, the cooler temperatures and often finer-textured soils in the more northern nurseries result in OM equilibrium levels of 3 to 5%. In the lower coastal plain of the southeastern United States where soils are sandy and warm temperatures prevail, this level is often near 1%.

The purpose of the preceding discussion was to provide a general overview of the character of soil OM. From this point, we will review the benefits of OM, then pose some questions/suggestions about our current OM maintenance strategies.

BENEFITS OF ORGANIC MATTER

Some have suggested that bareroot nurseries are analogous to hydroponic systems in that lack of OM and clay can be offset by frequent fertilizer additions. As Stone (1980) points out, this is not realistic because maintaining a continuous nutrient supply is not feasible in a large-scale operation unless some OM is present.

Studying or even thinking about soil OM is not a favorite pastime of very many people. But consider for a moment: If asked to defend expenditures for cover cropping or importing organic materials, what information can a manager present?

Of all the components of a nursery operation, it is likely that none provide as many important benefits as OM. Is our level of management in line with OM's level of importance? At this point, a review of the benefits of maintaining or increasing OM is in order (adapted from Blumenthal and Boyer 1982; Stone 1980; Davey and Krause 1980; Brady 1974):

Soil Physical Properties

- Water-holding capacity increased
- Porosity, friability increased
- Resistance to compaction increased
- Surface crusting, sand splash reduced
- Deep cover crop roots improve subsoil structure and porosity

Soil Chemical Properties

- Cation exchange capacity increased
- Nutrient leaching losses reduced
- More continuous supply of nitrogen
- Buffering capacity increased
- pH fluctuations reduced
- Total nitrogen reserve increased
- Micronutrient supply and availability increased
- Phytotoxicity of certain pesticides reduced

Soil Biological Properties

- Energy source for microbes increased
- Mycorrhizal development enhanced
- Saprophytic microbe population increased
- Increased microbe population may regulate pathogenic component

With OM benefits in mind, attention will next be turned toward the cost of OM maintenance programs.

COST OF ORGANIC MATTER MAINTENANCE

As forestry operations, of which nurseries are a part, face tightening economic constraints, managers must look at all practices from the cost:benefit perspective. How much of our current soil management practices are based on empirical evidence? on intuition? on conventional wisdom? on economics? What is the cost of an organic matter maintenance program? These are questions that a few nursery managers could answer, but many could not. If we claim to know the benefits of OM, it seems necessary to know the actual cost. While it may be difficult to place a dollar value on various OM benefits, it is relatively easy to calculate a cost and provide a basis for comparison of OM maintenance activities.

For this discussion, consider the two general categories of OM described by Davey and Krause (1980): material grown on the site (cover crops) and material imported (sawdust, wood chips, bark, peat, sludge, etc.). First, let's consider cover crops. For practical use, a cost analysis must be done with nursery-specific data. The following example is intended to be a point of discussion and in no way is meant to represent all nursery situations. Table 1 presents the cost per hectare for a hypothetical cover crop of sorghum x sudangrass (sudex) hybrid growing in a lower coastal plain nursery.

In this example, fixed and variable costs total \$1,215.57/ha. If we assume that drymatter production on this hypothetical hectare is 22.4 mt (generous assumption), then the production cost/mt of drymatter is \$54.27. If only 5 mt of drymatter (a more realistic figure) are produced, the cost runs up to \$108.53/mt.

One unique feature of this analysis is the suggested land rent of \$618/ha (See Table 1 for derivation). Typical agricultural land would probably have land rent values near \$62-\$86/ha. The point is, nursery land is expensive so a realistic land rent value must be used.

Table 1. Cost per hectare for a hypothetical cover crop of sorghum x sudangrass (sudex) hybrid growing in a lower coastal plain nursery (Adapted from T. D. Hewitt 1985, Food and Resource Econ. Dept., Univ. of Florida).

Item	Quantity	Price or Cost/Unit	Value or Cost
		--------Dollars--------	
Cash Expenses			
Seed	17.9 kg	0.77/kg	13.78
Fertilizer	448 kg 10-10-10	0.28/kg	125.44
	224 kg NH_4NO_3	0.55/kg	123.20
Pesticides	2.2 kg AAtrex	7.61/kg	16.74
Irrigation	6 applications	16.06/ha	96.36
Machinery	1 hectare	3.95/ha	3.95
Tractor	1 hectare	24.09/ha	24.09
Labor	1 hectare	11.74/ha	11.74
Land Rent	1 hectare	618.00/ha[1/]	618.00
Interest on Cash Expenses	$1,033.30	.13/yr	134.33
Total Cash Expenses			$1,167.63
Fixed Costs			
Machinery	1 hectare	9.27/ha	9.27
Tractor	1 hectare	17.05/ha	17.05
Taxes	1 hectare	12.35/ha	12.35
Total Fixed Costs			$ 47.94
Total Costs			$1,215.57

1/ Derivation: Assume market value of intensively prepared land including irrigation system is $9,975/ha, and that alternate investment opportunity exists at 6.2% annual yield. $9,975 x 6.2% = $618; this is the annual cost of owning the land under these assumptions).

Now consider the other option - importing organic material. Two factors play a large role in the cost of importing OM. First is the cost per unit of material; second is the haul distance between the source and nursery. Most organic materials such as sawdust and bark are sold by volume rather than weight. To make a valid comparison we must set some assumptions and convert volume to weight. The question of practical interest is, "What is the cost per dry ton of material delivered to the nursery site?". The following example, using peat and sawdust, illustrates the process.

Assume that:

- Haul distance between the source and nursery is 48 km, or 96 km round trip, at a cost of $1.55/km.
- Vehicle hauls 57 m^3 per load.
- 316 m^3 is required for a 3.17 cm layer of material over a hectare. This approximates 22.4 mt of dry material per hectare.
- Cost of application and incorporation is considered equivalent to the cost of chopping, discing, plowing and incorporation of a cover crop. This cost is not included in the analysis.

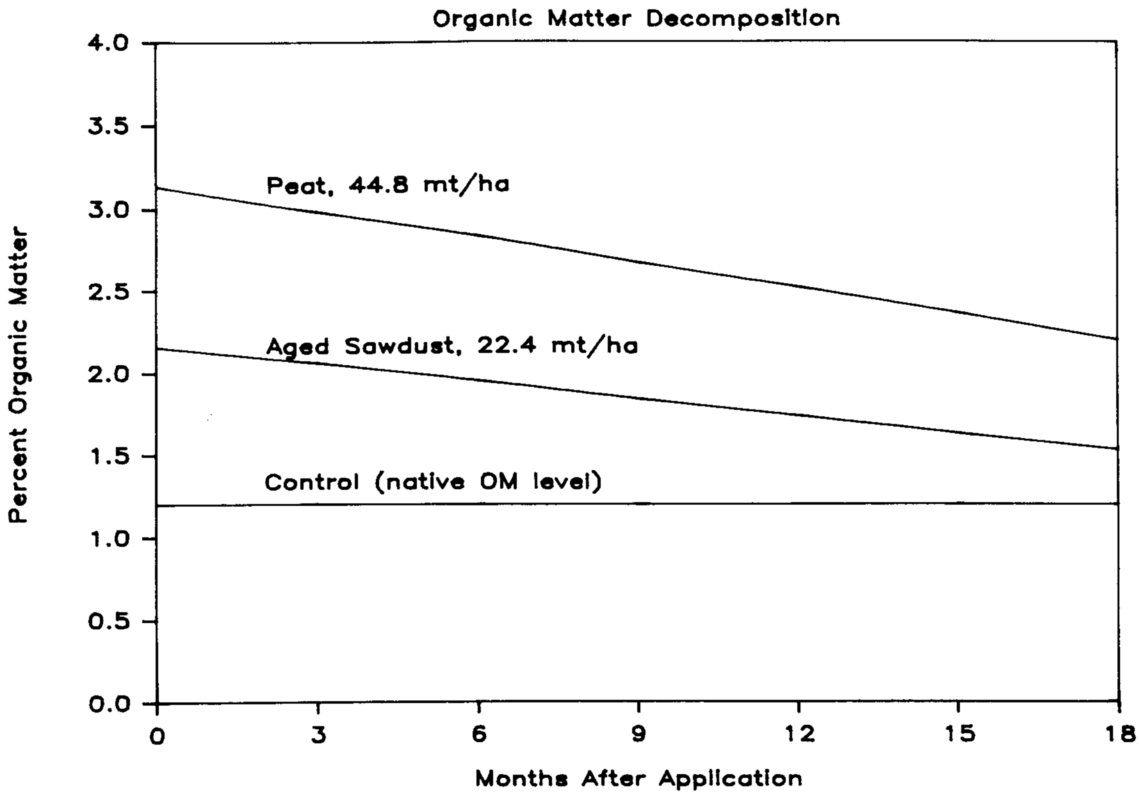

Figure 1. Organic matter decomposition in a north Florida nursery soil amended with aged sawdust and peat (adapted from Munson 1983).

Using these assumptions, the cost per year of benefit for the materials is:

Sudex: \$108.57 divided by 1.25 years = \$86.86
Sawdust: \$ 73.79 divided by 3.30 years = \$22.36
Peat: \$129.11 divided by 3.30 years = \$39.12

From this perspective sawdust provides the best value followed by peat, then sudex (by a large difference).

One can make the argument, however, that the OM is of little value until it is decomposed. This is true with respect to exchange capacity (of woody material such as sawdust; not so for peat), but many of the effects of undecomposed material on soil physical and biological properties are realized soon after addition.

Unmentioned thus far are the quality differences between a cover crop, sawdust and peat. These can be characterized as follows:

Cover Crop
- decomposes quickly
- wide range of constituents from simple sugars to lignins
- deep rooting; subsoil benefits
- low C/N ratio (N-source)
- may cause priming effect and lower native OM level
- decomposing crop releases nutrients

Sawdust

- o slower decomposition than cover crop
- o narrow range of constituents
- o high C/N ratio (N-sink)
- o low CEC
- o effective in zone of application

Peat

- o slower decomposition than cover crop
- o intermediate range of constituents
- o low C/N ratio (N-source)
- o N-release proportional to decomposition
- o high CEC, buffering capacity
- o effective in zone of application

These characteristics should be considered when selecting a material to ameliorate a certain soil condition. Based on observations, the author considers cover crops and peat to be high quality OM, while sawdust is mediocre at best. Combining acquisition cost, residence time and quality, peat is the preferred material in this example.

Implicit in the previous example in deciding between a cover crop or sawdust was that a seedling crop would follow immediately either activity. If fresh sawdust were used, this would not be feasible due to the potential nitrogen nutrition problems associated with incorporating high C:N ratio materials. In this case, one would likely grow a cover crop in the sawdust-amended soil before sowing a seedling crop. On the other hand, if aged sawdust were used, it may be feasible to follow its incorporation with a seedling crop. Similarly, many peat materials can be applied just ahead of a seedling crop.

This analysis of OM materials or practices is not complete until we consider the value of lost revenue from land growing a cover crop rather than a seedling crop.

Opportunity Cost

The demand for tree seedlings has been a cyclic phenomenon for several decades. When seedling demand is high, nursery managers usually have two choices: either continue a cover crop rotation and forego some revenue, or grow continuous seedling crops. There is an opportunity cost associated with each option.

If a manager chooses to grow a cover crop rather than a seedling crop, one must add to the cover crop cost the value of lost seedling revenue (opportunity cost). As an example, consider a nursery that produces 1.42 million packable seedlings per hectare at a cost of $15/thousand seedlings (M). If these seedlings are sold for $17/M, profit is $2/M, or $2,840/ha. This, added to the cover crop production cost of $1,216, yields $4,056/ha. This is a large sum of money to pay to cover crop a hectare.

The opportunity cost of continuous seedling cropping is more difficult to quantify. A key, unanswered question is "what effect does continuous cropping with additions of imported OM have on soil productivity?" This question can be answered only by long-term OM research, trials or observations in the nursery; until then we can only speculate. Since our definition of seedling quality (in nursery economics terms) is based on morphological standards, we would measure a decline in soil productivity indirectly by measuring the decline in packable seedling yields per hectare. This yield reduction (if in fact a reality) can be converted to a dollar amount, which then becomes the opportunity cost of continuous seedling cropping.

This example does not endorse continuous seedling cropping in perpetuity as a management practice. What it suggests is that cover cropping is expensive, and if done for the sole purpose of OM, in many cases may not be justified economically. It is important that the best information available be used and all options be explored when formulating an OM management strategy. Such a decision will involve facts, experience and common sense which would ultimately be used in a cost : benefit analysis.

COST : BENEFIT ANALYSIS - A HYPOTHETICAL CASE

If we could relate OM to seedling yields, either directly or indirectly by improving soil conditions, a cost : benefit analysis could be conducted. Following is an example of how an OM application could be evaluated on an economic basis:

Situation

- A nursery manager has decided that an application of OM is necessary to improve drainage and reduce compaction in a block that has recurring disease problems and subsequent low yields.
- There is a peat source 48 km from the nursery; cost/dry ton/year of benefit is $39.12 (as derived earlier in this paper).
- The manager plans to apply 22.4 mt/ha, for an "adjusted" annual cost of $876.29/ha.
- Target seedling yield is 1.92 million/ha.
- Records at the nursery show yields are near 1.36 million/ha
- Yield losses are thus 560 M/ha.
- Seedlings sell for $17/M.
- All costs for growing, land rent, equipment and grading have been incurred, so the real loss is $17/M or $9,520/ha.

Analysis

- The practical question is, "How much would yields have to increase to justify spending $876/ha on OM?"
- To answer this, calculate the breakeven point:
  $876/ha divided by $17/M seedlings = 51.5 M seedlings/ha (breakeven yield increase)

  $$\text{then, } \frac{\text{51.5 M seedlings (breakeven yield)}}{\text{1.36 MM seedlings/ha (historical yield)}} \times 100 = 3.8\%$$
- Thus, if the manager predicts a yield increase of more than 3.8% by the addition of the OM, the decision is economically justified.

When solving a particular problem, such as in this hypothetical case, a manager must choose a cost effective solution that has a high probability of success. Weighing the cost of implementing the prescription against the anticipated yield increases provides a rudimentary cost : benefit analysis.

This leads into the final portion of this paper, which suggests a direction to our quest for more complete answers to our OM questions.

OUTLOOK FOR ORGANIC MATTER

Nursery managers deserve recognition for being some of the most resourceful individuals in the agricultural/forestry business. With varying degrees of success, they have applied agricultural technology to situations in the nursery. But what have we really learned about OM? Do we know enough about OM? Can we biologically and economically justify the OM strategies that we use?

Reviewing the literature reveals a modest amount of work on specific components of the OM issue. We know the relationship between OM and exchange capacity and water holding capacity. We know that microorganisms are associated with OM. What, then, is the limiting factor that prevents us from linking past research results into a more definitive picture of OM maintenance?

I suggest that our limitation is twofold. First, we do not have a good quantitative definition or measure of seedling quality. Our standards now consist of height, diameter, stem and root form, and evidence of damage. We spend a great deal of effort developing production statistics, such as thousands of seedlings packed per man-day. But how do we keep track of the quality of our product? Physiological attributes such as root growth potential must be further developed and infused as seedling quality standards. Only then can we definitively relate nursery practices, such as soil OM maintenance, to seedling quality. For the near-term, however, we can weigh the cost of an OM program against the benefit of higher seedling yields.

The second limitation is the lack of a sustained nursery research program. With a few exceptions, most research has been of short-term nature, usually in response to a specific problem. Such problems as diseases and insects are visible and relatively easily attributed to a specific pest. Once a solution is found, the pest can be controlled fairly quickly; furthermore, the solution is applicable to the same problems at many nurseries. In contrast, soil management, especially OM level, is not visible and is unglamorous. The loss of nursery soil productivity via OM decomposition is an insidious process, and hence not very much of a "squeeking wheel." Few studies have tackled the question of OM decomposition under actual nursery conditions. Broad-scale application of results from studies of this nature is constrained by the fact that decomposition is a function of nursery-specific soil properties, management practices and climatic factors.

Most soil management practices interact with each other. To add another dimension to this discussion, consider OM and fumigation. It has been speculated that maintaining a diverse saprophytic microbial population may keep pathogenic organisms in check such that fumigation may not be needed. In most nursery soils, the only way to increase the microbial population is to increase the OM substrate.

If this speculation is true, would money spent on fumigation be better spent on OM? This is an unanswered question, but nonetheless important.

Soil OM studies must have management commitment and be of long-term. Historically, many research efforts have been short-term. Perhaps our approach to OM research should be altered. It is proposed that such studies be initiated at the nursery level, with consultation from technical specialists in soil science.Relative to other types of research, OM studies are inexpensive. Long-term studies initiated, installed, landmarked and maintained by nursery personnel will endure short-term turnover in public and industrial researchers. Small areas within a nursery can be dedicated to concurrent seedling production and research. Questions about the effects of continuous seedling cropping with OM additions on soil productivity can only be answered in this way.

A large sum of money is spent each year on OM maintenance of one form or another. These strategies are based on some fact, some "conventional wisdom," and some intuition. It's time we had more facts. Nurseries must recognize that long-term OM research, which may take the form of operational trials, should be initiated and maintained internally rather than relying solely on external agencies to answer these nursery-specific questions. In the interim, we should use all the information at hand to more objectively and quantitatively assess our OM maintenance programs.

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