THE QUALITY OF NYS AGRICULTURAL COMPOSTS

Final Report of the

COMPOST MARKETING AND LABELING PROJECT

Prepared by

THE CORNELL WASTE MANAGEMENT INSTITUTE

Ithaca, NY

Ellen Z. Harrison

Director

Prepared for

THE NEW YORK STATE

ENERGY RESEARCH AND DEVELOPMENT AUTHORITY

Albany, NY

Tom Fiesinger

Project Manager

NYSERDA

Report 6593

July 2003

Abstract and Keywords

Many livestock farms are employing composting as a means to manage manure. Finding markets for these composts is important. Label or seal of quality for consumer identification is desirable for consumer identification of compost quality. Several such programs exist but do not fully address consumer needs. However, establishing a new program would be difficult and it is not clear that it is warranted. There are few data regarding agricultural compost quality. Samples taken of ready-to-use composts from 25 NYS dairy and poultry farms were analyzed for many parameters and data was collected on composting practices. These NYS manure-based composts were suitable for many uses. They were generally low in heavy metals. Nitrogen levels from the sampled dairy composts ranged from approximately 0.5-3%. Measurements of fecal coliform levels were generally low. The pH of most of the composts was above 7. The percentage of organic matter was highly variable among the composts tested, ranging from about 25-75%. Most composts tested were more dense and less mature than suggested in guidelines for most uses. Samples were taken from each farm at least two different times. The data showed that for about a quarter of the farms, there was a significant difference in some of the measured parameters between the different sampling dates, which may reflect sampling a different batch or pile. The quality of the composts was found to be affected by composting methods used and by manure type (poultry, unseparated dairy, separated dairy).

Keywords:

compost; manure; compost use; windrow; compost specifications

Acknowledgements

Without the cooperation and participation of 30 compost producers in NYS, this project would not have been possible. Their willingness to take samples, answer questions and share information is greatly appreciated.

The contribution of Cornell Waste Management Institute personnel who worked on this project included many hours of field work, digging into compost piles to obtain samples and tedious hours pouring over data. Many thanks to Dan Olmstead whose knowledge of statistical analysis grew exponentially with this project; Molly Moffe who gathered information on guidelines for compost use; Christine Banks who developed the web pages on compost use guidelines; and Lauri Wellin who kept the pieces together. Particular recognition is deserved for Jean Bonhotal whose practical and detailed knowledge of NYS compost production and producers makes t his project part of a program that helps develop the knowledge and actions needed to make composting a viable means of managing organic residuals in NYS. Will Brinton at Woods End Research Laboratory was a key participant in the project. His knowledge and insights about compost quality and testing and data analysis and interpretation were critical to the project's success. Tom Fiesinger, project manager at NYSERDA, was in integral member of the project team. His administrative management was constructive and he provided thoughtful input to all aspects of the project.

Table of Contents

SUMMARY

Composting and marketing of composted manure is one option being used by livestock farms for managing manures. Revenue from compost sales is needed to support environmentally- sound and energy-efficient manure management composting systems. However many farms have difficulty finding markets for their composts. Consumers have little knowledge of compost qualities and sources. Few data exist on the quality of agricultural composts.

We investigated the potential for a label or seal of quality program to help consumers identify quality composts. We also investigated what guidelines are available that identify qualities desirable for composts in specific uses. There is inconsistency among the relatively few guidelines that exist. The potential for compost producers to provide quality information to consumers regarding their compost is hampered by fertilizer rules which prohibit a product from stating nutrient content unless meeting fertilizer regulations. Unfortunately those regulations were developed before compost was a common product and they are not appropriate for compost.

A survey was conducted to determine the composting practices and the quality of composts on 25 NYS livestock farms. Differences between poultry, separated and unseparated dairy manure composts were evaluated, as were the relationship of compost quality to various other factors such as bedding materials, type of pad beneath the compost piles, use of bucket turner vs. dedicated windrow turner and frequency of turning.

Compost samples were obtained from piles that the farmer considered ready to use. At each farm between 4 and 12 composite samples were analyzed during the course of the project. Composites consisted of 16 grab samples mixed together. Two to four replicate composite samples were obtained at each sampling event at each farm.

Using a scoring system developed by Woods End Research Labs, 18 of the 25 tested NYS manure-based composts were found to be suitable for use as garden compost, 10 for use as a seed starter, 9 as a nutrient compost and 4 for container mix. All the composts tested were found to be generally low in heavy metals, with concentrations well below guidelines. Most guidelines relied on metal limits established by USEPA for sewage sludge composts. On farms using copper sulfate, copper levels were somewhat elevated, but only one reached approximately half the guideline concentration. Nitrogen levels (TKN) from the dairy composts ranged from approximately 0.5-3%. Measurements of fecal coliform levels show that only one farm had average levels that exceeded1000 MPN, the level that sewage sludge composts must meet to qualify as “Class A” under federal and NYS rules. Seven farms had one or more samples that exceeded 1000 MPN. The pH of most of the composts were above 7 and quite a few were higher than suggested guidelines for many uses. The percentage of organic matter was highly variable among the composts

tested, ranging from about 25-75%. Most composts were more dense and less mature than suggested in guidelines for many uses.

Replicate composite samples obtained from the same compost pile showed a considerable range for some parameters at some farms while others were relatively consistent. This is demonstrated in the bars in the graphs presented in Appendix I. For example, TKN levels were relatively constant, while organic matter was variable in many composts. For samples taken the same day, variability indicates heterogeneity within the pile. This heterogeneity did not decrease with increased turning or with the use of dedicated turning machines. Heterogeneity presents a challenge for sampling and characterization of composts.

Samples were taken from each farm at least twice. The data showed that for about a quarter of the farms, there was a significant difference in some of the measured parameters between the different sampling dates. At some farms these may have been samples of the same pile taken at different times, however at other farms they may have been samples of different piles.

The properties of the composts varied with different compost types and processes. Different manure types (separated and unseparated dairy manures and poultry manure), turning methods (bucket-turned windrows, compost windrow turners, and passively aerated windrow systems), turning frequency (low turning frequency (less than 12 times/year) and high turning frequency (more than 12 times/year), type of pad for the compost pile (dirt, gravel or improved) and use of screens all affected aspects of compost quality such as organic matter and nitrogen content, weed seed content, C:N ratio and density.

It is clear in examining the data that the qualities and traits tested in composts reflected conditions prevailing within individual operations. Some of these circumstances can be controlled; others depend on factors that are not readily controlled. There were often trade-offs whereby enhancing one attribute was accompanied by diminishing another, thus there is no single “best” method for composting. For example, more frequent turning resulted in fewer weed seeds and greater maturity, but reduced organic matter and TKN. It may be useful to consider specific modifications in aspects of the composting process at a particular farm to alter compost properties in order to meet specific user needs.

COMPOST MARKETING AND LABELING PROJECT: FINAL REPORT

INTRODUCTION

Livestock on New York State's farms produce on the order of 15,000,000 tons of manure per year. Improper management of this manure can lead to runoff of nutrients, pollution of watersheds, and contamination of groundwater. With greater attention focused on these issues and the implementation of the new regulations for the large concentrated animal feeding operations (CAFOs), farmers are facing increased expenses to properly manage this large volume of waste. More and more farms are unable to landspread their livestock manure on nearby fields. Composting and marketing of composted manure is one option being tried by both small farms and large ones and by farms that have energy-producing anaerobic digesters. Revenue from compost sales are needed to support environmentally- sound and energy-efficient manure management composting systems. However many farms have difficulty finding markets for their composts.

Availability of sufficient quantities of a consistent product meeting user quality needs is important to enhancing markets. Sampling of commercially marketed, bagged composts shows that the quality is not specified and is highly variable (Long, 1999). Testing has not been required for agricultural composts which are not subject to environmental regulations, in contrast to sewage sludge-based composts. Thus there is little data on the quality of manure-based composts, which hampers their marketing.

Energy use and related environmental impacts will be reduced when composts are acquired from local sources rather than being transported from afar. Thus it is desirable for compost users to obtain suitable composts from near-by sources.

The properties that are important for different end uses vary, so that, for example, use of composts in potting mixes requires different characteristics than use for erosion control. Many potential compost users are not knowledgeable about compost properties and use.

OBJECTIVES

The overall goal of this initiative is to expand the marketing of quality New York State (NYS) agricultural compost and reduce the costs of managing agricultural residues. This project is designed to develop a proposed voluntary testing and information delivery program that will give compost users assurance of the quality of agricultural composts and information they can use to match compost characteristics with different compost uses. It is anticipated that the implementation of such a program will expand compost marketability and increase its value and the volume of sales. This will improve the economic viability of composting and anaerobic digestion, which will bring needed improvements in farm residue management.

Specific task objectives of this project include:

1. Develop and pilot a testing program for New York State agricultural composts;
2. Develop guidance for compost use to assist agricultural composters in providing guidance information on compost use for their customers;
3. Interpret the results of the testing program and its implications for a voluntary testing and information delivery program;
4. Work with interested stakeholders in the development of an implementable program to improve quality assurance of agricultural compost;
5. Work with interested stakeholders in the development of an implementable voluntary seal of quality program and/or other promotional program(s).

To achieve the objectives described above, the Cornell Waste Management Institute (CWMI) worked with subcontractor Woods End Research Laboratory (WERL) and consulted with the New York State Department of Agriculture and Markets (NYSDAM), NYS Department of Environmental Conservation (NYSDEC), and other stakeholders and interested parties including numerous compost producers, the New York Farm Bureau, Inc, the Organics Recycling and Composting Council of the New York State Association for Reduction, Reuse and Recycling, Inc., Empire State Development and the Northeast Organic Farming Association. In addition discussions were held with stakeholders in other northeastern states to explore the potential for a multi-state approach.

I. COMPOST LABELS, SEALS, SPECIFICATIONS AND USE GUIDANCE FOR CONSUMERS

One premise of this project was that implementation of a program that provided for a “seal of quality” and/or a label for agricultural composts could help promote them in the marketplace. Any successful program requires broad recognition among potential compost users, necessitating significant advertising. It also requires oversight to ensure that participants are meeting program requirements and “earning” the right to display the seal. Affordability to agricultural composters is another important consideration. Many farmers compost as a means to manage manure and do so on a scale that does not provide for expensive testing, registration and marketing.

There is a range of existing label, seal, specification and guidance programs. We compiled and reviewed all existing compost guidelines, label requirements, specifications for use and seal of quality or certificate programs that could be identified in order to consider their potential utility for achieving the project objectives. These are described briefly below (Table 1). We did not include those generated by a compost producer since those might be influenced by the attributes of their own compost. A number of European and Canadian countries also have compost guidelines or standards (Hogg et al. 2002 and Brinton 2000). A table summarizing each of them is found in Appendix H.

Table 1. Summary of Guidelines Provided by Compost-related Organizations

	Container Mix/Potting Soil	Topsoil Blend	NYS DOT Specifications	Vegetable Crops	Erosion Control	Nursery Beds	Turf Establishment	Backfill for Trees & Shrubs
Mulch & Soil Council	yes							
NRAES				yes				
NYS DOT			yes					
Rodale	yes							
US Compost Council	yes*	yes*		yes*	yes*	yes*	yes*	yes*

*Recommendations provided for two or more k as parameters are identical to other marked categories

Sources of information included:

- USEPA and NYSDEC: The environmental regulatory agencies at the federal and state levels have adopted rules pertaining to certain composts. Composts that include sewage sludges are covered by these rules. These rules pertain to environmental protection and do not address constituents or parameters that may be important to compost users but that do not have environmental implications. At the federal level and in most states (including NYS), agricultural and yard waste composts are not subject to such standards. Therefore these standards are not included in the discussion and analysis that follows. However, the guidelines for heavy metals adopted by the USCC are identical to the USEPA sludge standards.
- Mulch and Soil Council: formerly the National Bark and Soil Producers Association. The MSC mission is to "define quality products and promote and open marketplace for producers of horticultural mulches, consumer soils and commercial growing media." They have identified pH and soluble salt ranges for compost, topsoil and other products. http://www.nbspa.org/consumer/soilnomenclature.html
- Natural Resource Agriculture and Engineering Service: NRAES is an interdisciplinary, issue-oriented program sponsored by cooperative extension of fourteen member land grant universities. Their On-Farm Composting Handbook includes guidelines for compost used in agriculture (Northeast Regional Agricultural Engineering Service 1992).
- Rodale Organic Gardening Compost Quality Seal: A partnership between Rodale Organic Gardening and Woods End Research Laboratory (WERL), Inc. Rodale is well known as the publisher of Organic Gardening Magazine. WERL tests and conducts research on compost and produces compost testing kits and supplies. Under the Rodale Organic Gardening Quality Seal of Approval Program, compost producers submit samples to WERL where it is tested for key nutrients and trace elements, pH, C:N ratio, heavy metals, pesticide residues, weed seeds and pathogens. Where the product is not compost, but a soil amendment blend, the samples submitted are the final product and not the compost input. Based on the results, the tested material is then

classified for best use as seed starter, container mix, garden compost, topsoil blend, mulch or fertilizer. For the purposes of this project, specific values for parameters for the different uses were obtained from WERL on December 19, 2002. The program is designed to provide "a marketing edge for manufacturers, which can guarantee the quality of their products by displaying the seal on packaging and in promotions." Check for current costs. http://www.organicgardening.com/compostseal/ http://www.woodsend.org/pdf-files/seal_appl.pdf

- U.S. Composting Council: This not-for-profit organization published a USCC Field Guide to Compost Use which contains guidelines for different uses (US Composting Council 1996). They have also compiled specifications for compost use by state Departments of Transportation (US Composting Council 2001) and developed guidelines for use in the landscape industry and (US Composting Council 1997). USCC also created and administers the Seal of Testing Assurance (STA) program. Participating compost producers can display the seal if they submit samples to STA certified laboratories for analysis of selected physical and chemical parameters and meet standards for 9 metals equivalent to those required by US EPA for sewage sludges used as a soil amendment. There is no classification of composts for different uses. There is a fee for this program. Check for current costs. http://tmecc.org/sta/index.html
- State Departments of Transportation: A number of states have established specifications for compost used in transportation (DOT) projects. The USCC has compiled those in a publication (US Composting Council 2001). These specifications are used by DOTs as requirements for composts used in DOT projects. Since these differ from state to state, for this project we considered the NYS DOT specifications.

These various organizations have each published some specifications or guidelines for some or all of the following major compost uses:

- Backfill for Tree and Shrub Plantings
- Container Mix/Potting Soil
- Department of Transportation Uses
- Erosion Control
- Nursery Beds
- Topsoil Amendment
- Turf Establishment
- Vegetable Crops

The possibility of developing a new label or seal of quality program for NYS agricultural composts was explored through discussions with stakeholders including the agencies and organizations that might establish and administer such a program. The "Pride of New York" program of the NYS Department of

Agriculture and Markets was considered. This program provides a seal to specified agricultural commodities that meet certain requirements (these requirements vary with the particular product). It has been focused on traditional food products but does include a few turf and nursery products. Although the Pride of New York program does not appear ready at this time, compost products might be included in the future.

Consideration was also given to the potential for the NYS DEC to establish labeling requirements that might help meet project objectives. NYS DEC's role is to protect the environment. Most of the parameters of interest to compost users, such as weed seed content or water holding capacity, are not, however, related to the potential for compost to cause environmental problems and would not thus be among the items that NYS DEC could address. Thus a program through NYS DEC does not appear to be a feasible option.

Finally development and implementation of a labeling or seal program through either the Cornell Waste Management Institute or through the NYS Association for Reduction, Reuse and Recycling was considered. These possibilities were rejected due to issues of staffing, permanence, oversight and funding that would be needed for promotion of such a program. Refining existing programs is the preferred option.

One confounding issue in looking at the potential for a compost label program or even individual compost producers providing quality information to customers is that under NYS law (Article 10, Section 143-146) (http://assembly.state.ny.us/leg/?cl=4&a=23) and NYSDAM regulations, materials manufacturers making certain claims about their products in relation to plant nutrients fall under rules for fertilizers. Thus providing information regarding nitrogen, phosphorus, potassium, calcium, magnesium, copper, iron or zinc content, or even making a statement such as "helps plant growth", for example, would require that that product be registered as a fertilizer. Unfortunately, the fertilizer law was developed prior to the emergence of compost as a significant product in the market place. The current rules are not appropriate for composts which are a very different product. Composts, unlike most fertilizers, are applied as a soil amendment used to increase organic matter and establish beneficial microbial populations. Compost is not formulated, so it is a variable product. Fertilizer is used in pounds, compost in tons, so a per ton fee is not equitable. The rules also require labeling by product weight. Composts, unlike most fertilizers, are not dry products and the weight of a compost will change. One commercial compost producer reports overfilling bags by at least 10% so that loss of weight due to loss of moisture will not result in fines. Fertilizer rules would prohibit compost labels from including critical information such as organic matter content. To protect consumers, fertilizer laws require that any nutrient claims represent a guaranteed minimum nutrient content. However, composts exported from a farm that falls into the Confined Animal Feeding Operation (CAFO) rules are required to notify users of the average nutrient content. A farmer cannot simultaneously obey both. Finally specified test methods for fertilizers are not applicable to composts. (see Appendix D for summary of the incompatibilities of the fertilizer rules and application to composts.)

For several years the USCC has been working with the Association of American Plant Food Control Officials (AAPFCO) to develop a model law for composts and more recently to amend the model soil amendment law to make it appropriate for inclusion of composts. However, at this time there is no model legislation proposed or agreed upon. In NYS the fertilizer law exempts certain materials including "unmanipulated animal and vegetable manure." It would seem that composts produced from manure and vegetable matter might meet that criterion. If not, there is authority for the Commissioner of the Department of Agriculture and Markets to exempt additional materials. That would require a regulatory action. Another alternative is to adopt legislation to clarify the situation. A bill to exempt compost from the definition of a commercial fertilizer passed the NYS Assembly and Senate in June, 2003 and at the time of writing of this report it is awaiting the signature of the Governor.

Providing information to compost users in the form of both analytic data and a seal of quality remains an important goal. In the course of this project we identified few existing programs that can meet that need and determined that there is inconsistency among those programs in regard to recommendations concerning compost quality for different end uses. Because compost is a relatively new product, efforts are needed to work with compost end markets to identify compost traits and application practices necessary to meet their needs. At the same time, compost producers need to continue to work towards developing a consistent product and to test their composts periodically to determine the quality. An easy-to-read information label has been developed as part of this project (see Appendix G) and if the potential impediment of the fertilizer rules is overcome, this label might be used by compost producers and enable customers to be informed about the quality of composts they buy.

II. THE QUALITY OF NYS AGRICIULTURAL COMPOST

A survey was conducted to determine the composting practices and the quality of composts on NYS livestock farms. Exploratory testing was done prior to conducting the full survey in order to determine what parameters to include in the full survey, whether it mattered if the farmer or an experienced CWMI staff person collected the samples and whether depth into the compost pile had a significant impact on test results. The findings showed that the farmers could take samples, following sampling instructions provided by CWMI (see Appendix C). Depth was not a primary determinant of quality, but moisture, pH and conductivity were somewhat higher in the core of the several piles examined (see Appendix C). Parameters in the full survey were modified based on the pilot testing.

Samples were collected for laboratory analysis from 30 farms. (See Appendix E for descriptions of these farms and a map showing their locations and Appendix F for the analytic data for all of the compost samples.) Statistical evaluation was performed on 25 composting operations and this report is based on the data from those farms. Samples from 5 of the original 30 were determined not to be suitable for inclusion in the statistical evaluation and the discussion in this report. Those were a horse farm and samples from farms with raw, uncomposted dairy manure.

Differences between poultry, separated and unseparated dairy manure composts were evaluated. Seven of the farms in the project were composting poultry manure and 18 were composting dairy manure. Separators were used on 7 of the dairy the farms. They use physical processes to extract some of the solids which are then diverted to compost piles. The liquid fraction (which still contains approximately 40% of the total manure solids) is managed through other processes. Eleven of the dairy farms composted unseparated manure. The relationship of compost quality to various other factors such as bedding materials, type of pad beneath the compost piles and frequency of turning was also analyzed.

Compost samples were obtained from piles which the farmer considered ready to use. At each farm between 4 and 12 composite samples were analyzed. Composites consisted of 16 grab samples mixed together. Two to four replicate composite samples were obtained at each sampling event. Samples were analyzed by WERL using protocols consistent with the USCC guidance (USDA and US Composting Council 2002). Testing parameters and methods are briefly summarized below. (See Appendix B for a flow chart of lab procedures.) These parameters were selected because they are those routinely used to characterize composts or because they were identified as important to compost consumers through an earlier survey.

Testing Methods

Total Kjendahl Nitrogen (TKN). TKN was measured using TMECC Method 4.02 (2002).

Total Organic Matter (OM). OM was measured using TMECC Method 5.07 (2002).

pH and Electroconductivity (EC or salts). pH and salts were measured using a standard pH and EC probe, using a slurry, not a 1:5 dilution method.

Maturity. Maturity was measured by testing composts for CO2 and NH3 production using the Solvita method developed by Woods End Research Laboratory.

Density. Density was measured using TMECC Method 3.01 (2002).

Copper, Iron, Zinc, Arsenic, and Cadmium. Metals were measured using methods outlined in EPA 40 CFR Part 503 rules for Biosolids testing.

Fecal Coliform. Fecal coliforms were measured using methods outlined in EPA 40 CFR Part 503 rules for Biosolids testing.

Weed Seeds. Compost was diluted to a standard salt content using a professional peat-mix. Results were reported as number per liter.

Plant Response (Cress weight and germination). Compost was diluted to a standard salt content using peat and then seeded with Cress. Results were compared to a control group planted in a professional peat mix (Fafard B2) for % plant germination and weight.

Compost Quality and Use Guidelines

Overview and Explanation of Comparison Methodolgy. For this project, guidelines for compost use for various major compost use categories were compiled from available sources around the United States with the idea of comparing the quality of the tested NYS manure-based compost products to these suggested values. By doing so, areas in need improvement for marketability in specific use markets, such as landscaping and container mix, could be pinpointed. By analyzing the relationship of compost characteristics to composting methods, suggestions can be made regarding management measures that could improve quality.

For each of the use categories, a set of graphs was created that shows the average and individual sample values of a specified parameter for each of the agricultural composts and the suggested guideline values for that variable. Graphs for all use categories and criteria parameters can be found in Appendix I. An example of these graphs is displayed in the discussion of the Total Kjeldahl Nitrogen results later in this report (Figure 1).

Explanation of Guideline Sources and End Uses. For the purposes of this study, only published guidelines obtained from non-compost producing entities were used for comparisons to NYS composts. There are relatively few sources for such guidelines available and those few are often inconsistent. CWMI has not researched the validity of the guidelines and makes no claim that they are appropriate. In reviewing the available guidelines, we noted that the U.S. Composting Council Field Guide to Compost guidelines for most parameters is identical for all end uses. The USCC is considering reworking the guidelines to be more end-use specific. In general, there appears to be a need to work with end-users to better identify use-specific needs. In a current project, CWMI and others are working with the turf, vineyard and landscape industries to try to develop guidelines.

As mentioned above, the guidelines for which comparison was made with the quality of the composts surveyed came from:

- Mulch and Soil Council (MSC);
- Natural Resource Agriculture and Engineering Service (NRAES);
- NYS Department of Transportation specifications for compost used as a soil amendment (DOT).
- Rodale;

- U.S. Composting Council, Landscape Architecture for Compost Utilization and Field Guide to Compost (USCC).

The use categories for which guidelines were available from one or more of those sources are:

Backfill for Trees and Shrubs. "Backfill for Trees and Shrubs" is the name given by US Compost Council to the category of composts suitable for use as "a component to backfill mixes for the establishment or planting of various trees and shrubs (US Composting Council 1996)."

Container Mix/Potting Soil. Rodale provides specifications for a category of compost called "Container Mix." According to WERL materials meeting these guidelines can be used for growing nursery stock, houseplants and flowers in medium to large containers. Container Mix is generally a blend of compost and other material (Woods End Research Laboratory, Inc. 2001). USCC provides specifications for a category called "Growing Media Component" and is generally described as a compost product that is used as part of the organic fraction of growing media for the production of "containerized" crops (US Composting Council 1996). The Mulch and Soil Council defines "Potting Soil" as "any material for use in-container growing of plants (National Bark and Soil Producers Association 2001)". Guidelines provided by these programs are compared together under the heading of Container Mix/Potting Soil. However it should be noted that they are not directly comparable since the Rodale and MSC values refer to a finished product while the USCC guidelines are for the compost component of such a product.

NYSDOT Specifications. The New York State Department of Transportation provides guidelines for general DOT use in the publication "Compost Use on State Highway Applications (US Composting Council 2001)."

Erosion Control. "Erosion Control" is the name given to the category of composts by US Compost Council suitable for use as a soil mulch or cover to prevent erosion (US Composting Council 1996)."

Nursery Beds. "Nursery Beds" is the name given to the category of composts by US Compost Council suitable for use as a "soil amendment for the production of various ornamental crops in raised or ground nursery beds (US Composting Council 1996)."

Topsoil Blends. Rodale gives "Topsoil Blend" as a product that is suitable as a replacement for "topsoil, direct seeding, lawn-care, soil repair and garden raised beds (Woods End Research Laboratory, Inc. 2001)." This product is likely to be a mix of compost and other soil materials. The USCC gives a similar category using compost as a "Blended Topsoil Component" to produce various topsoil mixtures (US Composting Council 1996). It should be noted that these two guidelines are not directly comparable since the Rodale values refer to a finished product while the USCC guidelines are for the compost component of such a product.

Turf Establishment. "Turf Establishment" is the name given by USCC to the category of composts suitable for use as a "soil amendment for the establishment of turf grass - seed, sod, or sprig - (US Composting Council 1996)."

Vegetable Crops. USCC gives "Vegetable Production with Compost" as a category of compost that is suitable as a "soil amendment for the production of various vegetable crops (Northeast Regional Agricultural Engineering Service 1992)." NRAES also describes the desired qualities of composts to be used on vegetable crops. These two programs are compared under the heading of "Vegetable Crops" in this study because each describes a similar end use for the compost.

Summary of Findings. Using a scoring system developed by Woods End Research Labs, 18 of the 25 tested NYS manure-based composts were found to be suitable for use as garden compost, 10 for use as a seed starter, 9 as a nutrient compost and 4 for container mix. All the composts tested were found to be generally low in heavy metals, with concentrations well below guidelines. Most guidelines relied on metal limits established by USEPA for sewage sludge composts. On farms using copper sulfate, copper levels were somewhat elevated, but only one reached approximately half the guideline concentration. Nitrogen levels (TKN) from the dairy composts ranged from approximately 0.5-3%. Measurements of fecal coliform levels show that 8 farms had one or more samples that exceeded 1000 MPN/g. Under federal and NYS rules, to meet Class A standards, sewage sludge composts must either have less than 1000 MPN fecal coliform per gram or less than 3 MPN Salmonella in 4 grams. In general it seems that the Salmonella standard is easier to meet. We did not test for Salmonella. Seven farms had one or more samples that exceeded 1000 MPN. The pH of most of the composts were above 7 and quite a few were higher than suggested guidelines for many uses. The percentage of organic matter was highly variable among the composts tested, ranging from about 25-75%. Most composts were more dense and less mature than suggested in guidelines for many uses. Many of the composts had consistently low numbers of viable weed seeds. Others had high variability with some samples containing many weeds.

Replicate composite samples obtained from the same compost pile showed a considerable range for some parameters at some farms while others were relatively consistent. This is demonstrated in the bars in the graphs presented in Appendix I. For example, TKN levels were relatively constant, while organic matter was variable in many composts. For samples taken the same day, variability indicates heterogeneity within the pile. This heterogeneity did not decrease with increased turning or with the use of dedicated turning machines. Heterogeneity presents a challenge for sampling and characterization of composts.

Samples were taken from each farm at least twice. The data showed that for about a quarter of the farms, there was a significant difference in some of the measured parameters between the different sampling dates. At some farms these may have been samples of the same pile taken at different times, however at other farms they may have been samples of different piles.

Discussion of Particular Parameters in Relation to Guideline Values

Total Kjeldahl Nitrogen (TKN). TKN levels were relatively consistent in samples taken from the same farm. Values from different farms ranged from approximately 0.5% to 3.0%, except for two poultry composts with higher TKN of 6.5-7.5%.

Only Rodale includes recommendations for TKN and then only for container mix and not for the compost input to such a mix. Approximately one third of composts had higher TKN than container mix guidelines. Higher TKN is often seen as a positive attribute by compost users.

Container Mix and Potting Soil (See Figure 1-1 in Appendix I)
Guidelines (%): Rodale 0.5 – 2.0 (Note: Rodale value is for the end product, not for the compost component of such a product.)

About two-thirds (17 farms, 68%) of composts fell within suggested guideline for TKN with the balance (8 farms, 32%) exceeding the recommendation.

Figure 1 shows the results for TKN for each farm and compares them to guidelines for use as a container mix/potting soil. For each farm, the bar represents the range of analytic results with each tick mark being the value for a single composite analysis and the diamond representing the average of all of the individual analyses for that farm. It can be seen that for some farms (i.e. 7, 14, 24 and 25) there was a spread in TKN values from sample to sample, while for others (i.e. 1, 4, 11, 21, 22 and 23) the TKN values were very consistent. Similar graphs are shown in Appendix I for the parameters discussed as follows.

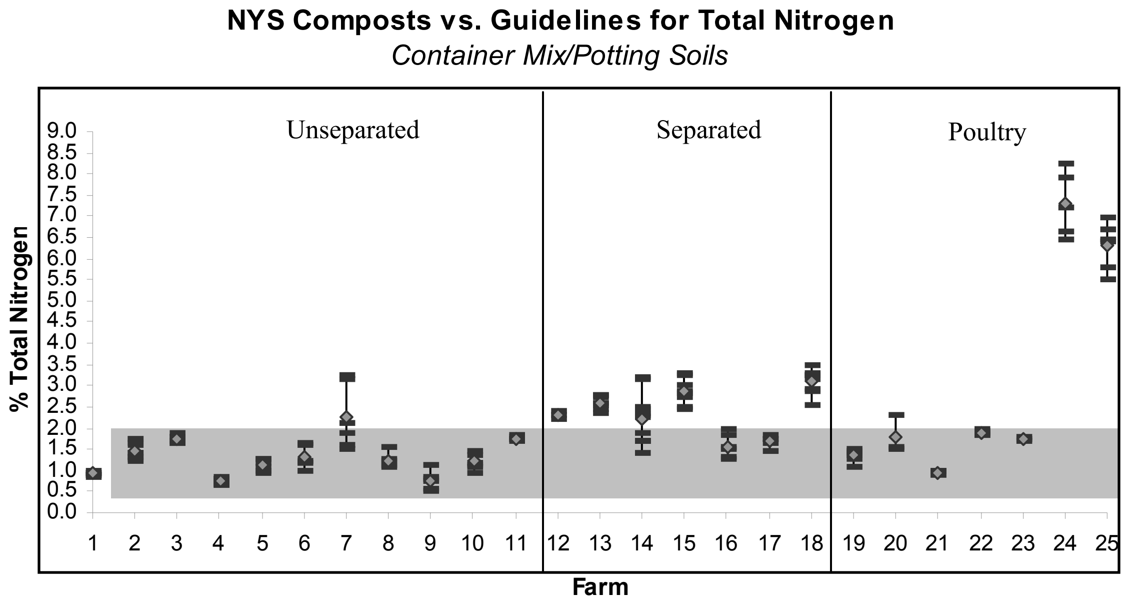

Figure 1. Suggested range of % total nitrogen for container mix and/or potting soils from Rodale - shaded area (0.5% - 2.0%). (Note: this is for the end product, not for the compost component of such a product.) Diamonds indicate average value and tick marks represent single sample values. Bars show range of values.

Organic Matter. The average OM value of NYS manure-based composts tested varied widely, ranging from 25% to 75%.

USCC, Rodale and DOT provide guidelines for OM in the use categories listed below. USCC values are identical for all use categories while Rodale guidelines vary according to end use. NYSDOT specifications call for a minimum of 30% OM.

In five use categories, average organic matter values for composts fell well below recommended values, while most farms met the NYSDOT guideline.

Container Mix and Potting Soil (See Figure 2-1 in Appendix I)
Guidelines (%): Rodale 30 – 80 (Note: Rodale value is for the end product, not for the compost component of such a product.); USCC 50 – 60

Many composts fell within Rodale guideline values for this use category. However, most container mixes would be a blend and composts would be only a component and the Rodale values are for the end product. 16 farms (64%) had an average OM that fell within values provided by Rodale and 5 farms (20%) had an average OM that fell within values provided by USCC.

Topsoil Blend (See Figure 2-2 in Appendix I)
Guidelines (%): Rodale 8 – 20 (Note: Rodale value is for the end product, not for the compost component of such a product.); USCC 50 – 60
Erosion Control (See Figure 2-3 in Appendix I)
Nursery Beds (See Figure 2-3 in Appendix I)
Tree and Shrub Backfill (See Figure 2-3 in Appendix I)
Turf Establishment (See Figure 2-3 in Appendix I)
Guidelines for all these uses (%): USCC 50 – 60
Vegetable Crops (See Figure 2-4 in Appendix I)
Guidelines (%): USCC and NRAES 50 - 60

Two thirds (64%) of the composts had OM lower than recommended for these use categories while 3 farms (12%) exceeded the recommended range and only 4 farms (16%) had average OM within recommended values.

NYSDOT Use (See Figure 2-5 in Appendix I)
Guidelines (%): DOT >30

Nearly two thirds (64%) of composts had higher OM than DOT minimum levels for OM.

C:N ratio. NYS composts tested were relatively consistent in C:N ratio both between different farms and within samples from the same farm. Values ranged from approximately 8-20, except for two poultry composts with very low values.

Only Rodale provides C:N ratio guidelines and only for container mix. Measured C:N ratio was lower than recommended values for container mix. However, most container mixes would be a blend and composts would be only a component and the Rodale values are for the end product.

Container Mix and Potting Soil (See Figure 3-1 in Appendix I)
Guidelines (ratio of C:N): Rodale 20 – 50 (Note: Rodale value is for the end product, not for the compost component of such a product.)

All of the composts had lower C:N than the guideline range for container mix.

pH. Average pH of the tested manure based composts ranged from 6.5 to 9.0, with most composts falling above 7. Within each farm, variation between samples of a half to one pH unit is common.

Values for pH were generally higher than suggested for most uses. Note that the USCC guidelines are identical for 5 of 6 use categories (5.5 – 8.0). In considering the impact of compost on the final pH of the soil to which the compost is added, not only the pH of the compost, but its lime content must be taken into account. Composts with a high pH but low lime content will have little impact. Some farms use lime and thus their composts may have both a high pH and high lime content. If used in significant quantities as part of a soil mix, they may be expected to alter the final pH.

The relationship between pH and moisture was investigated. No correlation between them was found.

Container Mix and Potting Soil (See Figure 4-1 in Appendix I)
Guidelines: MSC 4.5 – 7.5; Rodale 5.5 – 7.0 (Note: Rodale and MSC values are for the end product, not for the compost component of such a product.); USCC 5.5 – 8.0

A majority of composts did fall within the USCC guidelines. Most did not meet the Rodale or MSC guidelines for container mix. However, most container mixes would be a blend and composts would be only a component and the Rodale and MSC values are for the end product. 9 farms (36%) had an average pH >8, thus exceeding all maximum range recommendations. 16 farms (64%) had an average pH that fell within values provided by USCC, 5 farms (20%) had an average pH that fell within values provided by MSC, and only 2 farms (8%) had an average pH that fell within values provided by Rodale for the end product of container mix.

Topsoil Blend (See Figure 4-2 in Appendix I)
Guidelines: USCC 5.5 – 8.0; Rodale 5.5 – 8.0 (Note: Rodale values are for the end product, not for the compost component of such a product.)
Erosion Control (See Figure 4-3 in Appendix I)
Nursery Beds (See Figure 4-3 in Appendix I)
Turf Establishment (See Figure 4-3 in Appendix I)
Tree and Shrub Backfill (See Figure 4-3 in Appendix I)
Guidelines: USCC 5.5 – 8.0

9 farms (36%) exceeded maximum range values for pH in this use category and 16 farms (64%) had an average pH that fell within the guidelines above.

NYSDOT Use (See Figure 4-4 in Appendix I)
Guidelines: DOT range 6-8

Most composts had acceptable pH levels for DOT use. 16 farms (64%) had an average pH that fell within values DOT specifications.

Vegetable Crops (See Figure 4-5 in Appendix I)
Guidelines: USCC 5.0 – 8.0; NRAES 5.5 – 8.0

Two-thirds of the composts (16 farms, 64%) had pH values that fell within both sets of guidelines. 9 farms (36%) exceeded maximum range values for pH in this use category.

Soluble Salts. NYS composts were moderately high in soluble salts compared to use guidelines. Approximate values ranged from 0.5 - 22.0 mmhos. At a number of farms, substantial variation was measured in different samples from the same farm, indicating heterogeneity within the material.

Compared to use categories in general, about half of all composts fell within recommended values. USCC provided identical maximum values for container mix/potting soil, turf establishment, and tree and shrub backfill (<3 mmhos).

There was a relationship between moisture content and soluble salt concentration. Thirty-nine percent of the variance in soluble salts can be explained by differences in the moisture content. In general, drier composts had lower soluble salt concentrations.

Container Mix and Potting Soil (See Figure 5-1 in Appendix I)
Guidelines (mmhos): MSC 0 – 5.5; Rodale 0.5 – 3.0 (Note: Rodale and MSC values are for the end product, not for the compost component of such a product.); USCC <3.0

Soluble salts in most composts exceeded guidelines provided by USCC and Rodale guidelines for container mix. However, most container mixes would be a blend and composts would be only a component and the Rodale and MSC values are for the end product. 6 farms (24%) had average soluble salt contents that fell within values provided by Rodale and USCC and 15 farms (60%) fell within MSC values which are also for the end product.

Topsoil Blend (See Figure 5-2 in Appendix I)
Guidelines (mmhos): USCC <6

9 (36%) exceeded USCC guidelines for soluble salts in topsoil blends..

Nursery Beds (See Figure 5-3 in Appendix I)
Guidelines (mmhos): USCC <2.5

20 farms (80%) exceeded the recommended USCC value for soluble salts and 5 farms (20%) had averages that met USCC guidelines.

Turf Establishment (See Figure 5-4 in Appendix I)
Tree and Shrub Backfill (See Figure 5-4 in Appendix I)
Guidelines (mmhos): USCC <3.0

20 farms (80%) exceeded the recommended value for soluble salt content published by USCC in these use categories and 5 farms had averages that met them.

NYSDOT Use (See Figure 5-5 in Appendix I)
Guidelines (mmhos): DOT <4

9 farms (36%) fell within the DOT guideline of 4 mmhos or less.

Maturity. Maturity was measured using the Solvita method. USCC guidelines were interpreted as follows: highly stable =>7 Solvita; stable and moderately stable = 6 Solvita. While compost samples were considered "ready to use" by the farmers, composts exhibited a wide range of maturity values with farm averages ranging from 3 to 7. At many farms, samples showed wide variation indicating heterogeneity within the compost pile. The several guidelines are not consistent in regard to maturity. For some uses USCC guidelines recommend a more mature product than Rodale while for other uses this is reversed.

About half to two-thirds of average maturity values fell below recommended levels. USCC suggested maturity values were identical in 5 of 8 use categories.

Container Mix and Potting Soil (See Figure 6-1 in Appendix I)

Guidelines (Solvita maturity test): Rodale 7 to 8 (Note: Rodale value is for the end product, not for the compost component of such a product.); USCC ≥7 (highly stable)

4 farms (16%) met the maturity criteria provided by Rodale and 4 farms (16%) met the USCC recommendation.

Topsoil Blend (See Figure 6-2 in Appendix I)
Guidelines (Solvita maturity test):Rodale ≥7 (Note: Rodale value is for the end product, not for the compost component of such a product); USCC 5 to ≥7 (moderately stable to highly stable)

4 farms (16%) met the maturity criteria provided by Rodale and 22 farms (88%) met the USCC recommendation.

Erosion Control (See Figure 6-3 in Appendix I)
Nursery Beds (See Figure 6-3 in Appendix I)
Turf Establishment (See Figure 6-3 in Appendix I)
Tree and Shrub Backfill (See Figure 6-3 in Appendix I)
Vegetable Crops (See Figure 6-3 in Appendix I)
Guidelines (Solvita): USCC 6 -≥7 (stable to highly stable)

12 farms (48%) produced composts that fell within UCSS guidelines for these use categories. 13 farms (52%) fell below the minimum value.

Density. The average density of NYS manure-based composts tested ranged from 35 lb/ft^3 to 60 lb/ft^3. Some farms showed consistent density, but at many farms the density of samples, even those taken on the same day from the same pile, varied. This indicates that the piles at these compost sites are not very homogeneous. An ANOVA analysis found no differences in density between manure types.

The USCC and Rodale provide density guidelines for several different uses. The USCC guidelines (27-37 lb/ft3) are identical for all uses. The Rodale values vary according to end use.

Most composts tested were more dense than values recommended in the guidelines. Approximately two-thirds of the composts were higher than recommended values for all uses.

Container Mix/Potting Soil (See Figure 7-1 in Appendix I)
Guidelines (lb/cu ft); Rodale=12 – 43 (Note: Rodale value is for the end product, not for the compost component of such a product.); USCC=27-37

Overall, the composts faired poorly when compared to density recommendations for use in container mixes and potting soils. 15 farms (60%) exceeded maximum range values for density in this use category. 10 farms (40%) had an average density that fell within values provided by Rodale and 2 farms (8%) had averages that fell within values provided by USCC. However, most container mixes would be a blend and composts would be only a component and the Rodale values are for the end product.

Topsoil Blend (See Figure 7-2 in Appendix I)
Guidelines (lb/cu ft): USCC 27 – 37; Rodale 45 – 60 (Note: Rodale value is for the end product, not for the compost component of such a product.)
Erosion Control (See Figure 7-3 in Appendix I)
Nursery Beds (See Figure 7-3 in Appendix I)
Tree and Shrub Backfill (See Figure 7-3 in Appendix I)
Turf Establishment (See Figure 7-3 in Appendix I)
Guidelines for all of these uses (lb/cu ft): USCC=27-37

The average density value for most of the composts were high compared to the single USCC guideline for these use categories. 23 farms (92%) exceeded the maximum range value.

Vegetable Crops (See Figure 7-4 in Appendix I)
Guidelines (lb/cu ft): USCC =27-37; NRAES=30-40

Average density values for most NYS composts were high compared to guideline values provided by USCC and NRAES.

Copper. Average copper values, measured in parts per million (ppm), ranged from 25 - 800. Most composts (19 farms, 76%) had copper levels below 100 ppm. For those farms, there was little variation within samples from a single farm. Copper levels can be attributed to copper use on the farm. Farms that did not report the use of copper sulfate for hoof dip had an average value of 59 ppm copper, while farms that did report its use had an average value of 452 ppm copper (See Figure 8.1 in Appendix I).

Copper levels were lower than suggested maximum values except for the Rodale recommendation for container mix (350 ppm maximum), where 4 (16%) farms using copper exceeded that value. However, most container mixes would be a blend and composts would be only a component and the Rodale values are for the end product. USCC provided identical recommendations (<1500 ppm) for all use categories, sharing this value with NRAES for vegetable crops. 1500 ppm is the limit for copper established by USEPA and NYS DEC for sewage sludges applied to land without restriction.

Container Mix and Potting Soil (See Figure 8-1 in Appendix I)
Guidelines (ppm): Rodale <350 (Note: Rodale value is for the end product, not for the compost component of such a product.); USCC <1500

Most composts met copper recommendations for this use category. All farms had average copper levels below the maximum recommended value provided by USCC, while 4 farms (16%) had average copper levels that exceeded the maximum recommended value provided by Rodale for this use category. However, most container mixes would be a blend and composts would be only a component and the Rodale values are for the end product.

Erosion Control (See Figure 8-2 in Appendix I)
Nursery Beds (See Figure 8-2 in Appendix I)
Turf Establishment (See Figure 8-2 in Appendix I)
Tree and Shrub Backfill (See Figure 8-2 in Appendix I)
Vegetable Crops (See Figure 8-2 in Appendix I)
NYSDOT (See Figure 8-2 in Appendix I)
Guidelines (ppm): USCC <1500; NRAES <1500 for Vegetable crops; <1500 NYSDOT

None of the farm composts analyzed in this study had copper levels that exceeded the maximum recommended values for these use categories.

Iron. The concentration of iron in the composts varied widely both between farms and within samples from the same farm. Approximate values ranged from 25 ppm to 14000 ppm.

Guidelines for iron were provided only by Rodale and for only two uses. Most composts met the recommendations.

Container Mix and Potting Soil (See Figure 9-1 in Appendix I)
Guidelines (ppm): Rodale <12000 (Note: Rodale value is for the end product, not for the compost component of such a product.)

20 farms (80%) fell below recommended maximum levels. However, most container mixes would be a blend and composts would be only a component and the Rodale values are for the end product.

Zinc. Zinc concentrations ranged from 100 ppm to 600 ppm with most composts having less than 400 ppm. With one exception, composts Zn concentrations were relatively consistent in samples taken at a particular farm.

The guidelines provided by USCC and Rodale for all uses adopted the maximum concentration level established by USEPA for zinc in land-applied sewage sludges that can be applied without restriction (2800 ppm). DOT uses the NYS DEC standard of 2500 ppm. All composts tested fell well below that value.

Container Mix and Potting Soil (See Figure 10-1 in Appendix I)
Guidelines (ppm): Rodale 100 – 2800 (Note: Rodale value is for the end product, not for the compost component of such a product.); USCC <2800

All farm composts analyzed in this study had mean zinc concentrations that fell within recommended values.

Topsoil Blend (See Figure 10-2 in Appendix I)
Erosion Control (See Figure 10-2 in Appendix I)
Nursery Beds (See Figure 10-2 in Appendix I)
Turf Establishment (See Figure 10-2 in Appendix I)
Tree and Shrub Backfill (See Figure 10-2 in Appendix I)
Vegetable Crops (See Figure 10-2 in Appendix I)
NYSDOT (See Figure 10-2 in Appendix I)
Guidelines (ppm): USCC <2800; NRAES <2800 for Vegetable crops; NYSDOT <2800

All farm composts analyzed in this study had mean zinc concentrations that fell below suggested maximum concentrations.

Arsenic. Arsenic concentrations were generally below 20 ppm, with many composts having concentrations below 10. The variation within samples from a single farm was small for many farms, but large for the one farm with the highest concentration.

Only USCC, NRAES and NYSDOT provide a guideline for arsenic. The guidelines provided by USCC for all uses and for DOT adopted the maximum concentration level established by USEPA for arsenic in land-applied sewage sludges that can be applied without restriction (41 ppm). All composts tested fell well below that value.

Container Mix and Potting Soil (See Figure 11-1 in Appendix I)
Topsoil Blend (See Figure 11-1 in Appendix I)
Erosion Control (See Figure 11-1 in Appendix I)
Nursery Beds (See Figure 11-1 in Appendix I)
Turf Establishment (See Figure 11-1 in Appendix I)
Tree and Shrub Backfill (See Figure 11-1 in Appendix I)
Vegetable Crops (See Figure 11-1 in Appendix I)
NYSDOT (See Figure 11-1 in Appendix I)
Guidelines (ppm): USCC <41; NRAES <41 for Vegetable Crops; NYSDOT <41

All farm composts analyzed in this study had mean arsenic concentrations that fell below recommended values for these use categories.

Cadmium. Cadmium concentrations ranged from 0 to 5 ppm in the composts. All farms showed relatively consistent cadmium values among samples from the same farm.

Only DOT and USCC provide guidelines for Cd. The guidelines provided by USCC for all uses adopted the maximum concentration level established by USEPA for cadmium in land applied sewage sludges that can be applied without restriction (39 ppm). The NYSDOT specifications adopt the NYS DEC limit which is 10 ppm for cadmium. All composts tested fell well below that value.

Container Mix and Potting Soil (See Figure 12-1 in Appendix I)
Topsoil Mix (See Figure 12-1 in Appendix I)
Erosion Control (See Figure 12-1 in Appendix I)
Nursery Beds (See Figure 12-1 in Appendix I)
Turf Establishment (See Figure 12-1 in Appendix I)
Tree and Shrub Backfill (See Figure 12-1 in Appendix I)
Vegetable Crops (See Figure 12-1 in Appendix I)
NYSDOT (See Figure 12-1 in Appendix I)
Guidelines (ppm): USCC <39; DOT <10

All farm composts analyzed in this study had mean cadmium concentrations that fell below recommended maximum values provided by USCC for these use categories.

Fecal Coliform. Fecal coliform counts showed that most samples fell below 1000 MPN/g. Eight of the 25 farms had one or more samples that exceeded that level. On 6 of those farms, only one of the samples taken exceeded 1000 MPN/g. While sampling protocols called for use of clean equipment and gloves, it is possible that some samples showed higher coliforms due to contamination during sampling (See Table 13-1 in Appendix I).

Under federal and state regulations pertaining to sewage sludge composts, to meet Class A requirements no samples may exceed 1000 MPN/g fecal coliform or have Salmonella levels exceeding 3 MPN/4 gm of compost. The Salmonella test is apparently more “forgiving” than the coliform test. However, in this study we did not test for Salmonella.

Weed Seeds. Viable weed seeds varied in composts from none to more than 227 viable weed seeds/L in one sample. Eleven of the composts had consistently low levels (≤5/L), while 14 exceeded 5 at least once. There are no US guidelines for weed seeds, but German guidelines call for <5/L for high quality composts (See Table 14-1 in Appendix I).

Plant Germination. Plants germinated well in most of the composts tested. However, several of the poultry composts showed poor germination. Germination was found to be correlated with other parameters. The Solvita ammonia index explained 48% of the variance, soluble salts 42% and maturity 28%. These parameters are also related to each other (See Table 15-1 in Appendix I).

Plant Response. For many of the composts the plant response test results exhibited quite a range, even for samples taken on the same day from the same pile. Average results for half of the composts were 80% or greater than growth in the control. Some of the poultry composts showed low plant response. Plant response was found to be correlated with other parameters. The Solvita ammonia index explained 61% of the variance, maturity 39% and the C:N ratio 27%. These parameters are also related to each other (See Table 16-1 in Appendix I).

Relationships between Compost Parameters and Compost Processes

One of the goals of the project was to determine whether there were compost practices that farmers could modify in order to optimize compost properties for their desired market. We thus analyzed the relationships between various compost properties and processes. We found that in some cases there were trade-offs. For example, increased turning results in lower organic matter and nitrogen, but fewer weed seeds and increased maturity.

Compost Processes Analyzed

Bulking agent. Bulking agents used in composting operations were identified, but many farms use a mix of materials and may change materials, so this parameter was not examined in detail.

Compost turning method. Composting operations were divided into three methods for turning compost piles. These are compost windrow turners, bucket-turned windrows, and passively aerated windrow systems (PAWS).

Manure type. Manure types included in the data analysis are unseparated and separated diary manure and poultry manure.

Pad type. Composting operations were divided into three types of pads on which compost piles were located. These are dirt, gravel or improved, and concrete.

Screening. Some compost products have been processed using a screener to eliminate larger fragments. We divided these into screened and unscreened.

Turning frequency. Composting operations were divided into two groups based on how often compost piles are turned. These are low turning frequency (less than 12 times/year) and high turning frequency (more than 12 times/year).

Interactions between Compost Properties and Processes and Compost Quality

Many compost properties were affected by compost practices and feedstock. The results of Analysis of Variance tests (ANOVA) are presented below and in Appendix K. All reported differences have been found to be significant at a 90% level of confidence.

As results are presented, some averages for the same parameter may appear to be different in different sections. This is due to how the farms are grouped for the particular analysis. For example, a comparison of average organic matter values for separated and unseparated dairy manure will be different than the averages if third factor is added, such as turning frequency because it will be derived from a different set of farms.

The notable practices that influenced compost qualities, in decreasing order of significance by our interpretation, are as follows:

1. Separated vs. non-separated manure. Separation of manure is a mechanical process practiced on 7 out of 18 or 39% of the dairy farms, whereby solids are squeezed under centrifugal or slot-plate pressure to separate the, manure into a liquid and a semi-solid component. Farms choose different manure and barn management techniques. Some create a liquid manure stream where separation might be needed and others keep manure more solid. For those farms practicing separation, the solids are increased to

about 30% in the solid fraction that may be composted. In our study, compost made from these separated manures almost without exception had much higher organic matter and nutrient concentrations, especially N and K.

2. Type of pad. Composters can use various types of pads including unamended soil, concrete, asphalt, cloth, gravel and other materials. Whether a farm used or did not employ an improved surface for composting was shown to have an effect on compost properties. Farms with compacted or improved pads had higher organic matter, higher N, and higher K. Composts managed on soil pads had lower organic matter, most likely due to incorporation of soil when turning and moving compost.

3. Turning frequency. Increased turning decreased organic matter and N concentrations. This was particularly marked for chicken manure composts. Maturity increased by one unit on average for dairy manures with frequent vs. infrequent turning, and by almost 3 units for chicken manure composts. Frequency of turning greatly impacted weed seeds in dairy manure composts. Turning throughout the process reduced the amount of weed seeds. Thus a trade off exists whereby turning increased maturity and decreased weed seeds, while at the same time it decreased N and organic matter, particularly with poultry manure.

4. Turning method. A comparison was made of different types of equipment including dedicated turners, bucket loaders and passively aerated piles. PAWs were higher in organic matter and nitrogen, but the process took longer to reach maturity. Weed seed can be high if no turning is employed in any part of the process. While not measured, visual observation showed that particle size is coarse in unturned piles. Compost from dedicated windrow turners had the lowest number of weed seeds and the most balanced C:N ratio and produced generally smaller particle size. Windrow turners resulted in a drier product that was also higher in TKN than bucket turned composts but lower than PAWS. For infrequently turned piles, the windrow turner composts were more mature than those infrequently turned with a bucket loader. Results for frequently turned bucket turned composts were close to those of dedicated turners except for a lower C:N ratio.

Tables 2-6 summarize some of the more important results of our analysis of the relationship of compost properties to compost processes. Turning frequency, method and pad type significantly influence parameters such as TKN, OM, weed seeds, maturity, pH and C:N.

Turning Frequency	TKN	OM	Maturity	Weeds
High	-	-	+	-
Low	+	+	-	+

Table 2. Turning frequency vs. compost parameters. "+" means the value of that parameter is higher at the specified frequency, and "-" means it is lower.

Turning Method	TKN	OM	Maturity	C:N Ratio
Windrow Turner	+	+	++	++
Bucket Loader	*	*	+	+
PAWS	++	++	*	*

Table 3. Turning method vs. compost parameters. "*" means that the corresponding method had the lowest value compared to other categories. "+" is the next higher value and "++" is the highest value compared to other methods.

Frequency	Method	Weeds	Maturity
High	Turner	+	-
Low	Turner	-	+

Table 4a. Frequency and method combined influence on compost parameters. "+" means the value of that parameter is higher at the specified frequency, and "-" means it is lower.

Frequency	Method	Weeds	Maturity
High	Bucket	-	+
Low	Bucket	+	-

Table 4b. Frequency and method combined influence on compost parameters. "+" means the value of that parameter is higher at the specified frequency, and "-" means it is lower.

Pad Type	TKN	OM
Dirt	-	-
Improved	+	+

Table 5. Turning frequency vs. compost parameters. "+" means the value of that parameter is higher at the specified frequency, and "-" means it is lower.

Cement throughout	OM	TKN	K	pH	Weeds
Yes	+	+	+	+	-
No	-	-	-	-	+

Table 6. Effects of cement present throughout the compost systems vs. without, compared to compost parameters. "+" means the value of that parameter is higher at the specified frequency, and "-" means it is lower.

Organic matter. Separated manure had significantly more OM than unseparated manure and poultry manure. Unseparated dairy manure composts had an average value of 32.4% OM, while separated manure composts averaged 58.1% OM. Average OM for poultry composts was 39.2%. (ANOVA Set #1 in Appendix K).

Increased turning frequency reduced OM content and there is a significant interaction effect with differing manure types. Among the composts for which this analysis was performed, unseparated dairy manure had an average OM content of 32.8%, separated manure had 57.4% OM, and poultry had 44.3% OM. Farms with low turning frequency had an average of 49.7% OM, farms with high turning frequency had 40.1% OM. Farms with separated manure and low turning frequency had 63.3% OM, farms with separated manure and high turning frequency had 51.3% OM. Poultry farms with low turning frequency had 52.1% OM, and poultry farms with high turning frequency had 36.8% OM (ANOVA Set #2 in Appendix K).

Organic matter content is associated with turning method when poultry composts are excluded from the statistical analysis. Passively aerated windrow systems produced average OM of 63.8%, while windrow turners averaged 43.0%, and bucket-turned windrows were the lowest, at 37.8% (ANOVA Set #3 in Appendix K).

Pad type affects OM content of compost. There is a slight interaction with manure type within dairy groups favoring increased OM on improved pad with separated dairy manure. For the farms with sufficient data for this analysis, average OM for unseparated dairy manure was 32.8% and OM for separated manure was 56.6%. OM for dirt pads was 39.7%, OM for improved pads was 49.6%, and OM for dirt pads with unseparated dairy manure was 31.4% while OM for improved pads with unseparated dairy manure was 48.0%. OM for dirt pads with separated manure was 34.1% while OM for improved pads with separated manure was 65% (ANOVA Set #4 in Appendix K).

Screening alone was not found to have a significant effect on organic matter content. However when each manure type is looked at separately, screening had an effect. Screened unseparated dairy had higher OM than unscreened (average 35 vs. 30% OM) and screened poultry manure had a higher OM than unscreened (31vs. 44%). Screening did not change the OM content of separated manure composts (ANOVA Set #5 in Appendix K).

C:N ratio. There was a significant difference between poultry and dairy manure composts in regard to C:N. There was not a significant difference between the two dairy manure types. Poultry had and average value of 9 while unseparated dairy had a value of 14.3 and separated was 13.3 (ANOVA Set #6 in Appendix K).

Variations in C to N ratio between different turning methods were not found to be significant (ANOVA Set #7 in Appendix K).

Screened composts had higher C:N values than composts that were not screened (average of 14.5 vs. 11.9). There was an interaction between manure type and screening. For separated manure the average C:N value for screened was 19 while for unscreened it was 13. (ANOVA Set #8 in Appendix K).

Maturity. Maturity is related to manure type. Farms with unseparated dairy manure had a mean maturity value of 6.3, farms with separated manure had a maturity value of 5.7, and poultry farms had a mean maturity value of 5.1 (ANOVA Set #9 in Appendix K).

For unseparated and separated dairy manure composts, frequency of turning has a small but significant impact on maturity. Composts turned less frequently averaged 5.7 and those turned at higher frequency 6.2. Poultry farms with low turning frequency had a significantly lower maturity value of 3, and poultry farms with a high turning frequency had a maturity value of 5.5 (ANOVA Set #10 in Appendix K).

Although turning method was found to significantly impact maturity, the measured differences were small. Farms using windrow turners had an average maturity value of 6.5 and bucket-turned windrows had a maturity value of 5.6, passively aerated systems averaged 5.8. When poultry composts are eliminated from the analysis, the average value for passively aerated systems is 5.1.

There is also a significant interaction effect between turning frequency and turning method. Farms with low turning frequency and windrow turners had a maturity value of 7.0, farms with low turning frequency and bucket-turned windrows had a maturity value of 5.2, farms with high turning frequency and windrow turners had a maturity value of 6.1, and farms with high turning frequency and bucket-turned windrows had a maturity value of 6.1. Thus for infrequently turned composts, a dedicated turner resulted in a more mature compost, while for frequently turned piles there was no difference between bucket-turned composts and those turned with a dedicated turner. Why more frequently turned windrow-turner compost should be less mature than that turned less frequently is puzzling (ANOVA Set #11 in Appendix K).

Moisture content. Manure type significantly influences moisture in end product. Unseparated dairy manure had an average value of 55% moisture and separated manure had 67% while poultry had 35% (ANOVA Set #12 in Appendix K).

Frequency of turning did not have a significant influence on moisture content of composts, but turning method did. There were also significant interaction effects between turning frequency and turning method. Composts turned using windrow turners had average moisture of 49%, which was significantly lower than bucket turned windrows with a moisture content of 59% as well as passively aerated windrow systems that had average moisture of 61%. The difference in moisture between bucket-turned and passively aerated was not significant. Composts turned more frequently with a bucket were drier than those turned less frequently (52% vs. 65%). (ANOVA Set #13 in Appendix K.)

Total Kjendahl Nitrogen. TKN is associated with manure type. Poultry manure had average TKN of 3.4% and was significantly higher than both unseparated manure which had 1.3% TKN and separated manure which exhibited 2.4% TKN. The difference between unseparated and separated manure composts was also significant. (ANOVA Set #14 in Appendix K)

Increased turning frequency reduces TKN content and there is a significant interaction effect with differing manure types. More turning caused greater N losses with chicken manure as opposed to both other manure types. For the farms that had sufficient data for this analysis, unseparated dairy manure had average TKN of 1.4%, separated manure had 2.4% TKN, and poultry had 5% TKN. Farms with low turning frequency had 3.8% TKN, and farms with high turning frequency had 2.0% TKN. Farms with unseparated dairy manure and low turning frequency had 1.5% TKN, which was significantly higher than farms with unseparated manure and high turning frequency with an average of 1.2% TKN. Farms with separated manure and low turning frequency had 2.6% TKN and farms with separated manure and high turning frequency had 2.2% TKN which was significantly lower. Poultry farms with low turning frequency had 7.3% TKN and poultry farms with high turning frequency had 2.7% TKN, which was significantly lower (ANOVA Set #15 in Appendix K).

Average TKN value of composts made on dirt pads (2.3%) was not significantly different from that of improved pads when all farms were grouped together, but was significantly lower than TKN values from concrete pads (3.1%). Differences in TKN were not significant between composts made from unseparated dairy manure on dirt and improved pads. Separated dairy composts made on dirt pads had average TKN of 2.0% which was significantly lower than separated composts made on improved pads, which had a value of 2.9%. Separated dairy composts made on dirt pads were also significantly lower in TKN than separated composts made on concrete pads, which had average TKN of 2.9%. There was not a significant difference in TKN values between separated dairy composts made on improved pads and those made on concrete pads. Pad type did not significantly affect TKN values in poultry composts (ANOVA Set #17 in Appendix K).

Compost turning methods had a significant impact on TKN. Looking at all manure types together, composts made using PAWS had an average TKN of 3.9%, while windrow turners produced composts with average TKN of 2.0% and bucket turners 1.6%. Unseparated manure yielded similar results, with PAWS at 2.6%, windrow turner systems at 1.3% and bucket turned at 1.1%. For separated manure composts, PAWS composts had TKN of 3.1% and there was no significant difference between windrow turners and bucket turners. Data for poultry are based on only one PAWS system and no bucket turned windrows (ANOVA Set #16 in Appendix K).

Screening produced composts significantly lower in total nitrogen than unscreened products. Screened composts averaged 1.5% TKN while unscreened averaged 2.7%. There was an interaction between manure type and screening. For separated manure, screening increased TKN (1.4% vs. 1.2%). For separated, screening decreased TKN (1.6% vs. 2.5%). For poultry composts, screening had a large impact in decreasing TKN (1.6% vs. 4.4% in unscreened) (ANOVA Set #19 in Appendix K).

Phosphorus. There was no significant difference in phosphorus levels between unseparated dairy manure and separated manure composts. Poultry composts had significantly more phosphorus (1.6%) than unseparated dairy and separated dairy manure composts (0.4% P) (ANOVA Set #20 in Appendix K).

Potassium. Potassium levels are significantly different among all manure types. Dairy manure had an average of 0.6% K which was significantly lower than separated manure, which had 1.0% K. Poultry manure had an average of 1.8% K which was significantly higher than both unseparated dairy compost and separated dairy (ANOVA Set #21 in Appendix K).

Soluble salts. No significant difference in salt content between unseparated and separated manures was detected. Poultry composts had significantly higher salt content at 14.2 mmhos than either unseparated dairy composts, which had an average of 4.0 mmhos or separated dairy composts (4.2mmhos) (ANOVA Set #22 in Appendix K).

pH. The relationship between turning method and pH was examined. There were only minor differences in pH between the different methods, with PAWS producing a slightly higher pH (8.1 average for all manure types) than either the windrow turner or bucket turner, which were not significantly different from each other. No significant differences were found for unseparated manure or poultry manure composts. For separated manure composts, a slightly higher pH was found in PAWS and bucket turned composts (ANOVA Set #23 in Appendix K).

Screening had a small but significant impact on pH levels. Composts that were screened displayed lower values that those that were not (7.7 vs. 8). Manure type also influenced pH, with unseparated manure having a slightly lower pH than unseparated and poultry (average values 7.6, 8, 8.1). There are no interaction effects between pH, manure type and screening (ANOVA Set #24 in Appendix K). Data obtained earlier in a study of compost quality as it related to depth into the compost pile showed that the interior of piles were somewhat wetter and had higher ammonia and pH than the drier outside layers. It may be that pH could be decreased if composts were allowed to dry.

Fecal Coliform. Fecal coliform levels were lower in poultry manure than in dairy manure composts. There was no apparent effect on fecal coliform levels based on turning frequency or turning methods (ANOVA Set #25 in Appendix K).

Plant Growth and Germination. Plant growth, part of a larger suite of tests related to the phytotoxicity of composts, was measured by planting cress (*Lepidium sativum)* in compost samples diluted to a standard conductivity. Plant growth was not significantly different in separated vs. unseparated dairy manure composts. There was no significant difference in plant response related to composting turning method and turning frequency (ANOVA Set #26 in Appendix K).

Cress germination was significantly higher among composts that were screened, with screened composts averaging 95.6% while unscreened had a germination of 82.6%. Manure type also had an effect with poultry manure having a lower germination rate (76%) as compared to unseparated (98.3%) and separated (92.9%). There were also interaction effects between the manure type and screening for separated and poultry manure composts. Screened separated manure compost averaged 89% and unscreened 96.9%. For poultry, screened compost averaged 99% while unscreened averaged 53% (ANOVA Set #27 in Appendix K).

Viable weeds. Weed seeds were measured by measuring the number of weeds that grew from compost diluted to a standard salt content. When all 3 manure types are considered, manure type does not significantly affect weed seeds. Turning frequency does affect weeds, with more frequent turning reducing weed seeds. Average weed seed was 14/L in composts turned with low frequency and 3.4 in high frequency. When all manure types are considered together, there is no evidence of a significant interaction effect between turning frequency and differing manure types. However when manure types are looked at individually, unseparated dairy had 3.3/L for frequent turning and 18.7 for low turning. Differences for weeds in separated manure were not significantly associated with different turning frequency. For poultry, higher turning frequency resulted in lower weed seeds (2 vs. 23) (ANOVA Set #28 in Appendix K).

When poultry composts and passively aerated systems which are not turned are excluded, manure type (separated vs. unseparated dairy manure) did not have a significant effect on weeds, but turning method did and there was an interaction between method and frequency.   Composts produced with compost turners had an average of 1 weed seed/L while bucket turned composts had 15. Turning frequency had a large impact on bucket turned composts, with those that were turned frequently having 4 weed seeds/L versus 25.7 in those turned with low frequency. For compost turners, the impact of frequency was far less. (ANOVA Set #29 in Appendix K).

Screened composts exhibited significantly lower weed seed counts than those that were not screened (1.3 vs. 110.7/L). Manure type did not have a significant influence nor were there interaction effects between the manure type and screening. (ANOVA Set #31 in Appendix K).

<u>Consistency: Changes in Compost Characteristics over Time</u>

One question of interest is whether compost quality from a particular farm changes over time. At each of 21 farms, compost was sampled at two or more different times. The composts tested at the different times on a farm may or may not have been from the same pile, so that the results may indicate changes in a particular batch or changes between batches.

In assessing differences over time, note that for composts that exhibited very consistent values among samples, even a small change between sampling dates may be statistically significant. For farms with inconsistent values from samples taken on the same date, the high variance means that a larger difference between sampling dates might not be statistically significant.

23.8% (5 of 21) of the farm composts exhibited a small but significant change in pH over time 42.9% (9 of 21) showed a change in plant response measured as cress weight, with most composts showing decreased plant growth in the later samples. 28.6% (6 of 21) displayed changes in cress germination, all showing decreased germination. 26.3% (5 of 19) showed a change in maturity with 3 showing increased maturity and 2 decreased. 42.9% (9 of 21) showed a change in organic matter content with some increasing and some decreasing. (Appendix N).

Looked at by manure type, 17.6% (3 of 17) of dairy farms showed a significant change in pH, 41.2% (7 of 17) experienced a change in plant response measured as cress weight, 23.5% (4 of 17) experienced a change in cress germination, 26.7% (4 of 15) displayed a change in maturity and 47.1% (8 of 17) showed significant changes in OM over time. Results of poultry farm analysis, while statistically significant, are based on only 4 farms. 50% (2 of 4) experienced variation in pH, 50% (2 of 4) showed a change in cress weight, 50% (2 of 4) demonstrated variation in cress germination, 25% (1 of 4) displayed changes in maturity over time and 25% (1 of 4) showed a change in OM over time.

<u>Compost Control of Johne's Disease (Mycobacterium paratuberculosis)</u>

A concern regarding dairy manure composts is the degree to which composting reduces or kills *Mycobacterium paratuberculosis*, the organism that causes bovine Johne's Disease. To investigate this issue, we conducted a field experiment. A 6'x 6'x20 compost pile was built on the Cornell Farm Services compost pad using manure obtained from a Johne's-free farm and then inoculated with ~200 pounds or ~ 2 cow days worth of infected manure from a heavily shedding cow. The pile was turned weekly with a loader and daily temperatures in 6 locations in the pile were taken.

Composite samples were taken on days 1 7, 14, 21, 28 and 35 from several locations in the pile. In addition to Johne's analyses, samples were analyzed for compost parameters as well as fecal strep and fecal coliform.

Johne's was detected in the initial pile before composting. The analyses completed from day 7 to 35 were all negative, demonstrating that in this experiment, Johne's was killed in the first 7 days employing very simple composting methods. (See Appendix O for results of this experiment).

Johne's was not believed to be present in most of the farm operations included in the full study. To investigate the ability of typical on-farm composting to reduce Johne's, composts from four farms with a high incidence of Johne's were sampled. Raw manure ranged from 92 –21,000 (colony forming units) CFU/ gm. Four composite samples of compost were taken from each farm. The material that was tested varied in age from 6-12 months and in each case was reported to be ready for use. The farms each employed different management techniques including forced air, bucket and turner turned windrows. Only one of the 16 samples detected any Johne's and that was a single sample. This positive finding of a single CFU may have resulted from cross-contamination.

This testing supports the finding that composting will greatly reduce or eliminate Johne's.

III. STAKEHOLDER INVOLVEMENT

Stakeholders for this project include agricultural composters, state agency personnel in DAM, NYSDEC, Empire State Development (ESD) and NYSERDA, farm and composting organizations such as the NYS Farm Bureau and the Organics Council of the NYS Association for Reduction, Reuse and Recycling (NYSAR[3]). In addition, similar stakeholders from several other northeastern states were contacted to explore the potential for a multi-state labeling or seal program.

Methods for engaging these stakeholders included numerous meetings such as special meetings held for the purpose of working on the project. We also held discussions as part of the agenda of otherwise scheduled meetings (such as the annual NYSERDA agricultural conference, the BioCycle NE conference, and the Cornell Organic Residuals Program Work Team meetings). Email also served as a useful means of communication with stakeholders. More than 60 interested persons received numerous communications and requests for input.

IV. ACTIONS AND RECOMMENDATIONS

The development of a NYS-specific seal program is not recommended. There does not appear to be any entity equipped and willing to undertake such a program at this time and without significant advertising, a program would not enhance markets. Instead, compost producers should determine whether participation in one of the existing seal/certification programs would meet their needs. However, continued work with DAM to investigate the potential to include agricultural composts in the Pride of New York program should also be pursued. Development of promotional and educational programs aimed at various segments of the compost consumer market is recommended.

While labeling of composts is desirable so that consumers can obtain information, the fertilizer law and rules places major constraints on what can be included in a label. An easy-to-read information label developed as part of this project could help provide consistent information for consumers. (Appendix G.) Changing the applicable law and rules in NYS to provide a means for agricultural compost producers to legally provide information about their products should be pursued.

A northeast group of stakeholders recommended that a minimum label or information sheet would specify source material (compost inputs), compost process and length of the process. In several northeastern states the group is pursuing regulations to require such labels for all composts. NYS should be involved in this regional effort and determine the advisability of adopting such requirements.

Another means beyond labels for communicating with compost users is through the World Wide Web. Web pages have been created by CWMI (http://cwmi.css.cornell.edu) which provide the available published guidelines and recommendations for use of compost in: container/potting mix; topsoil mix; erosion control; nursery beds; turf establishment; backfill for tree and shrub planting; and use by Departments of Transportation. These pages were compiled from the materials described above. These pages are designed to assist potential compost users in identifying the properties they might seek in composts as well as how to use composts. They are also useful for compost producers to assist them in setting goals for their products associated with particular markets and for helping them to identify appropriate markets for their compost.

That said, there are few sound guidelines for compost properties for different end uses that are available. There is a need to work closely with potential compost end markets to develop and then to publicize appropriate use guidelines. A new CWMI project, supported in part by NYSERDA, will work to develop such guidelines in partnership with the turf industry and vineyards. The USCC is reportedly updating their landscape guidelines. The web pages should be updated as new information is developed on end use guidelines.

The maps of NYS compost facilities on the CWMI www site (http://compost.css.cornell.edu/maps/welcome.asp) have been updated. This map shows many of the compost producing facilities in NYS (those of which we are aware and which have agreed to be listed) and through use of a geographic information system it is linked to a database containing information on each facility. Appendix P contains an example map and information from a database search request. The maps and information will help potential compost users find local sources of compost as well as connecting compost producers with potential feedstocks.

Among the data we hope to make available through the CWMI www site will be compost quality data. Each compost facility will be able to submit to CWMI specific laboratory data regarding tests of their compost. Those data, including the date(s) of sampling and analysis, the laboratory performing the analyses, as well as analytic results, will be posted. CWMI will post a disclaimer stating CWMI does not endorse or certify that a compost meets, or fails to meet, a given criteria and will not verify the validity of test results. It will also make clear that these are the results for a particular sample and that the compost may vary at different times. Past analyses will not be deleted so that users can look at consistency over time. The hope is that a consumer can visit the site, compare the values of a compost product with guideline values provided on the website described earlier, and make an educated decision on their own about purchase and use of that compost. One potential problem is that if data regarding nutrients are included, that may trigger regulation as a fertilizer as described above.

A number of activities related to this project are planned or underway. The turf industry represents a large potential market for composts and vineyards are another NYS industry that can benefit from compost use. Over the next several years, in a project partially funded by NYSERDA, CWMI will be working with faculty, staff and industry representatives to develop use guidelines, conduct field research and demonstration and provide education on compost use. Continued work with the full range of stakeholders will take place in part through the "Managing Organic Residuals Program Work Team" operating through Cornell Cooperative Extension. The new president of NYSAR sees reactivation of the Organics Council as a high priority. Several agencies (ESD and NYSERDA) are interested in pursuing the potential for aggregation or joint composting and/or marketing of compost. Through a new NYSERDA funded project, CWMI technical assistance to composters of manure will continue.

In order to reach audiences beyond NYS, we will seek publication of results of this project in both magazines reaching broad audiences, such as BioCycle, American Agriculturist, NE Dairy Business and

Soil Conservationist as well as in more technical peer reviewed journals such as Compost Science and Utilization.

REFERENCES CITED:

Brinton, William F. *Compost Quality Standards and Guidelines*. Woods End Research Laboratory, Inc. 2000.

Hogg, Dominic, Josef Barth, Enzo Favonio, Massimo Centemero, Valentina Caimi, Florian Amlinger, Ward Devliegher, Will Brinton, and Susan Antler. Comparison of Compost Standards Within the EU, North America and Australasia. The Waste and Resources Action Programme (WRAP). 2002.

Long, Cheryl. "Buying Compost: The Good News and the Bad News." *Organic Gardening*. vol. 46 no. 4 (July/August 1999): 48-50.

National Bark and Soil Producers Association. Voluntary Uniform Product Guidelines for Horticultural Mulches, Growing Media, and Landscape Soils. 2001.

Northeast Regional Agricultural Engineering Service. *On-Farm Composting Handbook*. Edited by Robert Rynk. 1992.

USDA and US Composting Council. Test Methods for the Examination of Composting and Compost. 2002.

US Composting Council. Compost Use on State Highway Applications. 2001.

US Composting Council. *Field Guide to Compost Use*. 1996.

US Composting Council. Landscape Architecture Compost Use Specifications. 1997.

Woods End Research Laboratory, Inc. Table 1: Seal of Quality Approval Categories. 2001.