Plant Nutrients and Fresh Mushroom Compost

Dr. Mike Fidanza, Associate Professor of Biology (Plant and Soil Sciences), The Pennsylvania State University, Berks Campus, Reading, PA, Email: fidanza@psu.edu and

Dr. David Beyer, Professor of Plant Pathology, The Pennsylvania State University, University Park, PA, Email: dmb8@psu.edu

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The purpose of this research project was to measure the plant nutrient content and particle size distribution of fresh mushroom compost. Mushroom compost, formerly referred to as "spent mushroom substrate" or "SMS," is the composted organic material remaining after a mushroom crop is harvested. Although there have been a few scattered reports and observations on the chemical compounds found in mushroom compost that are useful for the growth of agricultural crops and other plants, no formal record exists specifically for fresh mushroom compost. The key word is "fresh" – the material obtained directly as it is removed from a commercial mushroom production facility and not "static-aged" by being stockpiled outdoors in a field for several months.

During late winter/early spring 2005, 30 fresh mushroom compost samples were collected from mushroom farms in Berks and Chester counties. Each sample was placed in a one-gallon plastic container, sealed and sent to the Agricultural Analytical Services Laboratory (Pennsylvania State University, University Park, PA) for processing and analysis. For this study, fresh mushroom compost samples were processed and analyzed, and results are presented on a wet weight basis, wet volume basis, and dry weight basis (Table 1), particle size distribution (Figure 1), and amount of plant nutrients on a per acre basis (Table 2).

pH Most agricultural and horticultural crops grow best within a soil pH range of 6.0 to 7.0 (i.e., < 7.0 is acidic, 7 is neutral, and > 7 is alkaline). Within this pH range, most nutrients in the soil exist in an available form that can be taken-up by plant roots. Keep in mind, there are exceptions. For example, blueberries prefer a more acidic soil pH. The average pH of fresh mushroom compost is 6.6, an excellent pH for any compost used as an organic fertilizer or soil amendment. Unfortunately, rumors have bounced around for years about the pH of mushroom compost being too acidic or too alkaline for growing plants but this is not the case.

Soluble Salts This statement has been repeated many times over the years: "…you can't use mushroom compost because of the high salt content." With soils and composts, the salts of concern are those positively charged cations: potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}) and sodium (Na^+). An excessive amount of these salts dissolved in the soil solution (i.e., the soil water environment) can increase the osmotic pressure of the soil solution, and this "salt effect," also referred to as salinity, inhibits water absorption by seeds and roots. Many composts and fertilizer products contain these salts in varying amounts. Potassium, calcium, and magnesium are actually essential nutrients beneficial to growing plants. When adding compost or fertilizer to soil, these salts are often diluted by leaching with adequate rainfall or irrigation, or by tilling or mixing those materials into the soil.

Soluble salt content in soil and compost is measured indirectly by electrical conductivity, and the methods vary with each laboratory. Penn State's laboratory determines soluble salts using a 1:5 (compost:water) slurry. The average soluble salt content of fresh mushroom compost is not in an amount high enough to cause problems with plant growth. With fresh mushroom compost or any other compost or fertilizer, however, over-application or incorrect application of these materials to the soil can result in an excessive salt load.

Excess sodium salt in soil can result in problems with soil structure and drainage as well as inhibiting water absorption by plant roots. The best way to address this issue with fresh mushroom compost or any compost or organic soil amendment is to calculate the sodium adsorption ratio (SAR) of the product or material. The SAR compares the sodium concentration relative to the concentrations of calcium and magnesium. The SAR is calculated as follows:

$$SAR = \frac{[Na^{+}]}{\sqrt{\dfrac{([Ca^{2+}] + [Mg^{2+}])}{2}}}$$

A SAR value ≥ 15 indicates an excess amount of sodium compared to calcium and magnesium, and that sodium would be adsorbed by the soil clay particles thus causing problems mentioned above. Applying 40 tons of fresh mushroom compost to one acre of land (calculated by using a bulk density amount of 575 lbs/yd^3) results in a SAR = 0.38, which is very low! Therefore, the presence of sodium in fresh mushroom compost is not a negative aspect of this product, since there is an ample amount of calcium and magnesium present to prevent sodium from accumulating on those soil particles.

The *bottom line* with fresh mushroom compost, or any compost or organic soil amendment or fertilizer, is *environmental stewardship*. Compost products used for agricultural crop production, horticulture plant production, gardening, or land use reclamation should be applied correctly and in the proper amount. For many years, mushroom compost was mislabeled as "mushroom soil," and the product was unfortunately treated like a soil. As a result, Pennsylvania's mushroom industry had to deal with the negative feedback of trying to explain why their mushroom compost was not behaving like topsoil. Mushroom compost is not topsoil, rather an excellent compost useful to improve soil health and plant growth.

Bulk Density, Solids and Moisture The average bulk density of fresh mushroom compost is essentially 575 lbs/yd^3 (wet volume basis), with over half of the overall weight attributed to water. Fresh mushroom compost contains solids at 42.7 percent (wet weight) or 243.4 lbs/yd^3 (wet volume), and moisture or water at 57.3 percent (wet weight) or 331.5 lbs/yd^3 (wet volume). The ideal moisture content of compost depends on the water holding capacity of materials used to produce the compost. Overall, composts higher in organic matter have a higher water holding capacity. A range of 35 to 55 percent (wet weight) for solids and 45 to 65 percent (wet weight) for moisture is ideal for most compost products. Fresh mushroom compost falls into those ranges.

Organic Matter and Carbon The average organic matter content of fresh mushroom compost is 26 percent (wet weight) or 147 lbs/yd^3 (wet volume). Fresh mushroom compost is an excellent source of organic matter, which represents a pool of plant nutrients to be slowly released over time. Also, due to the high organic matter and carbon content, fresh mushroom compost would be extremely useful to amend soils low in organic matter and nutrient availability, especially sand-based soils.

Carbon:Nitrogen (C:N) ratio The amount of carbon relative to the amount of nitrogen is an indicator of nitrogen availability for plant growth. The ideal C:N ratio for good composts should be within the range of 10:1 to 15:1, and no greater that 30:1. At higher C:N ratios, soil microorganisms can immobilize or tie-up nitrogen making it unavailable for plant roots. The average C:N ratio for fresh mushroom compost is ideal at 13:1.

Primary Macronutrients Nitrogen (N), phosphorus (P) and potassium (K) are important and essential primary plant macronutrients needed in higher quantities by plants than other nutrients. The average total N content of fresh mushroom compost is 1.1 percent (wet weight) or 6.4 lbs/yd^3 (wet volume). The majority of this N is in the organic form, with a very small percentage in the ammonium-form. In general, all organic compost materials (for example, composts made from landscape and yard wastes, plant residues, animal wastes) have low N content usually in the 1 to 3 percent range. Compost is a natural organic source of N, and the N is released slowly by soil microbial decomposition. Plants use N for growth and development, especially for amino acid and protein synthesis, and also for chlorophyll production. The average phosphate (phosphorus in the form of P_2O_5) content of fresh mushroom compost is 0.7 percent (wet weight) or 3.8 lbs/yd^3 (wet volume). Phosphorus is needed in plants for cell energy transfer and electron transport, and for DNA and RNA synthesis. Also, phosphorus is essential for seed germination and emergence. The average potash (potassium in the form of K_2O) content of fresh mushroom compost is 1.3 percent (wet weight) or 7.1 lbs/yd^3 (wet volume). Potassium is used by plants for enzyme reactions and the osmotic regulation of cells.

Secondary Macronutrients Calcium (Ca), magnesium (Mg), and sulfur (S) are considered secondary plant macronutrients, and are also required by most plants, but not in large quantities like the primary macronutrients of N, P, or K. Fresh mushroom compost contains Ca at 2.3 percent (wet weight) or 13.2 lbs/ yd^3 (wet volume), Mg at 0.4 % (wet weight) or 2.0 lbs/ yd^3 (wet volume), and S at 0.9 percent (wet weight) or 4.9 lbs/ yd^3 (wet volume). Calcium is important in plants for cell membrane structure and function. In plants, Mg is a central component of chlorophyll and vital for photosynthesis, and S is important for amino acid synthesis.

Micronutrients Iron (Fe), manganese (Mn), copper (Cu), and zinc (Zn) are all considered plant micronutrients and are needed in much smaller quantities compared to the macronutrients. Sodium (Na) and aluminum (Al) are not typically listed as micronutrients but are included in most compost analysis tests. All of these nutrients are available in fresh mushroom compost at a very low average range of 0.01 to 0.2 percent (wet weight) or 0.03 to 1.1 lbs/yd^3 (wet volume). Refer to Table 1 for the exact amounts of each nutrient. In plants, chlorophyll synthesis (Fe), formation of oxygen during photosynthesis (Mn), cellular respiration (Cu), and enzyme functions (Zn) are supported by these micronutrients. Again, rumors of excessive or toxic amounts of zinc present in fresh mushroom compost are not accurate as these results indicate.

Particle Size Approximately 91 percent of fresh mushroom compost is ≤ 3/8 inches in diameter (Figure 1). Therefore, fresh mushroom compost has a consistent and uniform size, which translates to ease of transport and application. Fresh mushroom compost is not "clumpy" or difficult to handle.

So, how much of these plant nutrients are supplied from fresh mushroom compost on a per acre basis? To apply evenly one-inch thick fresh mushroom compost to one acre of land would require 40 tons of fresh mushroom compost as calculated from an average bulk density of 575 lbs/yd^3 (Table 2). This calculation shows a total nitrogen amount of 891 lbs, of which 29 lbs is quickly available nitrogen (ammonium-nitrogen) used immediately by a crop in the same growing season when this compost is applied. A remaining amount of 862 lbs of organic nitrogen represents nitrogen that is slowly released over time. A typical "rule of thumb" is that 10 to 20 percent (86 to 192 lbs) of nitrogen could potentially become available during the growing season from this organic nitrogen pool. This kind of information is useful in field crop production in order to calculate nitrogen supplied by compost and nitrogen needed from fertilizer inputs. With the recent increase in synthetic fertilizer costs, nitrogen supplied from fresh mushroom compost represents an economical way to meet crop nutrient needs while minimizing the expense of applying synthetic fertilizers. Phosphate information on a per acre basis is also useful, since some states require detailed nutrient management plans for the purpose of monitoring the amount of phosphate being applied to the land.

In conclusion, fresh mushroom compost applied to soil or incorporated into soil has many benefits: improves soil structure, provides plant nutrients, increases plant nutrient availability, increases soil microbial populations, increases soil cation exchange capacity, increases plant root structure, increases soil aeration, improves soil water status, and reduces soil compaction. Fresh mushroom compost is a viable "green" product as an organic soil amendment and fertilizer for crop production systems and other land management issues.

For more information on the cost of Penn State's compost analysis and other related information, refer to the laboratory Web site at www.aasl.psu.edu. Also, before sending compost samples to any laboratory, make sure it is U.S. Compost Council certified (www.compostcouncil.org).

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Committee Members:
Chip Chalupa, Modern Mushroom Co
Phil Coles, Giorgi Mushroom Co.
Joe DiNorscia, Laurel Valley Soils
Linda Farrell, Blue Heron Consulting
Joseph Fecondo, Joseph Silvestri & Sons
Dan Greig, Chester County Conservation District
Charles Krallinger, Giorgi Mushroom Co.
Dr. Kenneth Lomax, University of Delaware
Sara Manning, CAC/AMI
Don Moore, Agronomist, Agricultural, Environmental & Technical Consulting (AET)
Mike Pia, Kaolin Mushrooms
Laura Phelps, American Mushroom Institute
Joseph G. Poppiti, JoBeth Farm
Chris Strohmaier, Chester County Conservation District
David Tranquillo, Giorgi Mushroom Co.

Further Reading

For more information on soils, refer to these publications:

Brady, N.C. and R.R. Weil. 2000. Elements of the nature and properties of soils. Prentice Hall, Upper Saddle River, NJ.

Brady, N.C. and R.R. Weil. 1996. The nature and properties of soils. Prentice Hall, Upper Saddle River, NJ.

Foth, H.D. 1984. Fundamentals of soil science. John Wiley and Sons, New York, NY.

Miller, R.W. and D.T. Gardiner. 2001. Soils in our environment. Prentice Hall, Upper Saddle River, NJ.

Singer, M.J. and D.N. Munns. 2002. Soils, an introduction. Prentice Hall, Upper Saddle River, NJ.

Sidebar: Success Story!

The Pennsylvania Department of Agriculture had classified mushroom compost (formerly listed as "spent mushroom substrate" or "SMS") as an agricultural waste product, which then involved regulation through the Pennsylvania Department of Environmental Protection. This classification was incorrect, and resulted in unfortunate environmental and economic challenges for Pennsylvania's mushroom industry. As a result of this research by Drs. Mike Fidanza and David Beyer, and CAC's Mushroom Compost Committee, mushroom compost has been reclassified correctly as a fertilizer and soil amendment. For a copy of a fertilizer/soil amendment label for fresh mushroom compost, refer to the website www.mushroomcompost.org or AMI's website www.americanmushroom.org.

Table 1. Average values from analysis of fresh mushroom compost on a wet weight basis, wet volume basis, and dry weight basis.

Parameter Measured[1]	*Wet Weight Basis*[2]	*Wet Volume Basis*[2]	*Dry Weight Basis*[2]
pH	6.6	---	---
Soluble Salts [3]	13.3 mmhos/cm	---	---
Bulk Density	---	574.7 lbs/yd^3	---
Solids	42.7 %	243.4 lbs/yd^3	---
Moisture	57.3 %	331.5 lbs/yd^3	---
Organic Matter	25.9 %	146.7 lbs/yd^3	61.0 %
Carbon	14.3 %	81.1 lbs/yd^3	33.4 %
Carbon:Nitrogen Ratio	12.8:1 (~13:1)	12.8:1 (~13:1)	12.8:1 (~13:1)
Total Nitrogen	1.1 %	6.4 lbs/yd^3	2.7 %
Organic Nitrogen	1.1 %	6.2 lbs/yd^3	2.6 %
Ammonium Nitrogen (NH_4-N)	0.03 %	0.2 lbs/yd^3	0.08 %
Phosphate (P_2O_5)	0.7 %	3.8 lbs/yd^3	1.6 %
Potash (K_2O)	1.3 %	7.1 lbs/yd^3	2.9 %
Calcium	2.3 %	13.2 lbs/yd^3	5.4 %
Magnesium	0.4 %	2.0 lbs/yd^3	0.8 %
Sulfur	0.9 %	4.9 lbs/yd^3	2.0 %
Sodium	0.1 %	0.7 lbs/yd^3	0.3 %
Aluminum	0.1 %	0.9 lbs/yd^3	0.3 %
Iron	0.2 %	1.1 lbs/yd^3	0.4 %
Manganese	0.02 %	0.1 lbs/yd^3	0.04 %
Copper	0.01 %	0.03 lbs/yd^3	0.01 %
Zinc	0.01 %	0.05 lbs/yd^3	0.02 %

(1)Fresh mushroom compost samples (*n* = 30) collected in one-gallon size amounts were analyzed by the Agricultural Analytical Services Laboratory (Pennsylvania State University, University Park, PA), from January through April 2005.
(2)Mushroom compost samples analyzed "as is" when received at the laboratory for wet weight and wet volume measurements; for dry weight basis, samples oven-dried to remove moisture, then analyzed.
(3)Soluble salts determined by measuring electrical conductivity in a 1:5 (compost:water, weight ratio) slurry.

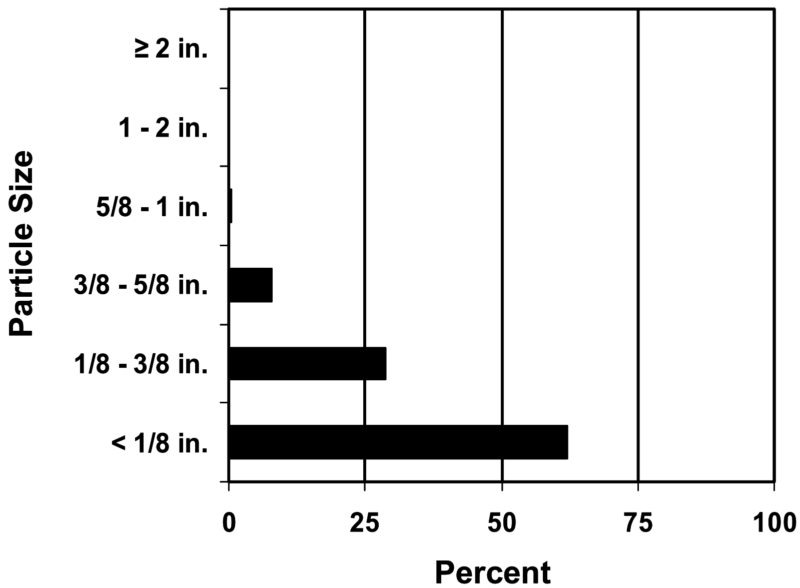

Figure 1. Average diameter values for particle size distribution of fresh mushroom compost as determined from a wet weight basis. Fresh mushroom compost samples (*n* = 30) collected in one-gallon size amounts were analyzed by the Agricultural Analytical Services Laboratory (Pennsylvania State University, University Park, PA), from January through April 2005.

Table 2. Amount of plant nutrients from 40 tons of fresh mushroom compost applied to one acre of land.

Parameter[1]	*Amount (lbs)*[2]
Solids	33,877
Moisture	46,140
Organic Matter	20,425
Carbon	11,294
Total Nitrogen	891
Organic Nitrogen	862
Ammonium Nitrogen (NH_4-N)	29
Phosphate (P_2O_5)	531
Potash (K_2O)	988
Calcium	1,834
Magnesium	280
Sulfur	683
Sodium	94
Aluminum	124
Iron	150
Manganese	17
Copper	6
Zinc	7

(1)pH = 6.6; C:N ratio = 13:1.
(2)Calculation based on applying one-inch thickness of fresh mushroom compost to one acre of land (one acre = 43,560 ft^2), which requires approximately 40 tons per acre using an average bulk density of 575 lbs/yd^3. For example, applying 40 tons fresh mushroom compost per acre will supply 531 lbs phosphate per acre.