SPENT MUSHROOM COMPOST

Traits and Uses

Mushroom compost is made from natural farm ingredients. On a wet weight basis, it may consist of a ratio of 1 poultry manure: 12 corn cob: 20 horse manure : 250 hay, or a variety of other ratios. These ingredients are mixed and then watered which activates the microorganisms which release heat, water vapor, carbon dioxide, and ammonia needed to convert the ingredients into cured compost. Compost is considered "spent" when one crop consisting of 4 to 6 breaks of mushrooms have been harvested. At this time, the farmer concludes that expected production will not provide revenue adequate for the resources needed to maintain the crop, and the compost becomes "spent". Nutrients and organic matter remain, but they are not available to the mushroom which is why farmers empty growing rooms and refill with newly made compost.

The corn field on the left was fertilized with spent mushroom compost, the right field was left untreated.

Paul J. Wuest
Professor, Department of Plant Pathology,
Penn State University,
University Park, PA 16801

Helen K. Fahy
Consulting Environmental Engineer,
Spring Mills, PA 16875

Spent mushroom compost contains no herbicides or nematicides, the two pesticide groups identified by EPA in 1990 as contributing the most to well-water contamination across the nation(1). The limited use of insecticides and fungicides within the integrated pest management plans in place at all mushroom farms, coupled with heat destruction of pesticides during two compost pasteurizations and the alkaline environment of compost foster the degradation of most pesticides that could be present in compost. An examination of laboratory analysis for pesticide residues discovered during an extensive search of DER inspection reports found no organochlorine pesticides (DDT, Lindane, Chlordane, etc.) and only trace amounts of the organophosphate diazinon, < 0.005 mg/l. The research project being summarized in this report did not include pesticide residues as a water quality feature because the authors knew: 1) long-lived pesticides were not used by mushroom farmers in 1988; 2) the short-lived, low impact pesticides used degrade via composting and steam pasteurization; 3) farmers were using fewer pesticides to accommodate the buying habits of the public. Pesticides in spent compost are a nonissue in the author's experience.

Aging spent mushroom compost has been normal farming practice at mushroom farms in the United States and other countries since the 1950's. The purpose of aging is to convert strawy, fibrous, light-colored compost into a friable, dark soil. Some authors (8,13) indicate there is a need to lower the soluble salt and ammonium present in the compost to foster thrifty growth of immature green plants(seedlings).

ANALYSIS OF SPENT COMPOST

Between three and four dozen truckloads of SMC were acquired from Chester and Berks counties, Pennsylvania in the Spring and Summer of 1988, 1989 and 1990. The supplier collected SMC at a number of mushroom farms in both counties as the material was being removed from the mushroom houses, and delivered it to the experimental site immediately thereafter. Random, hand-grab samples of SMC were collected following each delivery was completed and the plastic bagged samples were delivered to the laboratory for analysis.

The average analysis of the fresh SMC was 1.9-0.4-2.4 (N-P-K), and after weathering outdoors for between 8 and 16 months, the analysis was 1.9-0.6-1.0. These analyses indicate neither nitrogen nor phosphorus were lost (leached) during the weathering period, and potassium was much more leachable. These results are to be expected since the stability of nutrients in composted material has been known for decades. A profile of heavy metals revealed that SMC contains much less heavy metals than sewage sludge, and the low levels of heavy metals preclude the classification of SMC as a hazardous substance.

SMC is an alkaline substance with an initial pH of 7.28 and the pH after weathering at 8.05. These pHs make SMC an excellent material for land use since it is possible the SMC can supply the lime requirements of most soils in the region. Weathering caused the average organic matter content (volatile solids) to decrease from 63% to 44%, yet this rate of degradation is not high and it suggests SMC tilled into soil will have a positive effect on the organic matter in the soil for quite a few years.

CORN AND SILAGE YIELDS

SMC was tilled into a Buchanan silty clay loam in the Spring prior to planting. Pioneer 46X, a 90-day corn, was planted to provide ca. 140,000 plants per acre. SMC weighs ca. 0.5 t per cubic yard as delivered which means the rates of application, 1.5, 3 and 6 inches to different treatments equate to 100, 200 and 400 tons (fresh wgt) per acre. A starter fertilizer was applied at planting but no additional fertilizer was applied during or after the growing season. Rainfall during the test years was variable: 1988 had a severe drought, 1989 was mixed but judged o.k. because of the timing of rain, 1990 rainfall amounts and patterns were excellent for corn growth. Silage was harvested by chopping a measured number of linear feet, and this procedure was followed for the grain harvest. Yields were converted to tons per acre, with grain moisture adjusted to 15.5%. Nutrient analyses were performed by infrared spectrophotometry using the services available through Dairy Science Extension or the Plant Tissue Analysis Laboratory in the Department of Horticulture, both in the PSU College of Agriculture.

Use of SMC as an organic amendment always resulted in higher yields than the unfertilized control. Yield increases were notable with at least 40% increased silage per acre in 1988, 33% in 1989, and 68% more in 1990(table 1). Grain yields tracked along a similar path, although the magnitude of the increase varied from year to year(table 2). Grain yields increased a minimum of 14% in 1988, 44% in 1989 and 1500% in 1990. The yield increases are related to the moisture holding capacity of the SMC and the very slow release of its nutrients. In 1989 when June rains caused most other corn to be chlorotic, that growing

Table 1. Silage yields (Dry t/A and %N) for fields where spent mushroom compost was applied annually.

Trt (inches)[a]	1988[b]	1989	%N	1990	%N
0	1.13	2.42	0.80	4.67	1.09
1½	1.87	4.27	1.39	14.34	1.37
3	1.97	3.60	1.50	16.08	1.39
6	N[c]	3.98	1.58	15.78	1.37

a. Starter fertilizer applied at planting; no additional fertilization during year. 1.5" SMC = 100 t/A; 3" SMC = 200 t/A; 6" SMC = 400 t/A.

b. 1988-drought year; 1989-OK moisture; 1990-very good moisture.

c. No harvest due to death of plants when 6" high.

in soil amended with SMC was a dark green color in early July. SMC provided the nutrients the corn required as can be seen in Table 3. Soil analyses do not indicate toxicity problems because of excess nutrients, and the quality of ground water corroborates the soil chemistry.

Corn yields in Pennsylvania averaged 103 and 113 bu/A in 1989 and 1990, and yield of silage and grain in Centre County was reported at 13.5 t/A and 113 bu/A, respectively, in 1990, an excellent year for corn.

Yield data poise a number of interesting agronomic questions relating to the benefits of using SMC on corn land. Anecdotal information from farmers, especially in Berks County, indicate that those who have experienced the benefits of SMC on their corn land use it repeatedly. How long the benefits of SMC remain for corn will be partially answered since corn was planted in the plots in 1991 without additional SMC, and additional plantings will be made in future years.

SELECTED ATTRIBUTES OF SMC

CONTAINER GROWN PLANTS

Lohr, *et. al.* (13) studied the effects of SMC on the yield and quality of transplants. They concluded that plants grown in fresh SMC generally were smaller than those grown in aged SMC. They also observed that the initial soluble salt levels in media containing SMC were high, and leaching was effective in reducing these levels. They measured electrical conductance to infer soluble salt concentrations whereas our research used chemical analysis for chlorides, and relating these two methodologies is not possible. Chong *et. al.* (3) reported that dogwood and forsythia grown in containers containing fresh and aged SMC had increased dry weights compared to the control, and the salt levels except at planting (1030 mhos x 10^{-5}) were not considered high enough to cause plant injury. In a more recent study, Chong *et. al.* (5) reported conductance of unleached SMC from 5 sources to range from 1.9 to 8.3 mmhos/cm which did not interfere with the growth of 4 woody deciduous species grown in containers.

Chloride is one of the major inorganic anions in water and wastewater. Chloride concentration is not necessarily indicated by a salty taste in potable water. Salty taste depends on the cation in the water with the chloride anion. For example, a water containing 250 mg/l Cl^- may taste salty if the cation is sodium. However, water containing as much as 1,000 mg/l Cl^- will not taste salty when the cations are calcium and magnesium.

Table 2. Corn grain yields (bu/A at 15.5% H_2O) from research plots where spent mushroom compost was tilled in prior to planting.[a]

Trt (inches)	1988	1989	%N	1990	%N
0	18.8	33.1	0.80	16.7	1.09
1½	21.9	66.8	1.39	268.1	1.37
3	24.1	59.1	1.50	252.5	1.39
6	N	74.9	1.58	300.9	1.37

a. See Table 1 footnotes; data represent average of 3 reps.

CHLORIDES AND SMC

There was an increase in chloride in the soil moisture with the aging process. Other reports (13, 15), also observed an increase in electrical conductivity in leachate from aging SMC. Others observed that potassium, calcium and magnesium accounted for about 80 to 90 % of the total dissolved salts in the leachate. This increase in dissolved salts is due to their release as the organic matter decomposes. Sources of chloride in SMC are most likely the poultry litter used in the compost, and the swimming pool germicide sodium hypochlorite (HTH), used to manage bacterial blotch disease on the mushroom crop. Gerritts (8) reported the Cl^- content of SMC at 1.5 to 7.5 kg/1000 kg fresh wgt, while Chong and Wickware (4) reported 294 ppm in well-rotted SMC. Chong, *et. al.* (5) present data which reflect lower chloride contents in SMC as less chicken manure was used in fresh mushroom compost.

pH AND SMC

The pH of SMC in the bulk storage pile changed as its age increased. Others observed variations in pH between fresh and aged SMC due to the changes in NH_4-N concentrations in SMC, over time. Much of the bacterial population that converts NH_4-N to nitrates and nitrites are killed when the compost is steam pasteurized in the mushroom house prior its removal as SMC. Populations of these ammonium-producing organisms increase when the SMC is aerated during its removal and placement in a field, which causes an increase in NH_4-N and a rise in pH as NH_4OH forms. When Nitrosomonas and Nitrobacter species repopulate the SMC, they use NH_4-N and convert it into nitrates which form acids and a drop in pH may occur. This sequence of pH change can be observed in the analysis of the 1989 bulk storage pile. Fresh SMC had a pH of 7.3, after 8 months of aging the pH was 8.53 and after being aged 24 months, the pH was 7.8. Devonald (6) reported the pH of freshly collected SMC to range between 7.01 and 8.04 with a mean ammonium content of 174 ppm and NO_3^- at 39 ppm. Chong and Wickware (4) reported that well rotted SMC had a pH of 7.70, NO_{3-} at 15 ppm. In an earlier report, Chong, *et. al.* (3) indicated the pH of fresh SMC to be 7.9, with 2 yr. old, weathered SMC at pH 7.0. White (22) used weathered SMC (2 to 3 yr.) to grow flowering greenhouse plants and reported the pH to be 7.2.

DENSITY AND SMC

Piles of SMC decreased in volume, shrunk, over time. The bulk density in g/cm^3 of fresh SMC reported by Lohr *et. al.* (14) was 0.256 and of SMC composted in a seminclosed drum for 6 weeks (aged SMC) was 0.293g/cm^3. Devonald (6) reported an average United Kingdom SMC bulk density of 0.19, with a range of 0.15 to 0.24 g/cm^3, while Maher (15) indicated unweathered Irish SMC had a bulk density of 475g/l (=0.475g/cm^3) and Dvorak, *et. al.* (7) used two different Pennsylvania (USA) SMC collections with densities of 0.24 and 0.62 g/cm^3.

TABLE 3

Analyses of spent mushroom compost (SMC) used in PSU experiments in 1988 and 1990 and comparison figures for horse and chicken manure

Spent Mushroom Compost, SMC		AVG Fresh SMC	AVG Weathered 8-16 mos SMC	Horse Manure	Chicken Manure
Contents	Units				
Sodium, Na	% Dry Wt	0.72	0.22	0.3	0.13
Potassium, K	% Dry Wt	2.35	1.03	1.2	2.25
Magnesium, Mg	% Dry Wt	0.71	0.91	0.25	1.2
Calcium, Ca	% Dry Wt	4.93	6.16	0.85	8
Aluminum, Al	% Dry Wt	0.40	0.80	0.06	0.2
Iron, Fe	% Dry Wt	0.44	0.92	0.06	0.25
Phosphorus, P	% Dry Wt	0.36	0.55	0.9	2.5
Ammonia-N, NH4	% Dry Wt	0.11	0.03	NT	NT
Organic Nitrogen	% Dry Wt	1.83	1.89	3.5	6.11
Total Nitrogen	% Dry Wt	1.93	1.92	3.5	6.11
Solids	% Dry Wt	43.39	49.43	24	20
Volatile Solids	% Dry Wt	62.78	44.29	NT	NT
pH	Standard Units	7.28	8.05	7.2	6.5
Manganese, Mn	PPM Dry Wt	332.92	438.62	115	300
Copper, Cu	PPM Dry Wt	46.26	61.68	25	20
Zinc, Zn	PPM Dry Wt	103.88	136.41	130	175
Lead, Pb	PPM Dry Wt	14.89	18.17	NT	NT
Chromium, Cr	PPM Dry Wt	8.53	11.31	NT	NT
Mercury, Hg	PPM Dry Wt	0.07	0.19	NT	NT
Nickel, Ni	PPM Dry Wt	11.93	15.74	24	20
Cadmium, Cd	PPM Dry Wt	0.43	0.32	0.1	0.4
N-P-K ratio	PPM Dry Wt	1.9-0.4-2.4	1.9-0.6-1.0	1.2-0.3-0.4	3.0-1.3-1.2

% x 10,000 = PPM   NT=Not Tested

RELEVANT LITERATURE

Gerrits (8) studied fresh SMC composition and suggested possible applications for its use. Calcium and salt content were found high, suggesting that outdoor crops were probably better suited, since there would be more salt leaching. Fresh SMC was reported to cause ammonium toxicity in young plants.

Devonald (6) used fresh SMC to test its applicability as an alternative potting medium. Generally, none of the SMC mixtures produced growth results as good as the control. He suggested that the prolonged aging would reduce the conductivity and nutrient levels to achieve better growth results.

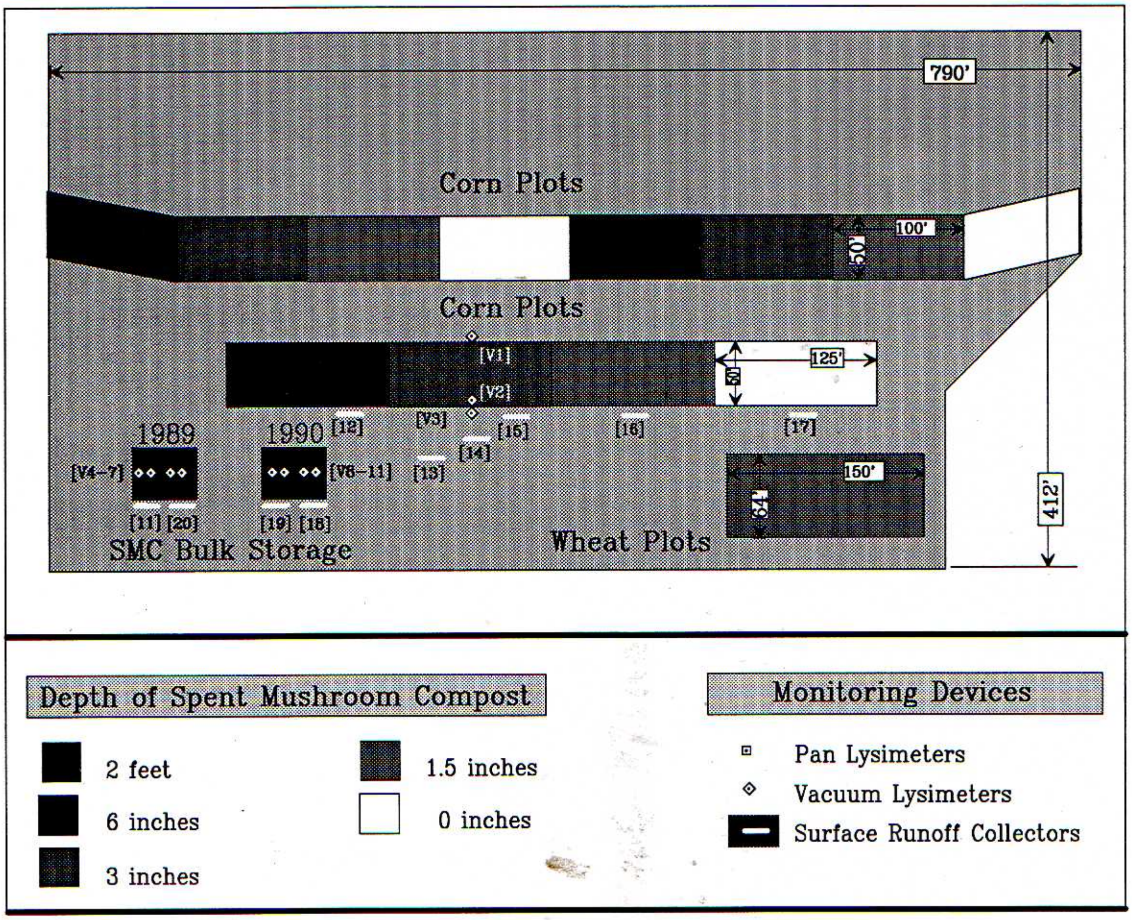
Wang *et. al.* (21), used fresh SMC as a soil amendment for field grown vegetables. Four rates, 0, 2, 10 and 20 kg/m^2 of SMC were applied to a sandy loam each year of the two year study. Bulk density decreased, pore space percentage, pH and electrical conductivity increased. Salt sensitive crops, such as snap bean, onion and radish, suffered severely reduced plant stands. Yield of cabbage, a relatively salt tolerant crop was not affected by SMC. Concentrations of K^+ in all leaf tissue increased significantly as the level of SMC increased. The concentration of Mg decreased due to antagonistic effects of increased K^+.

In another study the same authors reported on the growth response of vegetables grown in fresh SMC in a greenhouse (20). Total seedling emergence was not affected although the rate of emergence was delayed. Increased growth was observed in the range of 20 to 30% SMC. The elemental content in seedling tissue indicated an antagonism among K^+, Ca^{++}, and Mg^{++} in root uptake.

Vegetable growth outdoors provided a different set of data for Kaddous & Morgan (11) who reported no inhibitory or phytotoxic effects from using up to 80 t ha^{-1} of fresh, unleached SMC in a loamy sand soil. The site of this research allowed for year-round vegetable growing and the research consisted of a vegetable crop rotation of celery, lettuce, cauliflower and Western Red. Yields of marketable vegetables were lower where organic amendments were used because of N being unavailable until the fourth crop. Addition of SMC to the soil resulted in raising the pH, CEC, saturated hydraulic conductivity, moisture holding capacity, aggregation, and darkening the soil. In addition, the thermal conductance was reduced as was the bulk density. The addition of SMC also enhanced the availability of P, K and although the N increased, its availability was a limiting factor in the first three crops. The nutrient aspects of the Kaddous & Morgan report are validated through the work of Maher (15) and Maynard (16) who reported inadequate nutrients for crops with known nutrient requirements.

Lohr, *et. al.* (13) examined the use of soilless media containing SMC which was either fresh or aged (6 weeks), leached or unleached, at 25% or 50% by volume. Transplants grown in these mixes were examined and compared to those grown in commercially available, peat-vermiculite medium. Reduced growth and symptoms of ammonium toxicity were seen in transplants grown in fresh SMC. Transplants grown in 0% or 25% compost were larger than those in 50% due to high salinity. Leaching reduced soluble salts and generally improved plant yields. K^+ and Ca^{++} were higher, and P^+ and Mg^{++} were lower in the tissue of SMC grown transplants than those in peat-vermiculite mix which served as the control. High quality transplants were produced in 25% aged SMC while acceptable plants of slightly reduced quality were produced in 50% aged compost.

Chong and Wickware (4) reported that 14 different ornamental shrubs were successfully cultivated in mixes



Design and layout of a field study designed to measure the effect of Spent Mushroom Compost on water quality and corn fields.

containing 50% well-rotted SMC and that a few species did well in 100% SMC. These crops were grown in containers positioned either outside for growth or in a greenhouse. They noted that the salt values were within the optimum range, although the potassium, sulphate and chloride were high.

ACKNOWLEDGMENTS

Funds for this research were provided by the Pennsylvania Department of Agriculture through its competitive grants program. Planting, supervision and harvest of crops was organized by Lynn Hoffman, Sr. Res. Assoc., Department of Agronomy and Larry J. Jordan, farm coordinator, Department of Plant Pathology. The technical assistance of Jonathan Ferdinand and Karen Long was essential throughout the studies. Dr. Charles R. Krueger, Assoc. Dean and Assoc. Director, and Dr. H. Cole, Jr. provided administrative support and practical advice to the project, and thanks are extended to them.

REFERENCES

1. Anon. 1990. EPA, Office of Pesticides, Office of Toxic Substances. 16p.
2. Bringhurst, L.S., et.. al. 1959. J. Am. Med. Assoc. 171: 101-104.
3. Chong, C., et.. al. 1988. Proc. Ontario Hort. Crops Conf., Mushroom Session. 8p.
4. Chong, C. and M. Wickware. 1989. Hort. Rev. 7(6): 10, 11, 13. April 1st.
5. Chong, C., D. L. Rinker & R. A. Cline. 1991. Mush. Sci. XIII: 637-644.
6. Devonald, V. G. 1987. Compost: Production, quality and use. Els. Appl. Sci., London. 785-791.
7. Dvorak, D. H., et.. al. 1991. In: Proc. 1991 Nat'l Mtg. Am. Soc. Surf. Mine Rec., Rec. 2000, Tech. for Succ. Durango, CO. p. 109-122.
8. Gerrits, J.P.G. 1987. Compost: Production, quality and use. Els. Appl. Sci., London. pp. 431-439.
9. Grant, I.W.B. 1982. Cur. Per. All. Goetzl, J. & A. B. Kay, ed.: 78-92. Churchill, Edinburgh.
10. Kaddous, F. G. A. 1986. Dept. Agr. & Rur. Aff., Veg. Res. Sta., Frankston, Victoria, Australia.
11. Kaddous, F. G. A. & A. S. Morgan. 1986. In: Surf. soil mgt. Proc. New Z. & Aust. Soc. Soil Sci., Rotura, NZ. Nov. p. 138-147.
12. Lockey, S.D. 1974. Ann. All. 33: 282-288.
13. Lohr, V.I., et. al. 1984. J. Am. Soc. Hort. Sci. 109(5): 697.
14. Lohr, V.I., et. al. 1984. HortSci. 19(5):681-683.
15. Maher, M. J. 1991. Mush. Sci. XIII: 645-650.
16. Maynard, A. A. 1989. Conn. Agr. Expt. Sta., Front. Plt. Sci. 42(1): 2-4.
17. Richer, A. C., et. al. 1949. PSU Agr. Expt. Sta., Prog. Rpt. 16. 6p.
18. Sprague, H. B. and J. F. Marrero. 1932. Soil Sci. 34: 197-208.
19. van Griensven L.J.L.D., et. al. 1991. Mush. Sci. XIII: 317-321.
20. Wang, S.H.-L, et. al. 1984. J. Am. Soc. Hort. Sci. 109(5): 698-702.
21. Wang, S.H.-L, et. al. 1984. Plt. & Soil 82:31-40.
22. White, J. W. 1976. Mush. News 24(6): 17-19.