The Many Uses of Spent Mushroom Substrate

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Mushroom production has increased at a rate of about four percent annually and is now estimated to be 4.1 million tons per year worldwide. About 1 pound of dry weight mushroom compost, generally consisting of wheat straw, gypsum, poultry litter and water; wheat straw bedded horse manure; or a combination of mixed hay, corn cobs, or cottonseed hulls and cocoa bean hulls, is needed to a grow a pound of mushrooms. Before it is suitable for mushroom growing, the raw ingredients are processed into compost in windrows for 7-10 days by watering every few days and turning 3-4 times. Phase II, cook-out, removes ammonia and pasteurizes compost before spawning. After cropping, a second pasteurization kills pest fungi, flies and other pests and any remaining mycelium in a process performed routinely as part of mushroom farm sanitation programs.

The resulting product is spent mushroom substrate (SMS) and is a necessary byproduct of every mushroom farm operation. Currently, about 60% of SMS produced in Pennsylvania moves to other farms for use as a soil amendment. The storage and disposal of the remainder of this material, however, poses a problem for mushroom growers. A symposium, devoted to agricultural, environmental, and industrial uses of spent mushroom substrate, was held in Philadelphia in 1994. An international group of researchers presented information on the broad range of uses for this material. While only a few scientists throughout the world are studying SMS, the need for information on environmentally sound uses for this material has provided an impetus for more study. As mushroom production continues to increase, so does SMS generation and the demand that this byproduct be managed. What can be done to diminish its negative impact on environmental quality?

Fortunately, SMS has many positive attributes and potential uses. It has few weed seeds and, after storage outside, a diverse microflora capable of detoxifying a variety of organic chemicals. The material is a good nutrient source for agriculture, high in phosphorus and potassium but low in nitrate nitrogen. It has a high cation exchange capacity, a measure of the amount of nutrients a medium can hold, and a slow mineralization rate, retaining its qualities as organic matter. SMS contains 45% water and while bulky in volume, is light in weight.

Let's take a look at the many uses for this material.

AGRICULTURAL AND CONSUMER USES

In a farming experiment sponsored by the Pennsylvania Department of Agriculture, researchers at Penn State found that SMS, used as a nutrient source, maintained crop yields at a high level. Results from the field study headed by Dr. Ken Steffen, now at Quiet Springs Farm & AgroEcology Center in Indiana, demonstrated that a single large-scale application of compost and manure can support a succession of four different vegetable crops over three years without any additional fertilizer. "Yields from plots with added compost were consistently greater than or comparable to those in conventionally fertilized plots," Steffen says. "Our data suggest that although the initial cost of compost can be higher than that of conventional fertilizer, it may be cost effective in the long run."

In the first year of the study, the researchers incorporated about 28 dry tons per acre of spent mushroom compost and 25 dry tons per acre of well-rotted manure into the soil of selected plots. Other plots received no soil amendments but recommended levels of conventional fertilizer. Total marketable yield of tomatoes that year was 25 percent greater, and yield of U.S. number-1 grade tomatoes was 67

percent greater in the compost amended plots, Steffen says.

"In the second year, we no-tilled three varieties of sweet corn into the same plots," he says. "The unamended plots received the recommended nitrogen, while those amended with organic matter received no further nutrients. Depending on the maturity of the cultivar, our marketable sweet corn ear production was 15 to 76 percent greater in the plots amended with organic matter."

In the third year, following moldboard plowing, the researchers planted snap beans, followed later in the season by broccoli and cabbage. Unamended plots received recommended levels of fertilizer while those previously amended with organic matter received no further additions. Snap bean yields were comparable in both soil treatments, Steffen says. Broccoli heads had greater average weights and cabbage was more mature at harvest in the plots with added organic matter.

Evidence from other studies suggests that a large addition of composted organic matter does not increase soil nitrate losses above conventional fertilization practices. However, repeated additions of compost may increase soil salinity levels. This could lead to nutrient deficiencies and reduced yields in crops sensitive to high salt (2,500 parts per million total diluted salts) conditions.

As part of a current project sponsored by the Sustainable Agriculture Research and Education Program of USDA, researchers as Penn State University continue exploring the uses of SMS as a soil conditioner and fertilizer. In one of the vegetable production treatments, SMS is the sole fertility source, compared to other treatments where chemical fertilizers or green manures (cover crops) are used. After three years of study, yields of crops grown with SMS had similar yields as those crops grown with other soil treatments.

Because of the increased organic matter content of soil with SMS, water holding capacity increases. In fields of sweet corn that were not irrigated, yields were greater in silt loam soil with added SMS compared to those plots which did not have added organic matter. The changes in available water reflect changes in soil structure brought on by the addition of SMS. Soils where SMS has been incorporated are also better aerated and drained.

Floriculture is an area where SMS could make a big impact. Here, SMS is an effective and inexpensive additive to the growing medium. Calvin Chong, a researcher in Ontario Canada, found that many deciduous ornamental shrubs (e.g., forsythia, weigela, and rose) grew better when 25-50% by volume SMS was added to the soil in containers. Again, high salt levels may seriously reduce plant growth. Rapid leaching of salt from SMS may be the key to success in attaining growth benefits, according to Chong. When

containers of SMS were irrigated with a trickle system, acceptable levels of salt were attained within several days. In this case, plant growth in fresh SMS was indistinguishable from plant growth in aged SMS. Chong says that when leaching is used along with a slow release fertilizer, media consisting of up to 50% SMS may be beneficial for container-grown plants.

For the homeowner, SMS is a superb material for landscaping. Spread on newly seeded lawns, SMS retains water while the seeds germinate. Tilled into the soil as an amendment, SMS adds organic matter and improves soil structure. Many golf courses are using SMS in establishing new courses and fairways.

ENVIRONMENTAL AND INDUSTRIAL USES

SMS has recently been used in the role of treating water, soil, and other materials that are contaminated with toxic pollutants. Bioremediation offers a cost-effective method of treatment. J.A. Buswell, a researcher at the Chinese University of Hong Kong, reports new information where spent mushroom substrate from Shiitake mushrooms were mixed with sterile soil contaminated with pentachlorophenol, a wood preservative that is classed as a carcinogen. After 21 days incubation, about half of the pollutant had been metabolized.

Agaricus bisporus has long been able to degrade lignin. Because the bioremediation capacity of these fungal systems is dependent upon this ability, *A. bisporus* has the potential for degrading environmental pollutants. More work is needed to determine whether enzyme levels in SMS are high enough to make bioremediation feasible. If not, artificially increasing the concentration of lignin-degrading enzymes may improve this environmentally acceptable approach to toxic chemical cleanup.

In a related use, SMS may be used to prevent pesticide pollution. Pesticide residuals from spray and storage equipment may contaminate surface and groundwater. In a recent study, the high organic matter content and the associated microorganisms neutralized three carbamate pesticides. Research is currently underway to determine if other families of pesticides may be amenable to treatment with SMS.

Treatment of coal mine drainage is another emerging technology for SMS. Since the early 1980s, coal mine companies have constructed wetlands to passively treat aged runoff from mines. By increasing the alkalinity of the water, iron can be removed from the drainage water. Previously, materials such as sphagnum peat, sawdust, and a straw-manure combination were used to increase the pH in the wetlands. While all had some success in tying up iron, the limestone, gypsum, organic matter, and "bulk" that constitute SMS make it an ideal choice for passive treatment of coal mine drainage. Coal mine drainage can harm aquatic plants and animals. An artificial wetland constructed with SMS and supplemented with carbon to maintain conditions favorable for iron oxidation may improve water quality for many years.

FOLIAGE DISEASE SUPPRESSION

In general, use of composts as mulches improves plant growth and may decrease losses from root rots. Control of these diseases with compost may be as effective as some fungicides. Recently, research has focused on the use of compost in the form of teas—extracts of compost "steeped" in water. In this case, the tea is sprayed directly onto the foliage for disease suppression.

John Andrews, a professor in the Department of Plant Pathology at the University of Wisconsin in Madison, demonstrated that a tea made with SMS was the most effective measure for control of apple scab of thirty compost materials tested in the lab or on seedlings in the greenhouse. In field tests, however, SMS tea was promising but not conclusive for apple scab control.

In similar research on early blight control in tomatoes, Felix Lukezic, professor of plant pathology at Penn State University, says that compost teas are still worth investigating. Microbials in the compost teas are most likely producing toxins that may be effective against the early blight fungus, says Lukezic. While he has yet to show that tea made from SMS is as effective as teas made from cow manure or yard waste, research continues.

"The use of straw mulch with these teas may have an added effect in further reducing early blight," he says. More study is needed, however, to determine just how this interaction occurs. Lukezic's group is also evaluating the effects at different stages of the compost: before mushroom cultivation, after cultivation, and after steam out. The effectiveness of the tea may change as the compost ages. The interaction of straw mulch with these compounds is worthy of further study. While this research is still in its infancy, the loss of synthetic fungicides because of health and environmental concerns warrants more investigation into this promising arena.

LET'S NOT CALL IT "SPENT" ANYMORE

Because SMS has a variety of agricultural, environmental, and industrial uses, maybe we should rename this material "used" mushroom compost. Interestingly, what is now considered an environmental problem in itself may prove to alleviate some of the other environmental problems discussed here. With many new and potential uses, it is by no means "spent." **MN**