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Comparison of Spent Mushroom Substrate And Fertilizer As A Nutrient Source For Corn

L. Weber[1], P. Coles[2], M. Hautau[3] and C. Oshins [1]

[1]Rodale Institute, Kutztown, PA; [2]Giorgi Mushroom Co., Temple, PA, [3]Berks County Cooperative Extension, Leesport, PA

ABSTRACT

Spent mushroom substrate (SMS) was compared with inorganic fertilizer as a nutrient source for corn on three Berks County dairy farms. SMS with a moisture content of 56.5 percent was spread at the rate 67 to 80 ton/a in replicated plots on each farm. Starter fertilizer was the only additional source of applied nutrients for growing two successive years of corn. The SMS treatments were compared to the farmers' inorganic fertilizer practice. There was no statistical difference between the two nutrient sources in yield. Two continuous years of corn following the application of SMS produced yields equivalent to the inorganic fertilizer treatments. Based on this study, farmers can obtain the same economic return using SMS at the rate of 70 t/a if the hauling and spreading charges do not exceed the two-year cost for purchasing and spreading inorganic fertilizer. In addition to the nutrients supplied for two years of corn growth, benefits from the organic matter and residual nutrients in the SMS will continue to be realized in future years.

INTRODUCTION

Pennsylvania mushroom growers generate over half a million tons of spent mushroom substrate (SMS) each year. SMS is the composted material in which mushrooms were grown for a period of several weeks. It is the organic composted material that is removed after mushroom production is completed.

Substrate for growing mushrooms is made from a blend of natural products that can include poultry manure, wheat straw, hay, corn cobs, cottonseed hulls, cottonseed meal, cocoa bean hulls and gypsum. It is formulated and composted under controlled conditions.

Composting is a biological process in which microorganisms convert the organic materials into a soil-like material. It is part of the cycle we observe in nature. Leaves falling to the forest floor, for example, are converted into a humus-like material by microorganisms.

Although the SMS is no longer economical for growing mushrooms, it is a valuable soil amendment and source of nutrients for field crop production. SMS adds organic matter to the soil which increases the water and nutrient holding capacity of soils. The organic matter also improves the soil structure and helps buffer crops from extremes of excessive dry or wet weather (Levanon and Danai, 1995).

The nutrient value varies with different sources of SMS (Szmidt and Chong, 1995). The average nutrient content of fresh SMS is 16 lb nitrogen (N), 11 lb phosphate (P_2O_5) and 18 lb potash (K_2O) per ton on a dry weight basis (Rupert, 1995). As SMS ages, P tends to become more concentrated, thus aged SMS has a higher P content than fresh SMS (Szmidt, 1994).

Most of the N in SMS is in a stable organic form that must be mineralized by soil microbes before it is available for plant growth. The N is slowly released during the growing season which minimizes the potential for N loss due to leaching.

Although the total amount of N in a ton of SMS can be readily calculated, there is little research to indicate how much of the N will be available to the crop each year after application. Estimates of available N during the first year after application range from 10 percent (Maynard, 1993), 12-15 percent (Wuest, personal communication), to 20 percent (Rupert, 1995).

The biggest costs in using SMS for field crops are the expenses for transporting and spreading. It is common for farmers located near mushroom farms to spread three to six inches of fresh SMS, which is equivalent to 200 to 400 ton/a (Rupert, 1995). At these rates, significant quantities of nutrients are being applied.

Many of the previous studies focused on the use of SMS as a soil amendment. The objective of this study was to apply the minimum amount of SMS needed to provide the nutrients required for two successive crops of corn. Since N is the most limiting macronutrient in SMS, the SMS rate was based on this nutrient. This rate of SMS is lower than the rate commonly applied by farmers in this region. Applying a lower rate of SMS reduces the labor and costs of spreading, making it a more competitive alternative to purchased fertilizer. The lower rate also reduces the amount of non-N nutrients applied in excess of crops needs.

MATERIALS AND METHODS

SMS was applied in replicated trials on three Berks County, PA farms during the winter of 1994. The farms were selected to represent three distinct soils with a range of water-holding capacity: shaly silt loam, silt loam, and clay loam. Fields were selected in which corn had been grown for at least two years to minimize residual N from past hay crops.

The SMS had a moisture content of 56.5 percent and a N content of 2.75 percent. Estimating the availability of N to be 12 percent during the first year, and 10 percent the second year, we needed 70 ton/a of SMS to provide adequate N for two years of corn with a yield goal of 140 bu/a (Table 1).

The SMS was custom spread with a truck equipped with beaters for spreading manure. The goal was to evenly spread a minimum of 70 ton/a. The actual amount spread at each farm ranged from 67 to 80 ton/a. Each load was weighed to determine the actual amount of SMS applied.

The SMS amended plots were compared to each farmer's normal fertilizer practice in a Randomized Complete Block design with four replications on each farm. Table 2 lists the rates of N fertilizer and SMS that were compared at each farm. An equal rate of starter fertilizer was applied to the fertilizer and SMS amended plots at each farm. The SMS and starter fertilizer were the only sources of N for growing corn in the SMS amended plots in 1994 and 1995.

Soil samples were taken prior to SMS incorporation in the spring of 1994 and again in the spring of 1995. A composite of ten samples from each replication was analyzed for organic matter content.

Tillage and planting was done by the farmer following his standard practices. The corn was planted in 30 inch rows on the clay and shale sites, and in 36 inch rows at the silt loam site. Yield data was collected by machine harvesting a 200 foot length of four rows of corn in each treatment. Grain yields were adjusted to 15.5 percent moisture.

Table 1 Applied and Estimated Available Nitrogen for Two Cropping Seasons

Wet ton/a[1]	Total lb N/a	Year One lb N @ 12% availability	Year Two lb N @ 10% availability
70	1680	202	147

[1] *Moisture content of 56.5 %, N content of 2.75 %.*

Table 2 Rate of Fertilizer Nitrogen and Spent Mushroom Substrate Applied at Each Site

Type Soil	Fertilizer Treatment 1994	1995	SMS Treatment 1994	1995
	lb N/a		tons SMS/a	
clay loam	125	150	67	0
silt loam	100	130	80	0
shale silt loam	100	100	70	0

RESULTS

Rainfall patterns during the 1994 season provided adequate moisture for normal crop growth. Good soil moisture early in the 1995 season was followed by a dry summer. In 1995, corn growing in the conventional fertilizer plots in the clay and shale soils showed drought stress symptoms earlier than corn growing in the SMS-amended plots. Corn on both fertilizer treatments looked drought stressed as the dry weather persisted.

During both years there was little observable difference between the two treatments in the corn at the silt loam site. At the site with clay soil, the corn in the SMS treatment was taller and had a darker green color during the first year but in year two, the fertilizer corn was darker than the SMS corn. In the shale soil, SMS corn had darker green color and was taller than fertilizer corn during both years. Presidedress soil nitrate tests at the time corn was at the V-7 stage indicated soil nitrate levels in the SMS amended plots were lower than in the fertilizer treatments. Yearly stand counts in three 1/1000 acre sections of each treatment revealed no significant difference ($p=0.05$).

Although there were observable visual differences in corn growth during June, there was no statistical difference ($P \leq 0.05$) between the two nutrients sources in yields. Two continuous years of corn following the application of the SMS produced yields equivalent to the fertilized plots. At the rates of SMS used in this study, we did not see the increase in yield during dry seasons observed in other studies with annual applications of SMS (Wuest *et al.*, 1995). Corn yields for the three sites are listed in Table 3.

Less control of grasses with herbicides was observed in the SMS plots during the first year on the loam and shale soils. However, the reduced grass control did not affect yields. The increase in soil organic matter resulting from the SMS application reduced the efficacy of herbicides. Soils tests in 1995, one year after the SMS was incorporated, showed an average increase of 0.4 percent to 0.7 percent in organic matter in the SMS amended plots (Table 4).

DISCUSSION

The costs for farm use of SMS are the charges for spreading and hauling the SMS to the farm. Spreading SMS uniformly at the rate used in this study can be achieved by using a manure spreader or a custom spreader. The custom spreader used in this study would be able to spread an acre of SMS at 70 ton/a for $50. Since this rate supplies the nutrients needed for two years of corn production, the spreading charge amortized over two years would cost $25/a.

Farmers can determine the amount they can spend on SMS hauling costs by comparing the fertilizer equivalent and spreading costs for fertilizer and SMS over a two-year period (Table 5). The cost difference between these two nutrient sources, $62.20, can be applied towards hauling costs. Mushroom growers can also use this data to determine hauling costs that need to be subsidized for SMS to be used as an economical nutrient source. For example, if the combination of distance and volume resulted in a hauling cost per acre of $100, then a subsidy of $37.80 would be required to make the SMS system cost competitive. Actual hauling costs depend on the distance to the farm, the volume to be delivered, and the size of the truck.

Farmers using SMS will realize additional benefits beyond the first two years of crop production. The SMS will continue to provide soil tilth benefits and residual nutrients. The rate of SMS used was selected to meet the N requirement of the corn crop for two years. When using SMS as the sole N source, P_2O_5 and K_2O levels are applied in excess of the corn nutrient needs. In this study, the SMS with an analysis of 2.75-1.5-1.5 applied at the rate of 70 ton/a, supplied 910 lb P_2O_5, and 910 lb K_2O per acre. In addition to the primary nutrients, SMS also supplies calcium, magnesium and many of the secondary nutrients and micronutrients needed by crops. While it is important to account for the quantity of nutrients being applied with SMS as part of a nutrient management plan,

Table 3 Conventional Fertilizer and Spent Mushroom Substrate Corn Yields (bu/a)

Type Soil	1994 Fertilizer	1994 SMS	1995 Fertilizer	1995 SMS
clay loam	138	134	119	125
silt loam	113	119	105	104
shale silt loam	128	137	62	70

The Student T test showed no significant difference between treatments at $P \leq 0.05$.

Table 4 1995 Soil Organic Matter Levels in the Fertilizer and SMS Amended Plots

Type Soil	% Soil Organic Matter: Fertilizer	SMS Amended	Increase
clay loam	2.7	3.1	0.4
silt loam	3.3	3.9	0.6
shale silt loam	2.0	2.7	0.7

these nutrients only have value if they are needed by the crops grown in a rotation cycle.

This study demonstrated that SMS applied at rate of 67 to 80 wet ton/a produced two years of corn with yields equivalent to corn grown with the farmers' normal fertilizer practice. In addition to the nutrients supplied for two years of corn growth, benefits from the organic matter and residual nutrients in the SMS will continue to be realized in future years.

After two years of crop production, significant amounts of residual N remain and will be released gradually over a period of years. However, the amount released may be inadequate as the sole source of N for corn production. During the second year crop, soil nitrate levels at the site with clay soil were in the range where a yield response to supplemental N could be expected. Even though the amount of residual N is insufficient to supply all of future crop N needs, credit for the residual N should be part of the nutrient management plan.

Leaching of N resulting in high levels of nitrates in the groundwater is a concern with the application of materials with a high quantity of N. In a study with SMS applied at 50 ton/a each year for three years for vegetable production, Maynard (1993) reported crops appeared to use nitrates as fast as they were produced. Nitrate leaching was greater in plots with inorganic fertilizer than in SMS amended soils. Wuest *et al.* (1995) found that SMS at the rate of 220 ton/a for corn production had little effect on the water quality. In comparison to highly available sources of N, the potential for nitrate leaching losses is minimized by the gradual N release from SMS. Brinton (1985) reported lower soil nitrate levels in composted manure treatments compared to treatments amended with fresh manure and inorganic fertilizer.

When SMS is used at a rate to supply the N requirements of corn, excess P and K will be applied. Including crops in a rotation that have a high demand for P and K, such as alfalfa, may be needed to avoid accumulating excessive P and K levels in the soil with the use of SMS. A legume in the rotation also helps restore the balance of nutrients since legumes fix their own N when available soil N sources are depleted.

Table 5 Two-Year Corn Grain Costs for Nutrients, Spreading, and Hauling Allowance for Fertilizer and 70 ton SMS

	Fertility System Costs/a	
	Fertilizer	SMS
Fertilizer	$101.40[1]	$ 0[2]
Custom spreading	$ 10.80[3]	$50.00
Total cost	$112.20	$50.00
Hauling cost allowance[4]	$ 0	$62.20

[1] *The Agronomy Guide 1995-1996, Penn State College of Agricultural Sciences.*

[2] *Assumes no charge for the SMS.*

[3] *1994-1995 Statistical Summary Pennsylvania Department of Agriculture Annual Report.*

[4] *Difference between total cost of fertilizer and SMS.*

Leon Weber weighs a tarp holding spent compost. The spreader was calibrated by weighing SMS spread over tarps.

SMS was dispersed with a truck used for spreading chicken manure.

Nitrogen was applied with the herbicide in the control plots using a tractor with a sprayer boom.

Corn growing in the SMS amended shaly soil had a darker green color and was taller than the corn in the inorganically fertilized soil.

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