Spent Mushroom Substrate as a Component of Soilless Potting Mixes: Nutrient Changes During Composting©

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INTRODUCTION

The greenhouse and nursery industries in the U.S.A. are, to major extent, container plant industries and as such have a need for a continuous supply of growing media. The components that can be used to create a growing medium are numerous and often regional in terms of availability. Growers want components that are readily available, consistent, and economical. A component that has potential as a growing medium amendment is spent mushroom substrate (SMS).

The U.S.A mushroom industry generates 1 billion tons of SMS each year and that SMS is not recycled by the mushroom industry. The mushroom industry either puts the SMS on a field and lets it weather for a year or longer or the SMS must go into the waste stream. When placed on a field for weathering, the SMS continues to decompose and results in a product that has been used by gardeners. The product is called mushroom casing soil or spent mushroom compost, and it is highly organic and has some nutritional value. Problems with this procedure are that it requires land for the application of SMS and the supply of land is running out and there is potential for surface and ground water pollution.

Use of SMS fresh from the mushroom houses by the greenhouse/ornamental industries would solve both problems for the mushroom industry and provide a component for growing media. The disadvantages of this product are that it is extremely high in soluble salts, the pH is high, and it continues to decompose so that there is volume reduction.

Young et al. (2002) demonstrated that marigolds could be effectively grown in SMS from three sources where excess soluble salts had been leached from fresh SMS and could be used immediately as a growing medium amendment. Leaching of SMS creates a product that has a lower salt content (Chong and Hamersma, 1997). However, some of the salts in SMS leachate are plant nutrients and could be supplied to the plant as a replacement for existing fertilizer nutrients (Holcomb et al., 2000).

Therefore, the objectives of this research were to determine how easily the nutrients in SMS are leached, and what changes in nutrient content of SMS might occur as the fresh SMS continues to compost.

MATERIAL AND METHODS

Nutrient Leaching. The research on additional composting of SMS took place at two locations: The Pennsylvania State University and a commercial firm (NutraSoils, Toughkenenamon, Pennsylvania). All analyses were conducted at The Pennsylvania State University, University Park, Pennsylvania. Fresh SMS was obtained and passed through a 2-mm sieve and SMS that did not pass through the sieve was used for this work. The SMS was packed into 10 aluminum cores (8 cm in diameter and 7.5 cm in height) according to a procedure adapted from Bilderback et al. (1983). The bottom of each core was covered with cheesecloth to assure that the medium would not spill out. The 10 cores were divided into two treatments. One treatment was leached immediately while the other was leached at weekly intervals. The first five cores, which were leached repeatedly and each core served as a subsample, were placed in funnels and reverse osmosis (RO) water was added to bring the substrate in the core to container capacity with no leaching. Once at container capacity, the substrate in each core was leached with 100 ml of RO water. The volume of leachate from each core was recorded and leachate pH and EC were determined. A 10-ml subsample was removed from the leachate of each core and combined into a single 50-ml sample. The whole leaching procedure was repeated five times for a total of six leachings. All six 50-ml samples were sent to the Agricultural Analytical Lab (University Park, Pennsylvania) for solution analysis of Ca, K, Mg, P, and nitrate.

The substrate in the five remaining cores was brought to container capacity then leached weekly with 100 ml of RO water. The rest of the procedure described above was followed except that the leachings were done once each week rather than six times one after another. The leachings were labeled with the week during which the leaching occurred. Between leachings, the cores were removed from the funnels and placed in a covered container to minimize evaporation at room temperature. The same data were collected as above. Since the five subsamples were combined into a single sample that was analyzed, the value reported is the average value for the five subsamples, but the variation was removed by the combining.

Nutrient Changes During Composting. Fresh SMS was obtained from a commercial firm specializing in SMS composting (NutraSoils, Toughkenenamon, Pennsylvania) and was either transported to the Penn State site for additional composting or was composted at the NutraSoils site. The SMS was from a number of firms so there was no single handling procedure for the SMS prior to initiation of the experiment.

Composting at Penn State. Fresh SMS was placed in a vessel (aerated composting) or in a windrow (turned weekly) and composted for the next 5 to 6 weeks (Heinemann et al., 2003). The vessel was a modified hook-lift box 2.44 m wide × 2.44 m high × 4.27 m long that was divided into a 2.74-m × 2.44-m aerated floor processing section and a 1.52-m × 2.44-m enclosed instrument room. A blower in the instrument room supplied air to the processing section. The SMS obtained was divided so that approximately 10.7 m^3 was placed in the vessel and another 10.7 m^3 was placed in a static windrow. The static windrow was approximately 4.5 m long, 2 m wide, and 1.5 m high at the center. During that time, six 1-L samples of SMS were removed weekly from the vessel and windrow. For the vessel the cover was removed, the surface 10 cm of SMS removed, and then a 1-L sample was removed. The process was repeated in five additional places. For the windrow about 15 cm of surface SMS was removed and a 1-L sample was removed. The locations were in the middle of the windrow and one near each end and then again on the other side of the windrow. The six samples from each source were combined, shredded, and mixed and three 1-L samples were removed. The samples were mixed to reduce the variation due to sampling. Each of the three samples from each source was saturated with RO water, the pH was determined, then the solution was extracted under vacuum and the EC of the leachate determined. The leachate was diluted 1 part leachate to 10 parts of RO water and sent to the Agricultural Analytical Laboratory for analysis of N, P, K, Ca, Mg, and S. Three repetitions were carried out. The first and second repetitions were during July-August and November-December 2002, and the third repetition was during June-July, 2003. There were the two treatments, six weekly collections, and three replications at each collection time. Each factor (i.e., pH and EC) was measured separately and analyzed by analysis of variance with three repetitions and six weekly observations for each treatment.

RESULTS AND DISCUSSION

Nutrient Leaching. The nutrient in greatest supply was K. Potassium leached readily from SMS so that by the sixth leaching the K level was at a concentration that would be beneficial to plant growth (Fig. 1). Initially there was a difference in the K concentration in the leachate, however, the total K leached when summed was similar for the two methods of leaching. The K leached out at the same rate whether the solution was applied six times during the same day or whether it was applied at weekly intervals. This suggests that additional K was not being further released during the 6 weeks that the samples were being leached. Calcium and Mg were available in lower quantities and were released in the same manner as K (Figs. 2 and 3). Nitrate, although not available in as high a quantity as K, showed a different release pattern from K, Ca, and Mg (Fig. 4). Repetitive leaching reduced the nitrates as it did with K (Fig. 4). Weekly leaching initially decreased the nitrate content, but by Week 3 the amount of nitrate being leached increased and continued to increase through Week 6 (Fig. 4). It is apparent from these data that nitrate is continuing to be released as the SMS continues to compost. This additional nitrate would be beneficial for the growth of plants. Phosphorus had lower availability than nitrate but showed the same release pattern (Fig. 5). The repetitive leaching over 1 day reduced P in leachate while the weekly leaching increased P availability in leachate by Week 6 (Fig. 5). It appeared that P was being released as the SMS continued to decompose and that additional P will be beneficial for plant growth. Stewart et al. (2000) reported rapid leaching of K, Ca, Mg, and S and these repetitive leaching results are in agreement with those findings. Stewart et al. (2000) did not examine nutrient release over time however, as was done in this experiment.

Nutrient Changes During Composting: Penn State. The pH of SMS in the windrow was slightly higher than in the vessel during Weeks 1, 2, and 3, but by Week 5 they were similar (Table 1). Over the 5-week observation period the pH of the windrow was significantly higher than the pH of the vessel (Table 1). There was no consistent trend of EC over time, and there was no significant difference in EC between the vessel and windrow (Table 1). Potassium content in the extract from SMS in the vessel tended to decrease during the 5-week period of the experiment (Table 1). The K content of SMS from the windrow began to decrease slightly after Week 1 until Week 5 (Table 1). The K extracted from the vessel decreased consis-

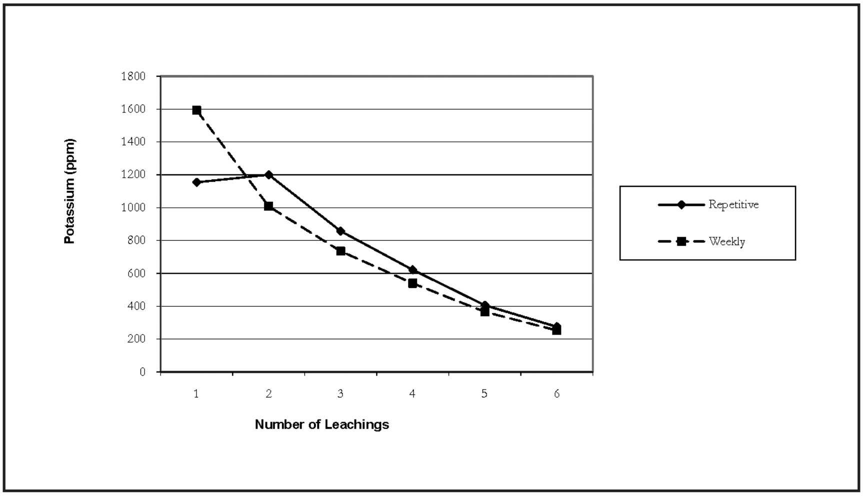

Figure 1. Potassium concentration in the leachate obtained from SMS where RO water was either applied in six 100-ml aliquots in the same day or applied in one aliquot weekly for 6 weeks.

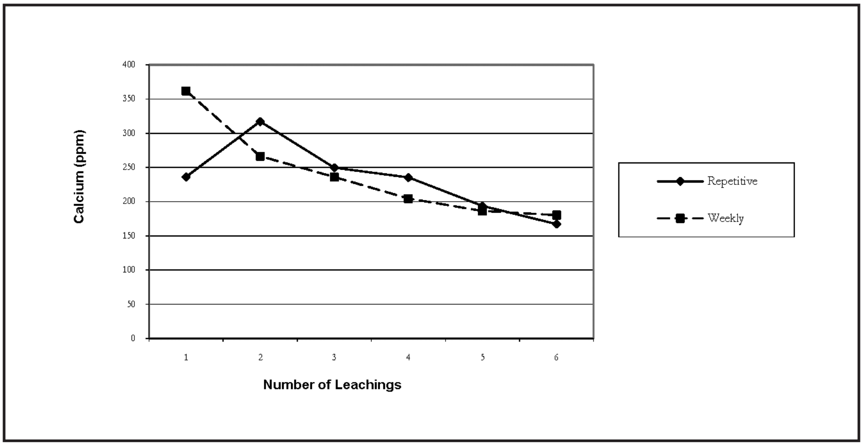

Figure 2. Calcium concentration in the leachate obtained from SMS where RO water was either applied in six 100-ml aliquots in the same day or applied in one aliquot weekly for 6 weeks.

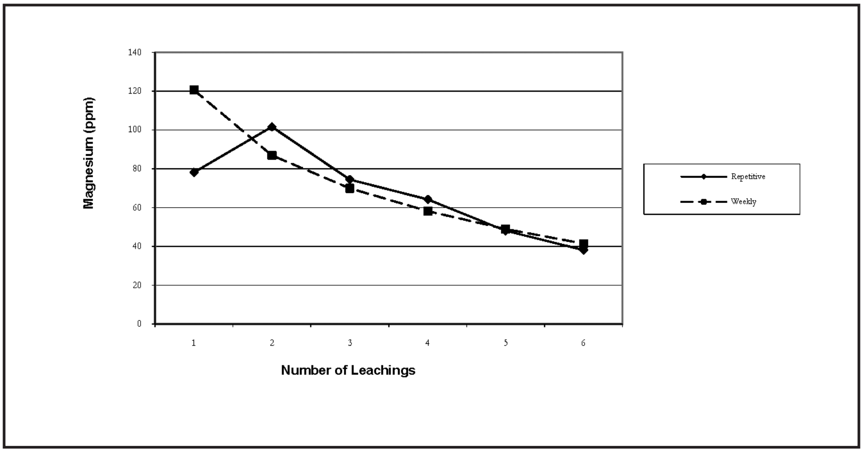

Figure 3. Magnesium concentration in the leachate obtained from SMS where RO water was either applied in six 100-ml aliquots in the same day or applied in one aliquot weekly for 6 weeks.

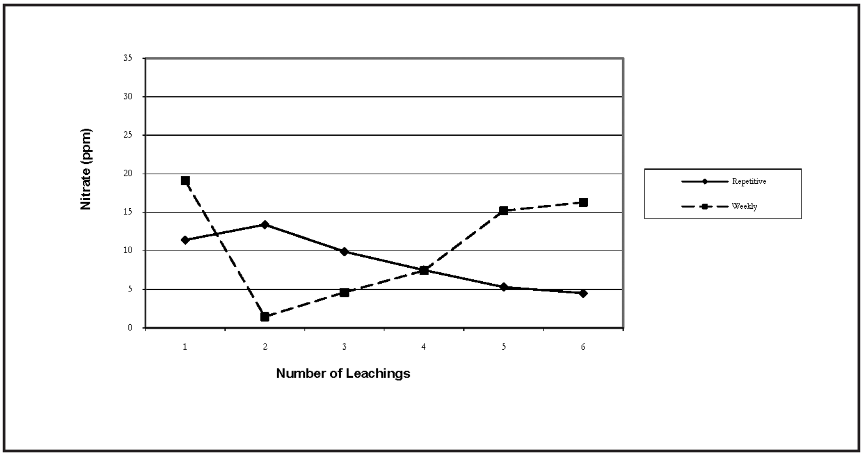

Figure 4. Nitrate concentration in the leachate obtained from SMS where RO water was either applied in six 100-ml aliquots in the same day or applied in one aliquot weekly for 6 weeks.

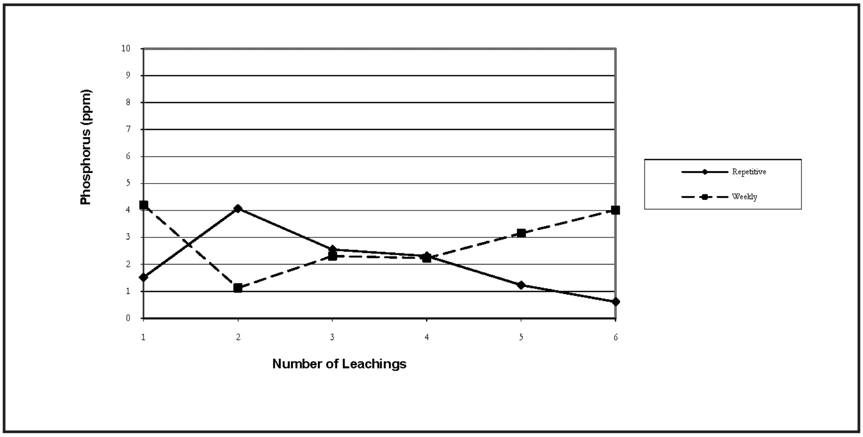

Figure 5. Phosphorus concentration in the leachate obtained from SMS where RO water was either applied in six 100-ml aliquots in the same day or applied in one aliquot weekly for 6 weeks.

tently except for Week 4 where there was an increase. A decrease in extractable K from 5000 ppm at the beginning to about 3000 ppm at Week 5 is an important decrease in extractable K. There was no significant difference in extractable K from the vessel compared to the windrow (Table 1). Extractable Ca and Mg content of the vessel was not significantly different from the content in the windrow (Table 1). Both Ca and Mg tended to decrease as was apparent with K. The P levels were low compared to other nutrients (Table 1). The extractable P from the vessel SMS was not significantly different from the windrow and showed a similar decrease as K (Table 1). Sulfur levels in the SMS were high initially and slowly decreased except for the windrow on Week 5 (Table 1). The level of extractable S from the vessel was not significantly different from the windrow.

The explanation for the nutrient changes at the Penn State site is not clear. In the first part of this work, nutrients were clearly leached from SMS by the volumes of water that were added. In the second set of experiments with vessel versus windrow composting, the reduction in nutrients was not related to leaching. The vessel was covered with a tarp to prevent precipitation from entering the vessel. There was condensation on the inside of the tarp and that water would drop onto the SMS. The volume of water that condensed was unknown so we can not verify that no leaching took place. The windrow SMS was piled to a height of 6 to 8 ft, and it is unlikely that rain could leach nutrients that far. In addition, each week the windrow was turned and mixed so if nutrients were leached from the surface SMS, the next week those nutrients were mixed into the windrow and no longer on the surface.

Nutrient Changes During Composting: NutraSoils. The pH of the SMS was stable for the 12 weeks of this experiment. The pH of turned SMS was consistently but significantly higher than the unturned windrow (Table 1). The pH of SMS at Penn State was initially similar to that at NutraSoils but at Penn State the pH increased to slightly above 8.0. Lohr et al. (1984) reported that the pH of fresh SMS

Table 1. Measurements of EC (dS/m), pH and nutrient values (ppm) of a saturated paste extract from SMS composted in a vessel or windrow (Wind) at Penn State or in a turned or unturned windrow at NutraSoils.

At Penn State

	pH	pH	EC	EC	K	K	Ca	Ca	Mg	Mg	P	P	S	S
Week	Vessel	Wind	Vessel	Wind	Vessel	Wind	Vessel	Wind	Vessel	Wind	Vessel	Wind	Vessel	Wind
0	7.60	8.07	19287	18688	5025	5203	1028	1004	470	479	50.4	35.5	2260	2367
1	7.44	8.07	19946	17886	5136	5412	567	598	504	507	63.6	34.3	2383	2668
2	7.72	8.14	13522	23647	4125	4980	837	832	363	382	41.2	20.5	1910	2079
3	8.12	8.15	17061	21187	3578	4637	443	419	306	323	20.0	17.3	1836	2211
4	7.94	8.11	22253	18573	5003	4512	846	609	404	300	27.1	12.6	2254	2005
5	8.14	8.15	15094	22220	2918	5073	413	448	255	340	20.5	30.4	1416	2512
AOV[z]	*		NS		NS		NS		NS		NS		NS	

At NutraSoils

Week	Turned	Unturned	Turned	Unturned	Turned	Unturned	Turned	Unturned	Turned	Unturned	Turned	Unturned	Turned	Unturned
0	7.33	7.13	38930	28937	3041	3163	855	896	400	422	54.1	210.2	1552	1605
4	7.61	7.30	32478	30221	2246	2017	540	663	196	231	14.6	14.1	1145	912
8	7.48	7.05	29244	83420	2912	3835	696	907	272	388	15.5	15.4	1804	1827
12	7.24	6.93	36687	20587	2692	2551	598	725	228	287	18.9	129.3	1285	1337
AOV[z]	*		NS		NS		NS		NS		NS		NS	

[z]Analysis of variance (AOV) compared vessel data versus windrow data at Penn State, and turned versus unturned data at NutraSoils. NS = nonsignificant at $P \leq 0.05$, * significant at $P \leq 0.05$.

was between 7.3 and 8.6, but the pH of the aged SMS was between 6.5 and 6.7. They related the difference in pH to the change in the ammonium ion concentration where increases in ammonium are associated with increases in pH (Lohr et al., 1984). Based on this assumption, the SMS at Penn State should have had higher levels of ammonium than those reported by Lohr et al. (1984). Data were not collected to confirm that conclusion.

The EC of SMS at NutraSoils did not change greatly during the 12 weeks of the experiment (Table 1). The difference in EC between the turned and unturned windrows was not significant. The windrow EC at Penn State increased to Week 2 then dropped, but the EC of the turned windrows at NutraSoils decreased. The Penn State data were collected for only 5 weeks compared to the 12 weeks at NutraSoils. Lohr et al. (1984) reported that there was an increase in EC of leachate from aged SMS compared to leachate from fresh SMS, and those results are in contrast to the data obtained in this experiment.

The extractable K from the turned windrows was not significantly different from the K from unturned windrows (Table 1). Both the turned and unturned K decreased during the first 4 weeks, then both increased to Week 8 and slightly decreased to Week 12. At Penn State the trend was similar in that there was an initial decrease in extractable K from the SMS, but the Penn State trial only lasted 5 weeks.

Calcium in the SMS dropped substantially during the first 4 weeks, rose in the next 4 weeks, and finally decreased in the last 4 weeks (Table 1). The extractable Ca from turned SMS was not significantly different from unturned SMS. The trends with Mg in turned and unturned windrows were similar and not significantly different (Table 1). The trends in Ca and Mg content observed at NutraSoils were similar to the ones observed at Penn State. Lohr et al. (1984) leached fresh and aged SMS and concluded that the K, Ca, and Mg content of the leachate was generally similar. In research reported here, the decrease in cations did not show a consistent pattern.

Phosphorus in SMS at NutraSoils decreased during the first 4 weeks and then remained stable for the turned windrow but increased at Week 12 for the unturned windrow (Table 1). The P level at Week 0 and Week 12 in the unturned windrow was dramatically higher than any other values observed, but there is no apparent explanation for these high values. The P level decreased during the first 5 weeks at Penn State and for the first 4 weeks at NutraSoils, and therefore the trends were considered to be the same.

Sulfur levels were initially high and dropped during the first 4 weeks of composting, increased for the next 4 weeks, and dropped for the last 4 weeks (Table 1). The S in the turned windrow was not significantly different from S in the unturned windrow. The trends observed at Penn State were similar, but the decrease at Penn State was not as great as the decrease at the NutraSoils site.

CONCLUSIONS

Changes in extractable K, Ca, Mg, P, and S during continued composting were similar at the two locations. Extractable K, Ca, Mg, P, and S tended to decrease slowly during the composting period, and the magnitude of the changes in nutrient content did vary between locations. However, pH of SMS increased slightly at the Penn State site while decreasing slightly at the NutraSoils site. There were no significant differences in nutrient content between turned and unturned windrows of

SMS. It can be concluded that turning SMS does not affect the nutrient availability as determined by leaching; thus, the end user does not need to be concerned about the turning frequency affecting the quality of the SMS.

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