THE EFFECT OF

SPENT MUSHROOM SUBSTRATE

ON

LANDSCAPE PLANT ESTABLISHMENT

by

Sarah Chatterson

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Honors Bachelor of Science in Natural Resource Management with Distinction.

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Approved: ______________________________

Dr. Susan S. Barton, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ______________________________

Dr. Julie L. Bruck, Ph.D.
Committee member from the Department of Plant and Soil Sciences

Approved: ______________________________

Dr. Daniel J. Leathers, Ph.D.
Committee member from the Board of Senior Thesis Readers

Approved: ______________________________

Alan D. Fox, Ph.D.
Director, University Honors Program

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ABSTRACT

Spent mushroom substrate (SMS) is compost that had been used to grow mushrooms, then steamed and pasteurized once it was discarded after mushroom production. Spent mushroom substrate has the potential to improve soil structure and provide nutrients when tilled into the soil as an amendment to a planting bed or when used as a topdressing mulch during landscape establishment (Guo 2004). The research objective was to determine the effectiveness of SMS for use in landscaping as a soil amendment or as a topdressing. This study observed plant growth and health in four landscape plants over the course of one growing season. The effect of incorporating and topdressing with SMS and the effect of tilling on successful plant establishment on two species of woody shrubs and two species of perennials were measured. This study concluded that SMS is as effective as using fertilizer without tilling the soil but has the added benefits of adding organic matter to the soil, preventing soil borne pathogens, improving soil structure, maintaining or increasing pH, increasing cation exchange capacity, and reusing organic waste. SMS should be used with caution, however, to avoid excessive levels of phosphorus and soluble salts.

Chapter 1

INTRODUCTION

Spent mushroom substrate (SMS) is compost that had been used to grow mushrooms, then steamed and pasteurized once it was discarded after mushroom production. It is composed of agricultural by-products including wheat straw, horse manure, hay, poultry manure, cotton seed hulls and meal, cocoa shells, and gypsum (Hy-Tech). Properly processed SMS has few weed seeds and "a diverse microflora capable of detoxifying a variety of organic chemicals" (American 1995). It tends to be high in phosphorous and potassium while relatively low in nitrate nitrogen. It has a very high cation exchange capacity, relatively high levels of soluble salts, a slow mineralization rate, and it is "light in weight yet bulky in volume" (American 1995). It has also been shown to have high water holding capacity (Guo 2004).

Spent mushroom substrate has the potential to improve soil structure and provide nutrients when tilled into the soil as an amendment to a planting bed or when used as a topdressing mulch during landscape establishment (American 1995, Guo 2004). SMS has also been shown to suppress various soil fungi (Davis 2005) and soil-borne plant diseases (Segarra 2007), as well as to increase microbial densities in soils (Perez-Piqueres 2007). Further, composts such as SMS can increase soil organic matter (Perez-Piqueres 2007), which improves soil quality by improving soil structure, water infiltration and retention, nutrient content, and buffering capacity (Steffen 1994). Often, composts such as SMS are not used because there is a belief that use results in an increase of weeds.

Currently, being sustainable and buying organic are salient issues in the United States. Consequently, there is a high degree of interest in reusing organic wastes and composting. There are environmental problems associated with disposal of organic wastes, such as high levels of nutrients from organic wastes polluting waterways (Hoitink 1986). Further, regulations regarding disposal of organic materials into landfills have increased, making composting an attractive alternative (Stoffella 2001). Increased demand from the commercial sector has also led to an increasing number of private composting facilities in the U.S. (Stoffella 2001). As a result of these factors, the production of composts in the U.S. is increasing (Stoffella 2001).

The use of SMS is especially pertinent in Delaware as Kennett Square, Pennsylvania, the "mushroom capital of the world," is located just north of the border. In fact, every year over 50,000 m^3 of SMS is generated in Pennsylvania as a by-product from white button mushroom production, providing a significant source of compost (Guo 2004). The demand for compost as a soil amendment exists in Delaware, as well. While compost has been proposed as a component of potting media for horticultural crops, the horticulture industry in Delaware is concentrated in landscape design, installation and maintenance (Hall 2006). According to Hall *et al.* (2006) the output of the production and manufacturing portion of the horticulture industry in Delaware is only $53 million, compared to $228 million in horticultural services (includes landscape design, contracting and maintenance). This ratio of 4.3:1 (horticultural services:production) is greater than states with a production-focused horticultural industry. California, for example, has a 2:1 ratio (horticultural services:production) (Hall 2006). This means that if Delaware is going to use a significant quantity of SMS in the horticultural industry, it will have to be as a landscape amendment.

SMS has been shown to effectively provide nutrients to plants. Weber *et al*. (1997) compared corn yields between a one-time application of SMS and traditionally fertilized plots over a two year period. They found that corn yields were equal between the two treatments and that other benefits from SMS could continue to be realized into the future. Stewart *et al.* (1998) reported that applications of SMS increased soil pH and provided plant-available nutrients. Although the applications increased soil EC it was not to a detrimental level. However, they also reported that SMS did not provide sufficient plant-available nitrogen and may need to be supplemented with inorganic N. Steffen *et al.* (1994) found that systems amended with well-rotted cattle manure and SMS had higher yields of three different vegetable crops continuing through three growing seasons compared to inorganic fertilizer. Further, the higher costs of the organic amendments would be compensated with greater yields and benefits continuing over several growing seasons.

These reported results show the benefits of using SMS in agricultural production systems. This study observed plant growth and health in four landscape plants over the course of one growing season. The research objective was to determine the effectiveness of SMS for use in landscaping as a soil amendment or topdressing.

Chapter 2

METHODS

In this study the effect of incorporating and topdressing with spent mushroom substrate (SMS) and the effect of tilling on successful plant establishment on two species of woody shrubs and two species of perennials were measured. The site for the study was on the research farm at the University of Delaware in Newark, DE. The treatments were as follows:

1. Tilled soil with commercial fertilizer
2. Tilled soil with SMS incorporated
3. Tilled soil with SMS as topdressing
4. Non-tilled with SMS as topdressing
5. Non-tilled, commercial fertilizer

Each plant bed was 6’ by 9’ (54 sq. feet) and planted with (3) *Buxus microphylla*, (3) *Viburnum opulus*, (3) *Chasmanthium latifolium*, and (3) *Rudbeckia subtomentosa* (six shrubs and six herbaceous plants per plot). There were three replications of each treatment for a total of 15 beds. SMS was spread to a depth of 1 inch and either tilled in (3 plots) or left as a topdressing (6 plots). One and a half cubic yards of SMS was required for all nine plots receiving SMS, and each plot receiving SMS had .16 cubic yards of SMS applied.

Table 1. Analysis of Spent Mushroom Substrate provided by Hy-Tech Mushroom Compost, Inc. Analysis from the Pennsylvania State University, Agricultural Analytical Services Laboratory.

	Dry Weight	Pounds/Ton*
pH	6.2	
Organic Matter	63.70%	
Moisture	62.90%	
Nitrogen-total	2.25%	
Nitrogen-organic	2.20%	44.00
Ammonium N (NH4-N	500 mg/kg	
Carbon	31.60%	
C:N ratio (calculated)	14.20	
Phosphorus as P2O5	1.61%	32.20
Potassium as K2O	2.84%	56.80
Calcium (Ca)	4.88%	97.60
Magnesium (Mg)	0.68%	13.60
Sulfur (S)	1.68%	33.60
Sodium (Na)	2998 mg/kg	
Aluminum (Al)	3446 mg/kg	
Iron (Fe)	3325 mg/kg	
Manganese (Mn)	342 mg/kg	
Copper (Cu)	108 mg/kg	
Zinc (Zn)	204.1 mg/kg	

* CALCULATED NUMBERS

The SMS was provided by Hy-Tech Mushroom Farm, Inc. in West Grove, PA. An analysis of the SMS was provided by Hy-Tech Mushroom Farms and is known to weigh 980 lbs/cubic yard, contain .008% organic nitrogen, and .00018% ammonium on an as-weight basis (see Table 1). In addition, the nitrogen has been estimated to mineralize at a rate of 20% per year. These values result in 1.75 pounds of available nitrogen per cubic yard of SMS. One inch of SMS was applied to each plot receiving

SMS. Therefore, we calculate that each plot will have received about .292 lbs nitrogen over the course of the first year (1.75lbs/cu.yd*.166cu.yds). This is equivalent to 4.6 lbs nitrogen per 1000 square feet. In comparison, many inorganic fertilizers are used at a rate that supplies 1 pound of nitrogen per 1000 square feet.

To better observe the effects of SMS and not just the effects of nitrogen fertilizer, plots not amended with SMS received slow release commercial fertilizer (Osmocote 19-6-12) with available nitrogen equal to .29 lb nitrogen released over the course of a year. This is equivalent to the amount of nitrogen that plots amended with SMS received.

SMS was delivered on April 13, 2008. It sat outside in a pile until it was applied. Plots were measured, staked out with flags, and then sprayed with glyphosate (a non-selective herbicide) to kill all plant material inside the plots. Each plot was then given a number and was assigned a treatment through a random process. On April 21, 2008 one inch of SMS was applied to the three plots that were assigned to have it tilled into the soil. Grounds crew at the College of Agriculture and Natural Resources then tilled the nine plots that were assigned to be tilled with a large rototiller, the depth of till being approximately 8-10 inches. After tilling, plots were raked to create an even planting surface. Plants were then randomly assigned to each plot, planted, and watered on April 27 and May 4, 2008. The herbaceous plants were all planted on one day, and the woody plants were all planted on one day a week later. At planting, plant height and width were measured. After planting, one inch of SMS was manually applied as a topdressing (using rakes and shovels) to 3 tilled plots and 3 untilled plots.

The commercial fertilizer (Osmocote 19-6-12) was then sprinkled on top of all plots that did not receive SMS. Lastly, one inch of hardwood bark mulch was applied to plots that did not receive SMS topdressing in order to be similar to plots with SMS topdressing. The fertilizer was spread on top of designated plots before the mulch was applied.

Each month after establishment plant height and width were measured and an overall aesthetic rating (on a scale of 1-5) was recorded. The aesthetic rating was assigned based on appearance and plant health. All plots were watered as needed throughout the growing season and were weeded weekly. In addition, the number of weeds on each plot was counted once a week before they were weeded. All plots received equal amounts of watering and weeding. The area surrounding the plots was also mowed throughout the summer.

A soil sample including soil from each of the fifteen plots was conducted on April 18, 2008, before plots were tilled and planted. According to the Plant and Soil Sciences Department, one soil sample should consist of 15-25 cores taken throughout the sampling area and is effective for up to 40 acres of land (UD Soil). Therefore, one sample was taken from each plot using a garden trowel for a total of 15 cores and thoroughly mixed in a clean plastic bucket. A final sample was then taken from this mixture. In addition, a soil sample of each plot was taken at the end of the growing season on August 19 in order to determine the change in soil chemistry as a result of the treatments (See Tables A.2 and A.3). One core was taken from each plot to obtain the soil samples because of the small area of the plots. The soil testing method used at the University of Delaware is the Mehlich 3 Soil Test.

Chapter 3

RESULTS

The woody plants were not included in this analysis because most of their growth may not have been related to the treatment they were planted in. Woody plant shoots may be either determinate or indeterminate (Pallardy 2008). Determinate growth is characterized by one flush of growth at the beginning of the growing season, and indeterminate growth is characterized by continuous growth during the growing season (Pallardy 2008). Viburnum and boxwood are determinate growth species. Therefore, it is possible that the majority of growth of the woody plants was in the early spring before they were planted. Further, early season growth of woody plants is largely dependent on stored nutrients and carbohydrates from the previous year (Pallardy 2008). Therefore, woody plant growth should be measured over several growing seasons in order to have an accurate measure of response to treatments.

An ANOVA framework was used to determine if the treatment effects differ from an overall mean. One plant was excluded from the study because it had been disturbed in the plot and was a significant outlier. The response variable is plant growth, determined by taking the difference between the final height and initial height. The treatments were (1) tilled soil with commercial fertilizer, (2) tilled soil with SMS incorporated, (3) tilled soil with SMS as topdressing, (4) non-tilled with SMS as topdressing, (5) and non-tilled, commercial fertilizer. The model also controlled for the different species, which ended up contributing the most to explaining growth. In the test of treatment and species on growth (overall R^2=.913 for the full model) there was a small interaction between treatment and species (p=.050) and species was the most determining factor in height gain. However, treatment also had a small effect, although there was a small interaction between treatment and species (p=.050). In terms of a direct effect, tilling soil and using commercial fertilizer had a significant positive effect on growth at the $p<.01$ level. In addition, there were interaction effects between some treatments and the species. For example, tilling soil with SMS as a topdressing had a significant negative effect on growth of *Chasmanthium latifolium* ($p<.05$). Finally, tilling soil and using commercial fertilizer had a significant positive effect on the height of *Chasmanthium latifolium* ($p<.05$).

Health was analyzed by using an average of all three health ratings for each plant. The test of treatment and species on average health had a relatively poor fit (R^2=.378). This is in part due to the fact that health was heavily skewed and had a significant interaction between treatment and species ($p<.01$). As with the previous model, species was the main determinant of health. Although the effect of treatment on health was not significant, looking at the average health rating of each treatment has some value (see Figure 1). Tilling with fertilizer and tilling with SMS as a topdressing had the highest average health ratings, while SMS tilled into the soil had the lowest.

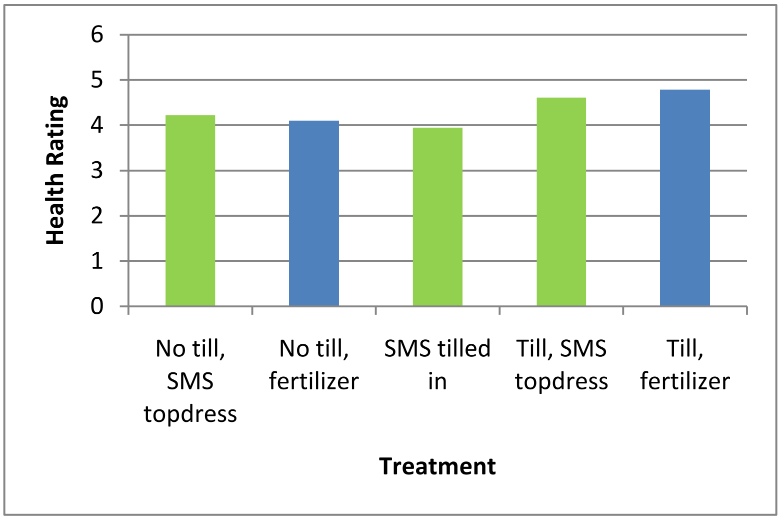

Figure 1. Average health by treatment.

Finally, till had a significant positive effect on plant height. In a test of till and species on plant height (overall model R^2=.890), till had a significant positive effect on plant height ($p<.05$).

3.1 Soil Test

The soil test revealed that the pH across all plots was lower than the pH in the initial soil sample (see Figure 2). However, treatments with SMS had slightly higher average pH than plots without SMS. Out of all treatments SMS tilled in had the highest average pH while no till with fertilizer had the lowest.

There was not a large difference in organic matter (OM) content between plots with SMS and plots with fertilizer (see Figure 3). Across all plots and between the plots amended with SMS, tilled in SMS had the highest average OM content. In plots not amended with SMS, tilled with fertilizer had the highest average OM content.

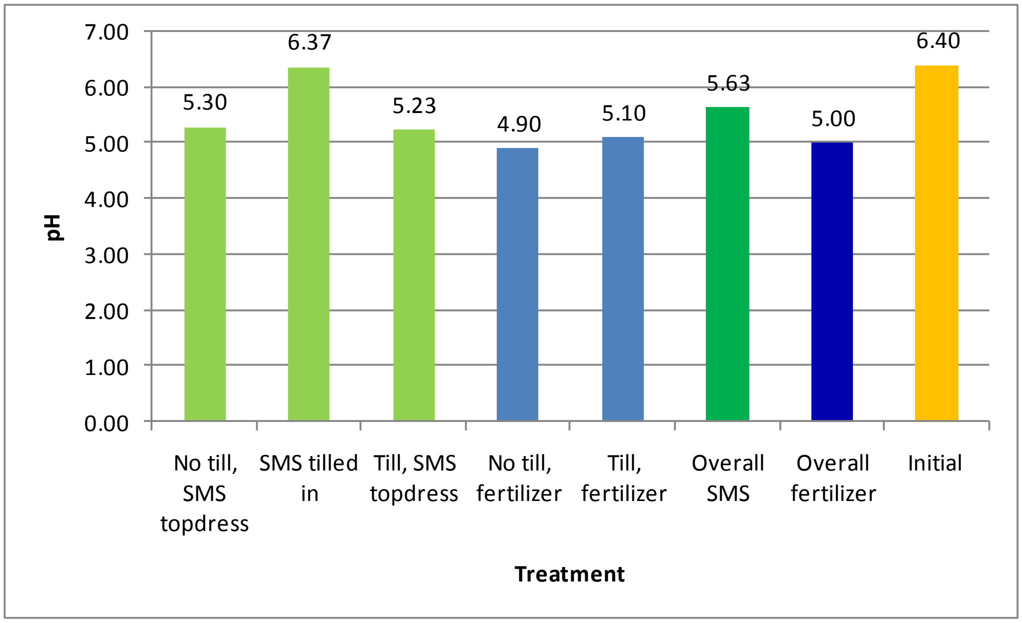

Figure 2. Mean pH by treatment.

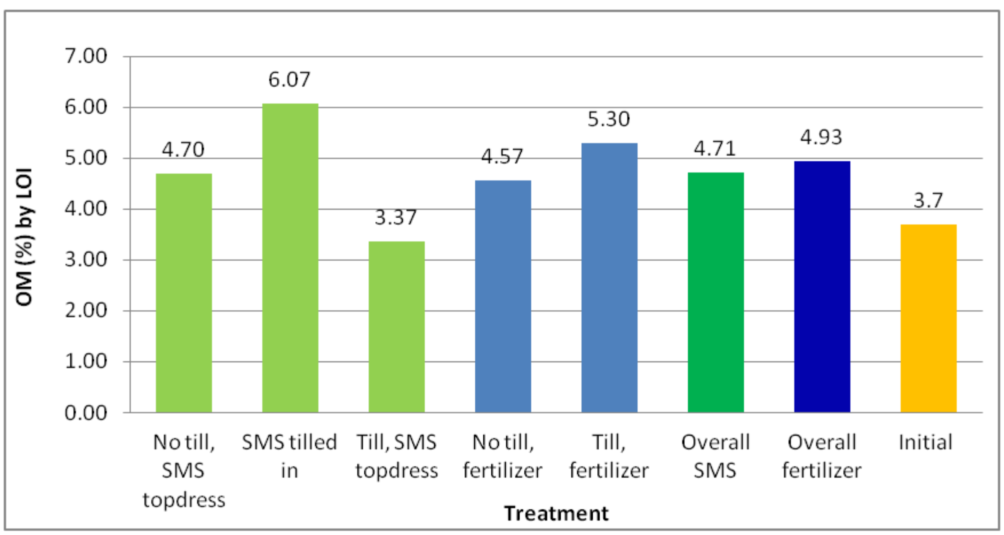

Figure 3. Mean organic matter content by treatment

Plots amended with SMS had higher average levels of soluble salts than those with fertilizer (see Figure 4). Across all plots and out of plots amended with SMS, tilled soil with SMS topdressing had the highest average level of soluble salts. Out of plots not amended with SMS, no till with fertilizer had the highest level of soluble salts.

Treatments with SMS had higher average levels of phosphorous than plots with fertilizer (Figure 5). Across all treatments, SMS tilled in had the highest average phosphorous. There was not a large difference in phosphorous between plots not amended with SMS.

Plots amended with SMS had higher average cation exchange capacity (CEC) than plots with fertilizer (see Figure 6). Plots with SMS tilled in had the highest average CEC while plots with no till and fertilizer had the lowest CEC. However, there is very little difference in CEC between plots not amended with SMS.

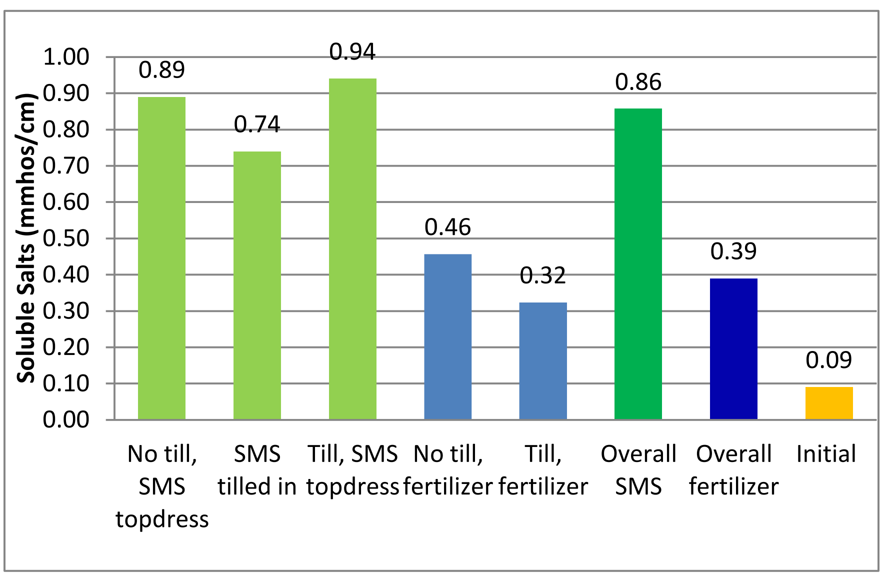

Figure 4. Mean soluble salts by treatment

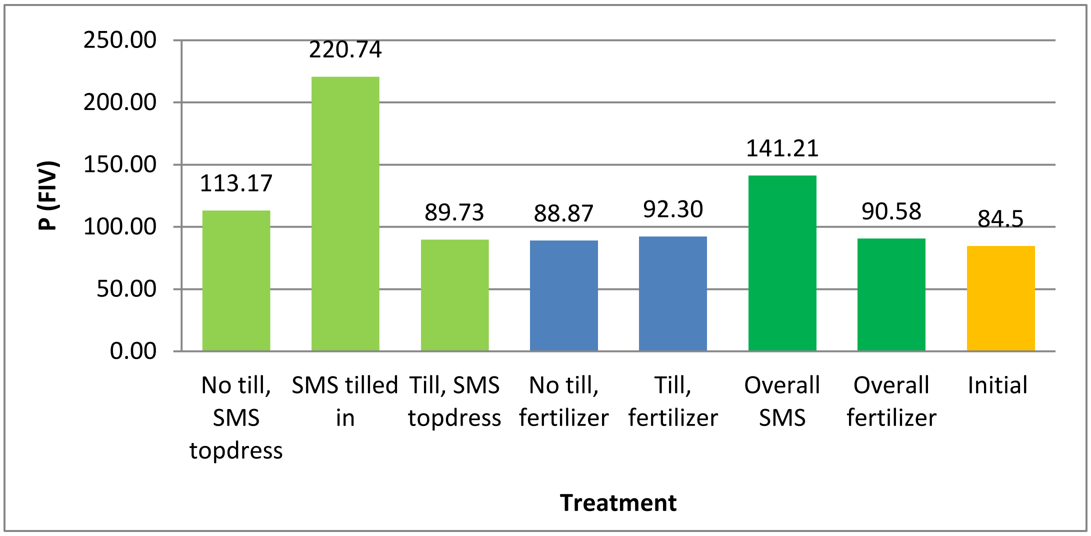

Figure 5. Mean levels of Phosphorus by treatment

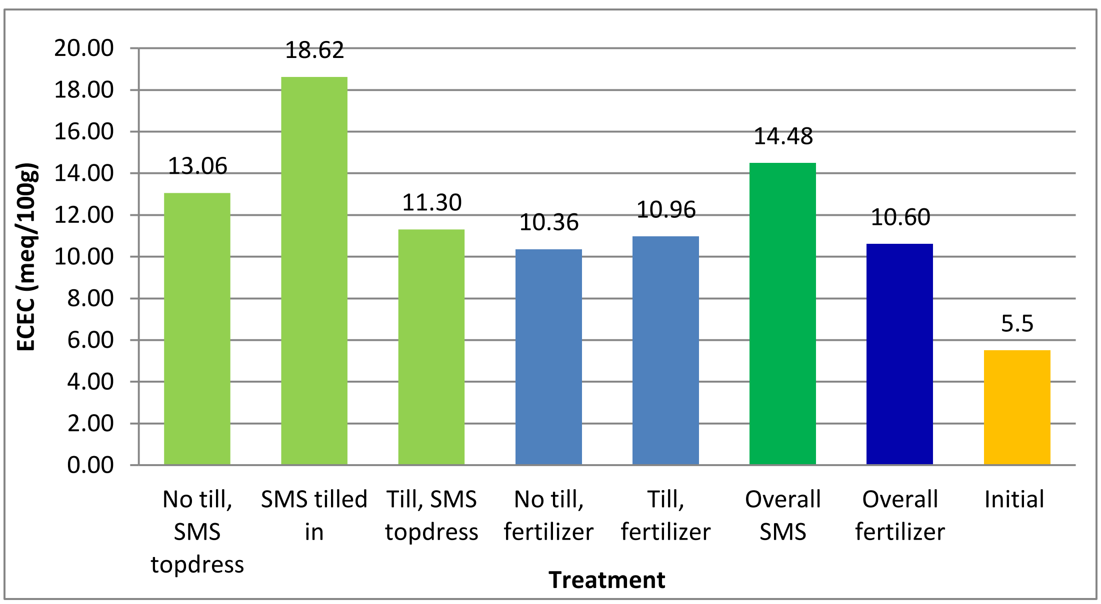

Figure 6. Mean cation exchange capacity by treatment

3.2 Weed Data

The number of weeds for each plot was combined to get the total number of weeds for that plot over seven weeks during the growing season (see Table A.1). The data was then divided by variable and the mean and median taken for each (see Figure 7). There was a larger difference in weed count between tilled plots and untilled plots than between plots amended with SMS and plots amended with fertilizer. In addition, there was a larger disparity between the mean and median in plots amended with SMS and fertilizer than there was in tilled and untilled plots.

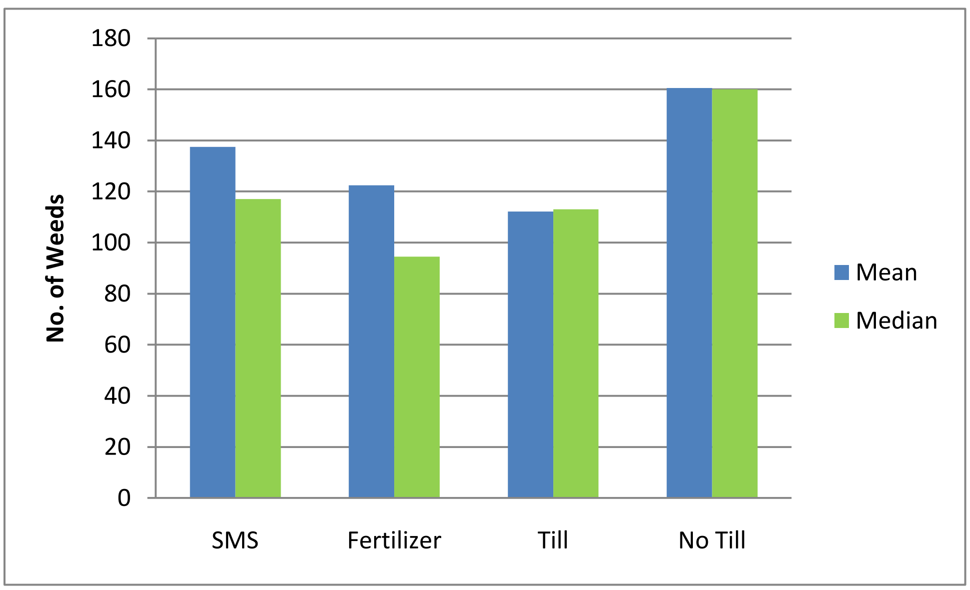

Figure 7. Mean and median weed counts over seven weeks by variable

Chapter 4

DISCUSSION

Overall, treatment had a small effect on plant growth and health. In the case of *Chasmanthium latifolium* the effect of different treatments varied. The only treatment that resulted in significantly improved plant growth was tilling soil and using commercial fertilizer, which is the conventional treatment for establishing a plant bed. The fact that none of the other treatments were statistically different from each other suggests that any of the SMS amendments are equally as effective as applying fertilizer without tilling soil. This is relevant because most homeowners do not have the time or equipment to till their planting beds, and using SMS would therefore give them the same result.

In this case, health was not an effective measure of the effectiveness of each treatment. The health rating itself is very subjective, and an average rating given by several people for each plant might be more accurate. However, anecdotal evidence from average health ratings shows us that the treatment with the highest health rating (till with fertilizer) is also the treatment with a significant positive effect on plant growth. Till also had a significant effect on plant growth. Therefore, even if amendments such as SMS or fertilizer are not added to the soil, tilling can still improve plant growth.

4.1 Soil Data

It is unclear why the pH dropped considerably for all plots. The consistency of pH values across all of the plots in the second sample collection suggests that they are accurate. There is some seasonal variation in pH which may accounted for the decrease in pH, however some error in the collection of the initial soil sample might have resulted in an inaccurate pH value. It is possible that mineral fertilizer is acidifying, therefore lowering the pH to the treatments which it was applied. The fact that plots amended with SMS had a higher pH than those without suggests that SMS does not lower pH as much as fertilizer. Further, SMS can possibly maintain the pH of the soil when tilled in. This is reasonable considering that the pH of the SMS itself is 6.2. This ability of SMS to maintain pH may offset the need for homeowners to add lime to soils in addition to fertilizer, thus offsetting some of the costs of SMS.

Organic matter (OM) influences soil fertility, soil structure, and soil permeability (Troeh 2005). According to Soils and Soil Fertility, "more organic matter usually means a more productive soil" (361). There are no set standards for organic matter content because it is relative based on the type, texture, use of the soil, and other factors. However, most mineral soil A horizons contain 1-6% OM, and the higher the percentage the better the soil (Troeh 2005). Tilling in SMS was effective in increasing soil OM. However, when the OM levels are compared across the average of all SMS treatments and all fertilizer treatments they are very close (see Figure 3).

Plots amended with SMS had higher average levels of soluble salts than those with fertilizer (see Figure 4). Figure 8 shows that the average levels of soluble salts for treatments containing SMS were at high or very high levels. At high levels, seedlings may be injured, and at very high levels, some burning may occur (UD Soil 1984). This could be one reason why SMS did not have a significant positive effect on plant growth. Plots amended with fertilizer had medium levels of soluble salts, which is satisfactory for most plants (UD Soil 1984).

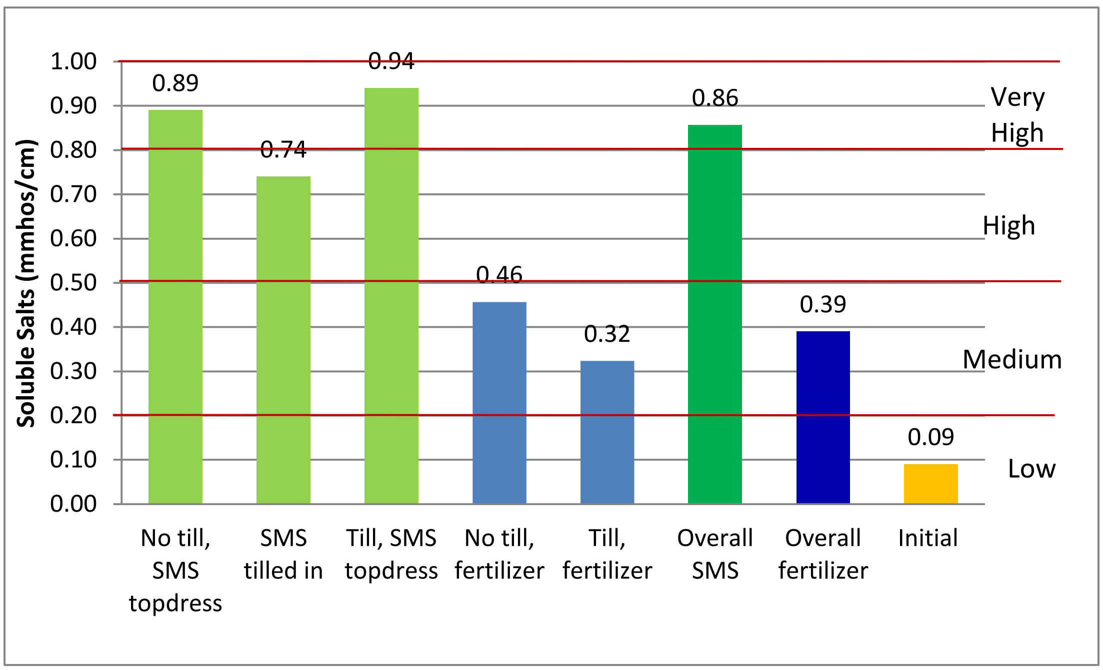

Figure 8. Relative levels of soluble salts by treatment

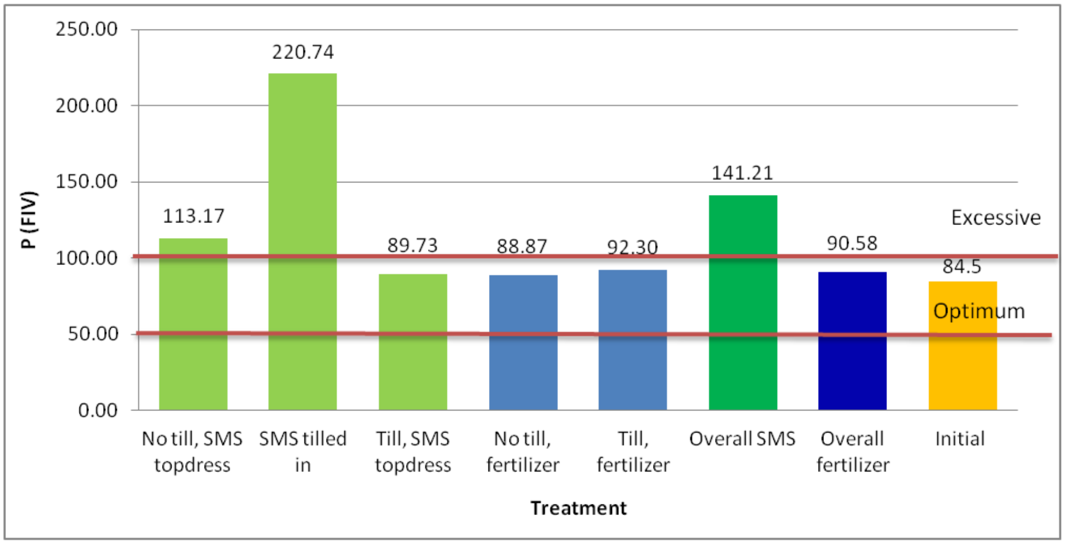

Figure 9. Relative levels of Phosphorus by treatment.

Treatments with SMS also had higher levels of phosphorus than plots with fertilizer (see Figure 9). The treatments no till with SMS topdressing and SMS tilled in had excessive levels of phosphorous, and tilled soil with SMS topdressing had an optimum level of phosphorous. Both treatments without SMS amendments had optimum levels of phosphorous. According to material from the University of Delaware regarding soil test results, excessive levels of phosphorus in soil can have negative effects on surface water quality resulting from soil erosion and runoff. Therefore, SMS should be applied carefully to avoid excessive levels of P.

Plots amended with SMS had higher average cation exchange capacity (CEC) than did plots with fertilizer (see Figure 6). Cation exchange capacity is important in soil fertility and involves holding nutrients in the soil (Troeh 2005). Therefore, SMS can increase the CEC of a soil and therefore its nutrient holding capacity. Fertilizer also increases the CEC, but not as significantly as the SMS.

4.2 Weed Data

Although plots amended with SMS had slightly more weeds than plots amended with fertilizer, there was a larger difference in weed count between tilled plots and untilled plots (see Figure 7). This suggests that till has a more significant effect on the number of weeds than the type of soil amendment does. Therefore, fear of increased weeds is not a valid reason to avoid using SMS or other composts. In addition, tilling reduces the amount of weeds. There was also a larger difference between mean and median in SMS and fertilizer weed counts than there was in till and no till. This suggests that the till data were more consistent without any outliers, and may therefore be a better indicator of the amount of weeds.

Chapter 5

CONCLUSION

In most situations SMS is as effective as using fertilizer but has the added benefits reported in the literature of adding organic matter to the soil, preventing soil borne pathogens, improving soil structure, maintaining pH, increasing cation exchange capacity, and reusing organic waste. SMS should be applied with caution, however. Heavy applications of SMS can result in high levels of soluble salts in the soil that can damage plants. This may be avoided by leaching salts from SMS before use. Further, applying SMS according to nitrogen needs may oversupply nutrients and result in excessive levels of phosphorus that can pollute water ways. As a result, SMS should not be tilled into phosphorous-rich soils. This study has also shown that tilling soil promotes plant growth as well as potentially reducing the amount of weeds. Finally, according to this study fear of weeds is not a valid reason to avoid using SMS, but further research needs to be done in this area before any conclusions can be made.

This project needs to continue for several growing seasons in order to observe the effect of SMS on woody species, the effects of long term use of SMS versus fertilizer, what happens when SMS cannot be tilled into the soil in future years because of existing plants, and to see if soil structure in plots amended with SMS improves over time. There are several ways that this project could be improved in future years. First of all, there wasn’t a plot that had did not have either fertilizer or compost, and future research should compare SMS and fertilizer to nothing at all. In addition, SMS might be combined with bark mulch in order to achieve better coverage and weed prevention without over applying SMS. SMS might also be combined with another type of compost in order to decrease the levels of soluble salts and phosphorous.

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APPENDIX

Table A.1. Number of weeds per plot.

Treatment	Till	Amendment	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	TOTAL
No till, SMS topdress	N	SMS	17	12	10	12	6	6	11	74
No till, SMS topdress	N	SMS	35	26	21	26	30	24	23	185
No till, SMS topdress	N	SMS	38	51	22	32	21	17	42	223
No till, fertilizer	N	Fertilizer	2	7	11	15	8	15	24	82
No till, fertilizer	N	Fertilizer	30	20	25	40	51	58	40	264
No till, fertilizer	N	Fertilizer	27	21	15	19	14	19	20	135
SMS tilled in	Y	SMS	14	9	14	13	8	30	16	104
SMS tilled in	Y	SMS	30	20	16	16	12	11	8	113
SMS tilled in	Y	SMS	22	37	10	14	14	18	14	129
Till, SMS topdress	Y	SMS	23	17	9	15	11	18	22	115
Till, SMS topdress	Y	SMS	49	17	10	8	8	11	14	117
Till, SMS topdress	Y	SMS	38	33	25	27	13	24	17	177
Till, fertilizer	Y	Fertilizer	10	12	11	16	3	8	22	82
Till, fertilizer	Y	Fertilizer	8	18	4	15	7	5	8	65
Till, fertilizer	Y	Fertilizer	19	18	13	8	5	17	27	107

Table A.2. Soil data results by treatment. Table is divided in SMS plots (top) and no-SMS plots (bottom)

Treatment	pH	Buffer pH	OM (%) by LOI	Sol. Salts (mmhos/cm)	M3-P (FIVs)	M3-K (FIVs)	M3-Ca (FIVs)	M3-Mg (FIVs)	M3-Mn (lb/ac)	M3-Zn (lb/ac)	M3-Cu (lb/ac)	M3-Fe (lb/ac)	M3-B (lb/ac)	M3-S (lb/ac)	M3-Al (lb/ac)	P Sat. Ratio
No till, SMS topdress	5.3	7.51	4.1	0.75	105.20	268.00	88.80	134.20	68.37	15.58	5.31	382.65	2.24	164.66	1352.21	32.9
No till, SMS topdress	5.4	7.55	4.7	1.36	142.10	313.40	143.50	189.90	82.73	16.88	5.38	261.82	2.97	223.92	1308.53	45.6
No till, SMS topdress	5.2	7.49	5.3	0.56	92.20	216.60	110.70	155.70	57.75	11.31	4.22	537.65	2.52	109.99	1316.76	28.8
SMS tilled in	6.2	7.67	5.9	1.04	253.10	333.70	197.10	171.50	78.30	23.53	6.87	344.13	3.79	180.49	1138.36	85.0
SMS tilled in	6.3	7.63	5.5	0.65	146.00	279.70	156.50	160.90	65.37	16.49	5.86	253.37	2.44	103.13	1124.00	53.1
SMS tilled in	6.6	7.68	6.8	0.53	263.11	562.15	2488.44	266.47	35.68	13.83	4.50	206.01	2.05	56.61	557.24	87.6
Till, SMS topdress	4.7	7.45	3.7	1.42	74.90	220.60	72.80	130.70	89.46	8.93	3.11	279.30	2.09	91.73	1407.54	24.7
Till, SMS topdress	5.1	7.49	2.8	0.89	100.80	232.70	74.70	119.90	65.21	9.08	4.77	319.58	1.83	165.04	1432.58	30.9
Till, SMS topdress	5.9	7.54	3.6	0.51	93.50	204.00	128.30	162.40	62.20	11.36	5.62	415.77	2.94	112.11	1434.56	28.2
MEAN	5.6	7.6	4.7	0.9	141.2	292.3	384.5	165.7	67.2	14.1	5.07	333.36	2.54	134.19	1230.20	46.31
MEDIAN	5.4	7.5	4.7	0.8	105.2	268.0	128.3	160.9	65.4	13.8	5.3	319.6	2.4	112.1	1316.8	32.9
INITIAL	6.4	7.57	3.7	0.09	84.5	130.2	82.1	129.8	90.03	12.30	5.31	384.32	1.81	35.78	1707.98	23.0

Treatment	pH	Buffer pH	OM (%) by LOI	Sol. Salts (mmhos/cm)	M3-P (FIVs)	M3-K (FIVs)	M3-Ca (FIVs)	M3-Mg (FIVs)	M3-Mn (lb/ac)	M3-Zn (lb/ac)	M3-Cu (lb/ac)	M3-Fe (lb/ac)	M3-B (lb/ac)	M3-S (lb/ac)	M3-Al (lb/ac)	P Sat. Ratio
No till, fertilizer	4.8	7.44	4.1	0.45	92.30	151.80	63.70	107.30	77.16	12.73	4.55	348.60	2.08	79.17	1344.49	29.8
No till, fertilizer	4.8	7.41	6.1	0.38	104.80	112.10	76.40	134.50	112.67	15.15	4.44	325.76	1.38	68.19	1382.65	32.7
No till, fertilizer	5.1	7.45	3.5	0.54	69.50	208.30	92.20	158.90	67.65	10.10	4.93	388.82	2.75	93.16	1508.44	21.5
Till, fertilizer	4.9	7.50	6.0	0.42	73.00	164.10	57.20	102.70	68.49	9.35	3.03	238.02	2.37	65.35	1236.10	26.9
Till, fertilizer	5.2	7.45	4.8	0.28	99.00	174.30	81.70	143.10	59.63	9.87	4.52	509.63	2.26	58.54	1434.31	29.0
Till, fertilizer	5.2	7.44	5.1	0.27	104.90	155.00	88.50	135.80	72.18	12.16	5.21	496.48	2.67	58.94	1444.61	30.4
MEAN	5.0	7.4	4.9	0.4	90.6	160.9	76.6	130.4	76.3	11.6	4.71	371.62	2.26	78.38	1400.62	30.28
MEDIAN	5.1	7.5	4.8	0.4	92.3	155.0	81.7	134.5	72.2	12.2	4.6	384.3	2.3	65.4	1434.3	29.0
INITIAL	6.4	7.57	3.7	0.09	84.5	130.2	82.1	129.8	90.03	12.30	5.31	384.32	1.81	35.78	1707.98	23.0

Table A.3. Soil data results by treatment continued. Table is divided in SMS plots (top) and no-SMS plots (bottom)

Treatment	Exch Ca (meq/100g)	Exch K (meq/100g)	Exch Mg (meq/100g)	Exch Na (meq/100g)	Buffer Acidity (meq/100g)	ECEC (meq/100g)	Sand (%)	Silt (%)	Clay (%)	Textural Class
NTCtop	5.3	1.36	1.8	0.08	3.92	12.48	39	43	18	Loam
NTCtop	ISS						45	39	16	Loam
NTCtop	6.3	1.01	1.9	0.05	4.40	13.63	34	44	22	Loam
TCin	9.8	1.53	2.2	0.05	2.64	16.20	47	38	15	Loam
TCin	10.6	1.61	2.3	0.05	3.60	18.15	39	42	19	Loam
TCin	13.3	1.57	2.6	0.05	4.08	21.50	28	50	22	Silt loam / Loam
TCtop	3.8	0.86	1.4	0.02	4.40	10.48	32	49	19	Loam / Silt Loam
TCtop	4.5	1.12	1.5	0.11	4.08	11.34	42	39	19	Loam
TCtop	6.4	0.88	1.8	0.04	2.96	12.09	41	37	22	Loam
MEAN	7.490	1.243	1.935	0.055	3.760	14.484	38.556	42.333	19.111	
MEDIAN	6.355	1.243	1.850	0.049	4.000	13.057	39.000	42.000	19.000	
INITIAL	3.52	0.53	1.32	0.01		5.5	42	39	19	Loam

Treatment	Exch Ca (meq/100g)	Exch K (meq/100g)	Exch Mg (meq/100g)	Exch Na (meq/100g)	Buffer Acidity (meq/100g)	ECEC (meq/100g)	Sand (%)	Silt (%)	Clay (%)	Textural Class
NTNC	3.3	0.67	1.2	0.01	4.48	9.72	45	39	16	Loam
NTNC	4.3	0.52	1.7	0.02	4.72	11.17	55	34	11	Sandy loam
NTNC	4.2	0.79	1.5	0.02	3.68	10.18	34	41	25	Loam
TNC	***ISS***									
TNC	4.9	0.80	1.7	0.02	2.56	10.01	26	52	22	Silt loam
TNC	5.1	0.70	1.7	0.02	4.40	11.91	24	54	22	Silt loam
MEAN	4.355	0.696	1.561	0.018	3.968	10.599	36.800	44.000	19.200	
MEDIAN	4.251	0.700	1.657	0.020	4.400	10.184	34.000	41.000	22.000	
INITIAL	3.52	0.53	1.32	0.01		5.5	42	39	19	Loam