Evaluating SMS for Nutrient Management of Pumpkins

OBJECTIVE: The objective of this study was to evaluate spent mushroom substrate (SMS) at varying application rates and two different timings of application in a pumpkin crop.

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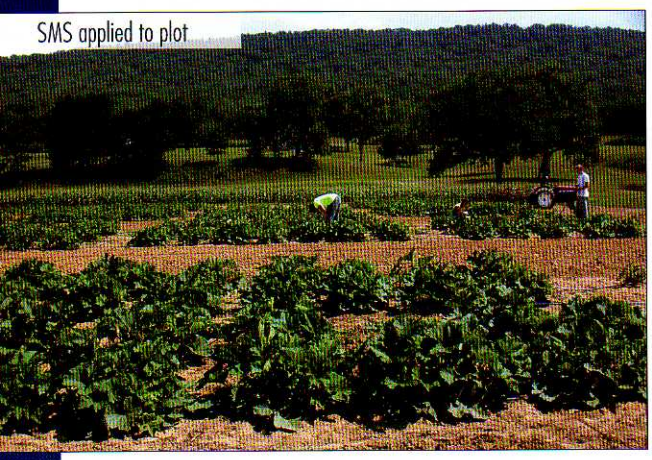
MATERIALS & METHODS

The study was conducted in 2007 and 2008 on a one-acre field consisting of a Hagerstown silt loam and located at the Horticulture Research Farm, Russell E. Larson Research Center, Rock Springs, PA.

Treatments consisted of SMS applied assuming varying rates of mineralization and at two timings of application (Table 1). Additionally, three control treatments were included: ammonium nitrate at a rate of 80 lbs nitrogen per acre applied at two timings and an unamended control. Based on compost analysis (Table 2) conducted by the Agricultural Analytical Services Laboratory, Penn State, the amount of material to apply was calculated. Treatments were arranged in a randomized complete block design. Each treatment was replicated four times on plots 1125 ft^2 in size. Treatments implemented two or three weeks before planting were applied on May 15, 2007 and May 24-26, 2008 and soil incorporated on May 22, 2007 and May 26, 2008 to a depth of about eight inches using an S-tine. The remaining treatments were implemented on May 29, 2007 and June 12-13, 2008 and soil incorporated on the same day.


SMS applied to plot

Four-week-old *Racer* pumpkin plants were transplanted on May 30, 2007 and three-week-old plants were transplanted on June 16, 2008 using 3 ft in row spacing and 6 ft between rows. A drip irrigation system was installed to provide

Table 1: Treatments being used in this study.

Nutrient Source, Nitrogen Rate	Mineralization Rate (%)	Timing of Application	Amount of SMS Applied
SMS, 80 lbs N/acre	10	2 or 3 weeks preplant	26.7 tons/acre
SMS, 80 lbs N/acre	20	2 or 3 weeks preplant	16.7 tons/acre
SMS, 80 lbs N/acre	40	2 or 3 weeks preplant	9.5 tons/acre
SMS, 80 lbs N/acre	10	At planting	26.7 tons/acre
SMS, 80 lbs N/acre	20	At planting	16.7 tons/acre
Control – Ammonium nitrate, 80 lbs N/acre	–	2 or 3 weeks preplant	235 lbs/acre
Control – Ammonium nitrate, 80 lbs N/acre	–	At planting	235 lbs/acre
Control – unamended	–	–	–

supplemental water to the plants when needed. Insect pests and diseases encountered included cucumber beetles, squash bugs, viruses and powdery mildew. These were managed with insecticide and fungicide sprays. Weeds were managed by periodic cultivation.

Soil samples were collected from each plot on May 21, 2007 and May 23, 2008 prior to applying treatments and on Sept. 29, 2007 and Sept. 26, 2008 after harvest. Samples were collected with a soil auger to a depth of 12 inches. Samples were submitted to the Agricultural Analytical Services Laboratory, Penn State for analysis of soil properties and nutrient levels.

Leaf samples for nutrient analysis were collected on July 11, 2007 and July 28; 42 days after planting. Eight recently fully expanded mature whole leaves (petioles were removed) were harvested from border plants in each plot. Leaf samples were submitted to the Agricultural Analytical Services Laboratory, Penn State for determination of micro- and micro-nutrient contents.

Table 2: Analysis of the SMS used in this study.

Analyte	Results (as is) 2007	Results (as is) 2008
pH	7.9	7.1
Soluble Salts	16.02 mmhos/cm	14.61 mmhos/cm
Solids	37.1%	39.1%
Moisture	62.9%	60.9%
Organic Matter	20.0%	23.5%
Total Nitrogen	0.87%	1.0%
Organic Nitrogen	0.80%	0.90%
Ammonium N	687.2 mg/kg	614.1 mg/kg
Carbon	10.7%	11.7%
Carbon: Nitrogen Ratio	12.3	12.2
Phosphate	0.73%	0.57%
Potash	1.25%	1.31%
Calcium	2.59%	2.53%
Magnesium	0.32%	0.33%
Sulfur	0.81%	0.67%
Sodium	1338 mg/kg	1108 mg/kg
Aluminum	1811 mg/kg	1333 mg/kg
Iron	1456 mg/kg	1460 mg/kg
Manganese	147 mg/kg	128 mg/kg
Copper	50 mg/kg	36.6 mg/kg
Zinc	71 mg/kg	75.5 mg/kg

Hand harvest occurred on Sept. 20, 2007 and Sept. 15, 2008. Yield parameters measured and recorded were the weight and number of marketable and unmarketable pumpkins. Unmarketable pumpkins were categorized as diseased, damaged by insects or under mature (less than 50 percent orange).

Data were analyzed with General Linear Model Analysis of Variance using Statistical Analysis System 9.1.3.

When significant differences at $P \leq 0.05$ were detected, Duncan's least significance difference test was used to separate means.

RESULTS & DISCUSSION

Total Yield

In both years, the lowest yields by weight were observed when no supplemental nutrients were supplied (Tables 3 and 4). This was expected as nutrients are applied to maximize yield potential.

In 2007, larger yields by weight were observed from plants where SMS was applied at planting assuming a 10 percent mineralization rate compared to applying SMS two weeks before planting using a 10 percent mineralization rate or applying inorganic fertilizer. Intermediate yields resulted from applying SMS with a 20 percent mineralization rate regardless of timing of application. Applying SMS using a 10 or 20 percent mineralization rate and applying at planting resulted in a higher number of pumpkins produced than applying ammonium nitrate two weeks before planting to supply nutrients or providing no supplemental nutrients. All other treatments resulted in intermediate numbers of pumpkins being produced.

In 2008, larger yields by weight were observed from plants where SMS was applied at planting assuming a 10 percent mineralization rate compared to applying SMS assuming a 20 percent mineralization rate and ammonium nitrate at planting. Applying SMS assuming a 20 percent mineralization rate and ammonium nitrate three weeks prior to planting resulted in intermediate yields by weight. In terms of numbers of pumpkins produced, applying ammonium nitrate three weeks before planting resulted in the most pumpkins. All other treatments resulted in more pumpkins being produced than supplying no supplemental nutrients, but not different from each other.

In both years of the study, applying SMS at planting assuming a 10 percent mineralization rate resulted in large yields by weight. Nitrogen availability based on this treatment was likely higher than the other SMS treatments. The nitrogen in compost is primarily in two forms: the organic form and ammonium-N. The pumpkin plants likely benefited from the

Table 3: 2007 total, marketable and unmarketable yields of pumpkins that were supplied nutrients using varying mineralization rates of SMS and ammonium nitrate applied two weeks preplant or at planting.

Treatment [1]	Total Yield		Marketable Yield		Unmarketable Yield	
	Number[2] (from 14 plants)	Weight (lbs)	Number (from 14 plants)	Weight (lbs/14 plants)	Number (from 14 plants)	Weight (lbs)
SMS, 10%, 2 weeks	28_{ab}	207_{b}	10	87_{b}	18_{a}	120_{a}
SMS, 10%, planting	34_{a}	281_{a}	19	174_{a}	15_{a}	107_{a}
SMS, 20%, 2 weeks	29_{ab}	252_{ab}	14	119_{b}	18_{a}	133_{a}
SMS, 20%, planting	33_{a}	239_{ab}	14	121_{b}	15_{a}	118_{a}
SMS, 40%, 2 weeks	29_{ab}	214_{b}	11	97_{b}	18_{a}	117_{a}
NH_4^+-NO_3^-, 2 weeks	26_{bc}	202_{b}	12	107_{b}	14_{a}	95_{a}
NH_4^+-NO_3^-, planting	28_{ab}	202_{b}	12	97_{b}	16_{a}	105_{a}
unamended	21_{c}	137_{c}	15	107_{b}	6_{b}	30_{b}
Significance[3]	*	*	NS	*	*	*

[1] SMS applied at 10, 20 or 40% mineralization rates two weeks preplant or at planting; ammonium nitrate applied two weeks preplant or at planting; unamended control

[2] Values followed by different letters within a column are significantly different using Duncan's least significant difference test at the 5% level.

[3] * = significantly different at $P \leq 0.05$; NS = no significant differences

Table 4: 2008 total, marketable and unmarketable yields of pumpkins that were supplied nutrients using varying mineralization rates of SMS and ammonium nitrate applied two weeks preplant or at planting.

Treatment [1]	Total Yield		Marketable Yield		Unmarketable Yield	
	Number[2] (from 14 plants)	Weight (lbs)	Number (from 14 plants)	Weight (lbs/14 plants)	Number (from 14 plants)	Weight (lbs)
SMS, 10%, 3 weeks	15.3_{b}	140.1_{ab}	13.0_{c}	124.3_{ab}	2	16
SMS, 10%, planting	15.3_{b}	153.9_{a}	14.5_{abc}	146.9_{a}	1	7
SMS, 20%, 3 weeks	14.3_{bc}	104.6_{c}	12.8_{c}	98.8_{b}	2	6
SMS, 20%, planting	14.3_{bc}	122.2_{bc}	13.3_{bc}	116.4_{ab}	1	6
SMS, 40%, 3 weeks	13.8_{c}	102.4_{c}	13.8_{abc}	102.4_{b}	0	0
NH_4^+-NO_3^-, 3 weeks	16.8_{a}	135.7_{ab}	15.3_{ab}	130.7_{ab}	1	5
NH_4^+-NO_3^-, planting	15.5_{b}	118.5_{bc}	15.8_{a}	118.3_{ab}	0	0
unamended	13.8_{c}	70.0_{d}	10.8_{d}	60.0_{c}	3	10
Significance[3]	*	*	*	*	NS	NS

[1] SMS applied at 10, 20 or 40% mineralization rates two weeks preplant or at planting; ammonium nitrate applied two weeks preplant or at planting; unamended control

[2] Values followed by different letters within a column are significantly different using Duncan's least significant difference test at the 5% level.

[3] * = significantly different at $P \leq 0.05$; NS = no significant differences

Table 5: 2007 unmarketable pumpkins categorized as diseased, insect damaged or under mature as affected by nutrients supplied using varying mineralization rates of SMS and ammonium nitrate applied two weeks preplant or at planting.

Treatment [1]	Diseased		Insect Damage		Under Mature	
	Number (from 14 plants)	Weight (lbs/14 plants)	Number[2] (from 14 plants)	Weight (lbs/14 plants)	Number (from 14 plants)	Weight (lbs)
SMS, 10%, 2 weeks	6	35	7_{ab}	73_{ab}	5	13
SMS, 10%, 1 day	3	28	7_{ab}	62_{ab}	5	18
SMS, 20%, 2 weeks	5	30	9_{a}	86_{a}	5	17
SMS, 20%, 1 day	5	50	6_{ab}	55_{ab}	4	13
SMS, 40%, 2 weeks	5	31	7_{ab}	63_{ab}	6	24
NH_4^+-NO_3^-, 2 weeks	4	29	5_{a}	42_{bc}	5	24
NH_4^+-NO_3^-, 1 Day	4	24	6_{ab}	56_{ab}	6	25
unamended	3	16	1_{c}	9_{c}	2	6
Significance[3]	NS	NS	*	*	NS	NS

[1] SMS applied at 10, 20 or 40% mineralization rates two weeks preplant or at planting; ammonium nitrate applied two weeks preplant or at planting; unamended control

[2] Values followed by different letters within a column are significantly different using Duncan's least significant difference test at the 5% level.

[3] * = significantly different at $P \leq 0.05$; NS = no significant differences

application of both nitrogen sources as well as other compost properties. Ammonium is readily available for plant use while organic nitrogen must be mineralized prior to becoming available for plant uptake. In 2007 the SMS contained 1.4 lbs ammonium per ton. Using a 10 percent mineralization rate to apply the SMS resulted in 37 lbs of ammonium/acre; 20 percent mineralization rate resulted in 24 lbs ammonium/acre; and 40 percent mineralization rate resulted in 14 lbs of ammonium/acre. In 2008 the SMS contained 1.2 lbs ammonium per ton. Using a 10 percent mineralization rate to apply the SMS resulted in 32 lbs of ammonium/acre; 20 percent mineralization rate resulted in 20 lbs ammonium/acre; and 40 percent mineralization rate resulted in 11 lbs of ammonium/acre. Timing was also a factor with SMS application at planting resulting in the largest yields. Ammonium is a cation and subject to volatilization while nitrate is subject to leaching. It is possible that applying two or three weeks earlier resulted in some ammonium volatilization and nitrate leaching before planting.

Marketable & Unmarketable Yield

In 2007, the number of marketable pumpkins produced was not different by treatment (Table 3). Applying SMS using a 10 percent mineralization rate and applying at planting resulted in the largest yield by weight.

In 2007, the fewest number and lowest total weight of culls resulted from no supplemental nutrient application (Table 3). Unmarketable pumpkins were further categorized as diseased, damaged by insects or under mature. Pumpkins categorized as diseased often also exhibited insect damage. The number and weight of diseased and under mature pumpkins were not different by treatment (Table 5). In general, the unamended treatment resulted in the least insect damaged pumpkins by number and weight.

The 2007 growing season was hot and dry. Water was supplied to the plants via a drip irrigation system between rain events when needed. However, across

Table 6: 2007 soil properties of field plots before applying nutrient treatments.

Treatment [1]	Soil Property				
	pH	Phosphate	Potash	Magnesium	Calcium
		lb/acre			
SMS, 10%, 2 weeks	7.3	406	305	382	5388
SMS, 10%, 1 day	7.3	410	327	413	5703
SMS, 20%, 2 weeks	7.2	452	343	376	5007
SMS, 20%, 1 day	7.1	416	306	388	5042
SMS, 40%, 2 weeks	7.2	430	361	388	5136
NH_4^+-NO_3^-, 2 weeks	7.2	377	311	407	5335
NH_4^+-NO_3^-, 1 day	7.2	432	312	381	5340
unamended	7.2	425	315	375	5243
Significance[2]	NS	NS	NS	NS	NS

[1] SMS applied at 10, 20 or 40% mineralization rates two weeks preplant or at planting; ammonium nitrate applied two weeks preplant or at planting; unamended control

[2] * = significantly different at $P \leq 0.05$; NS = no significant differences

Table 7: 2008 soil properties of field plots before applying nutrient treatments.

Treatment [1]	Soil Property				
	pH	Phosphate	Potash	Magnesium	Calcium
		lb/acre			
SMS, 10%, 3 weeks	7.05_a	401	265	477	4405
SMS, 10%, 1 day	6.88_{ab}	452	268	501	4107
SMS, 20%, 3 weeks	6.75_b	388	262	526	4244
SMS, 20%, 1 day	6.80_b	431	268	511	4383
SMS, 40%, 3 weeks	6.93_{ab}	450	269	530	4403
NH_4^+-NO_3^-, 3 weeks	6.93_{ab}	456	283	488	4832
NH_4^+-NO_3^-, 1 day	6.75_b	462	267	503	4280
unamended	7.03_a	398	270	501	4755
Significance[2]	*	NS	NS	NS	NS

[1] SMS applied at 10, 20 or 40% mineralization rates two weeks preplant or at planting; ammonium nitrate applied two weeks preplant or at planting; unamended control

[2] * = significantly different at $P \leq 0.05$; NS = no significant differences

the state pumpkin maturity was hastened due to these environmental conditions. To have pumpkins during the peak of the selling season (around Halloween for face pumpkins), it was recommended that growers either harvest and store their pumpkins in cool dry conditions or delay harvest and spray fungicides to minimize rot. In this study, fungicides were sprayed in the field to minimize diseases and harvest was delayed. Despite these efforts a considerable amount of pumpkins rotted and the ideal time for harvesting was slightly missed. For these reasons, marketable yield was somewhat low and unmarketable yield was somewhat high.

In 2008, marketable yields by weight were higher from plants where SMS was applied at planting assuming a 10 percent mineralization rate than when SMS was applied three weeks prior to planting assuming a 20 percent mineralization rate and not applying supplemental nutrients (Table 3). All other treatments resulted in intermediate marketable yields by weight. More marketable pumpkins were the result of applying ammonium nitrate at planting than applying SMS assuming a 20 percent mineralization rate regardless of timing, assuming a 10 percent mineralization and applying it three weeks prior to planting or using no supplemental nutrients.

In 2008, very few pumpkins were unmarketable and no significant differences between treatments were detected (Table 3). No differences were detected when unmarketable pumpkins were sorted by insect damage, disease or immaturity (data not shown).

Just as with total yield, in both years of the study applying SMS at planting assuming a 10 percent mineralization rate resulted in large marketable yields by weight. In 2008, most other treatments resulted in

Table 8: 2007 soil properties of field plots after applying nutrient treatments.

Treatment [1]	Soil Property						
	pH	Phosphate[2]	Potash	Magnesium	Calcium	Organic Matter	Salts,
		lbs/acre				%	mmhos/cm
SMS, 10%, 2 weeks	7.1	628_a	708_{ab}	477_b	6170_b	2.1_a	0.46_b
SMS, 10%, 1 day	7.1	656_a	875_a	553_a	6874a	2.3_a	0.67_a
SMS, 20%, 2 weeks	7.0	575_{ab}	595_{bc}	446_b	5447c	2.0_{ab}	0.40_{bc}
SMS, 20%, 1 day	7.1	532_{abc}	586_{bc}	452_b	5478c	1.8_{bc}	0.41_{bc}
SMS, 40%, 2 weeks	7.1	480_{bcd}	483_c	422_b	5382c	1.7_{bc}	0.31_c
NH_4^+-NO_3^-, 2 weeks	7.0	309_e	210_d	337_c	4668d	1.5_{cd}	0.12_d
NH_4^+-NO_3^-, 1 day	7.1	404_{cde}	222_d	309_c	4732d	1.6_{cd}	0.13_d
unamended	7.4	368_{de}	241_d	328_c	4837cd	1.4_d	0.12_d
Significance[3]	NS	*	*	*	*	*	*

[1] SMS applied at 10, 20 or 40% mineralization rates two weeks preplant or at planting; ammonium nitrate applied two weeks preplant or at planting; unamended control

[2] Values followed by different letters within a column are significantly different using Duncan's least significant difference test at the 5% level.

[3] * = significantly different at $P \leq 0.05$; NS = no significant differences

marketable yields not different than when applying SMS at planting and assuming a 10 percent mineralization rate. Based on these results, this treatment would most likely result in successful pumpkin production when using these methods.

Pre-Season Soil Properties

To serve as baseline levels, the soil properties of each plot were analyzed. In 2007, soil pH and phosphate, potash, magnesium and calcium levels were not different prior to implementing treatments (Table 6). These levels exceeded crop needs for calcium (using Penn State recommendations). They were within optimal ranges for the other nutrients (about 330-480 lbs/acre for Mg; 275-710 lbs/acre for phosphate; 225-400 lbs/acre for potash). In 2008, phosphate, potash, magnesium and calcium levels were not different across the field and once again exceeded crop needs (Table 7). Also, soil pH levels varied slightly throughout the field.

Post-Season Soil Properties

In 2007 using a 10 percent mineralization rate to apply SMS resulted in higher phosphate levels than using a 40 percent mineralization rate, applying ammonium nitrate or not applying supplemental nutrients (Table 8). Using a 20 percent mineralization rate to apply SMS resulted in intermediate soil phosphate levels at the end of the growing season.

In 2008, using a 10 percent mineralization rate to apply SMS resulted in higher phosphate levels than applying ammonium nitrate at planting or not applying supplemental nutrients (Table 9). The remaining treatments resulted in intermediate soil phosphate levels at the end of the growing season.

This result was expected because ammonium nitrate contains no phosphate. Also, the amount of phosphate applied with SMS was positively correlated with the amount applied; 390 or 304 lbs/acre when applied based on 10 percent nitrogen mineralization, 254 or 190 lbs/acre when applied based on 20 percent nitrogen mineralization and 150 or 108 lbs/acre when applied based on 40 percent nitrogen mineralization in 2007 and 2008, respectively. While phosphate levels exceeded crop needs prior to applying treatments, the application of SMS further increased levels. Soil phosphate levels should be monitored with soil testing when using SMS (or other nutrient sources containing phosphorus) to avoid exceeding crop needs.

In both years, applying SMS regardless of timing or

mineralization rate resulted in higher soil potash levels than applying inorganic fertilizer or no supplemental nutrients. This result was also expected because ammonium nitrate contains no potash. Generally, the increase in soil potash corresponded with the amount of compost applied: levels were lowest assuming a 40 percent mineralization rate and highest assuming a 10 percent mineralization rate. Applying SMS regardless of mineralization rate and timing, resulted in above optimal levels of potash. The ammonium nitrate treatments resulted in deficient levels of potash while the unamended control resulted in soil potash levels within the optimal range.

In 2007, calcium and magnesium levels were generally affected the same by the treatments with the lowest levels observed when ammonium nitrate or no supplemental nutrients were applied. Levels were highest when SMS was applied at planting using a 10 percent mineralization rate. The remaining treatments resulted in intermediate levels. Calcium levels generally exceeded crop needs optimum (over 4915 lbs/acre) when SMS was used and within the optimal range for the remaining treatments. Magnesium levels were deficient when ammonium nitrate was applied at planting.

Table 9: 2008 soil properties of field plots after applying nutrient treatments.

Treatment [1]	Soil Property				
	pH	Phosphate[2]	Potash	Magnesium	Calcium
		lb/acre			
SMS, 10%, 3 weeks	7.13_{a}	557_{ab}	739_{a}	578_{ab}	5484_{a}
SMS, 10%, 1 day	7.03_{a}	676_{a}	793_{a}	615_{a}	5250_{a}
SMS, 20%, 3 weeks	6.95_{ab}	502_{ab}	499_{b}	552_{abc}	4788_{ab}
SMS, 20%, 1 day	7.00_{a}	556_{ab}	634_{ab}	601_{a}	5195_{a}
SMS, 40%, 3 weeks	7.00_{a}	519_{bc}	499_{b}	587_{ab}	4818_{a}
NH_4^+-NO_3^-, 3 weeks	7.18_{a}	440_{bc}	259_{c}	486_{c}	4929_{ab}
NH_4^+-NO_3^-, 1 day	6.75_{b}	403_{c}	226_{c}	513_{bc}	3877_{c}
unamended	7.13_{a}	380_{c}	249_{c}	510_{bc}	4338_{bc}
Significance[3]	*	*	*	*	*

[1] SMS applied at 10, 20 or 40% mineralization rates two weeks preplant or at planting; ammonium nitrate applied two weeks preplant or at planting; unamended control

[2] Values followed by different letters within a column are significantly different using Duncan's least significant difference test at the 5% level.

[3] * = significantly different at $P \leq 0.05$; NS = no significant differences

In 2008, magnesium levels were higher when SMS was applied at planting compared to applying ammonium nitrate or no supplemental nutrients. Applying SMS prior to planting resulted in intermediate magnesium levels. Calcium levels were higher when SMS was applied at planting or assuming a 10 percent mineralization rate than when ammonium nitrate was applied at planting or no supplemental nutrients were supplied. These results are unexpected because ammonium nitrate does not contain magnesium or calcium and were not expected to influence their soil levels. Variability of these nutrients in the field was likely high accounting for these results.

Potassium, magnesium and calcium are cations and high levels of any one can induce deficiency of another one through competition for plant uptake. SMS should likely not be used yearly to avoid above optimum soil nutrient levels and adverse cation competition. Instead it may be better used in combination with other nutrient sources (green manures, manure, inorganic fertilizer, etc.) to get the benefits of nutrients and organic matter, but not result

Table 10: 2007 Nutrient levels of pumpkins based on tissue analysis.

Treatment [1]	Leaf Nutrient Content												
	Macronutrients					Micronutrients							
	N[2]	P	K	Ca	Mg	Mn	Fe	Cu	B	Al	Zn	Na
	%					ug/g						
SMS, 10%, 2 weeks	5.4a	0.64a	3.4a	2.2	0.42c	44d	186c	11ab	32	141c	46b	12
SMS, 10%, 1 day	5.4_a	0.65_a	3.4_a	2.8	0.47_{bc}	50_{bcd}	187_c	12_a	33	120_c	51_a	12
SMS, 20%, 2 weeks	5.2_a	0.61_{ab}	3.3_a	2.3	0.44_c	51_{abcd}	191_c	10_b	31	155_c	43_b	12
SMS, 20%, 1 day	5.2_a	0.58_{abc}	3.2_a	2.6	0.45c	53_{abcd}	223_c	10_b	33	177_c	47_{ab}	16
SMS, 40%, 2 weeks	5.2_a	0.56_{bc}	3.2_a	2.5	0.45c	48_{cd}	224_c	8_c	30	199_c	37_c	11
NH_4^+-NO_3^-, 2 weeks	5.2_a	0.51_c	2.9_a	2.7	0.55_a	56_{abc}	324_b	7_c	31	381_b	24_{de}	13
NH_4^+-NO_3^-, 1 day	5.4_a	0.57_{abc}	2.9_a	2.6	0.53_{ab}	61_a	396_b	7_c	31	363_b	28_d	19
unamended	4.9_a	0.65_a	3.3_a	2.2	0.49_{abc}	60_{ab}	592_a	7_c	30	642_a	20_e	18
Significance[3]	*	*	*	NS	*	*	*	*	NS	*	*	NS

[1] SMS applied at 10, 20 or 40% mineralization rates two weeks preplant or at planting; ammonium nitrate applied two weeks preplant or at planting; unamended control

[2] N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; Mn = manganese; Fe = iron; Cu = copper; B = boron; Al = aluminum; Zn = zinc; Na = sodium; Values followed by different letters within a column are significantly different using Duncan's least significant difference test at the 5% level.

[3] * = significantly different at $P \leq 0.05$; NS = no significant differences

in above optimal levels of nutrients. Soil testing should also accompany its use.

In 2007, organic matter content was increased over the unamended control when using any SMS treatment. Higher organic matter contents were observed using a 10 percent mineralization rate to apply SMS regardless of the timing of application compared to using a 20 percent mineralization rate at planting, a 40 percent mineralization rate or ammonium nitrate. Organic matter provides many benefits to soil properties and plant growth. It changes very slowly. SMS increased the organic matter significantly in one season. The increase was positively correlated with the amount of SMS applied.

Organic matter contents were not determined in 2008.

Salt levels were lowest with the ammonium nitrate and unamended treatments and highest when SMS was applied using a 10 percent mineralization rate at planting. The remaining treatments resulted in intermediate salt levels. It was to be expected that applying higher amounts of SMS would result in higher salt levels (positive correlation). Also, the SMS applied two weeks before planting was more exposed to factors (rain) promoting leaching of salts than when it was applied at planting. It is possible that during the winter rain and snow will promote leaching and salts may not be an issue in future growing seasons. However, salt levels should be monitored with soil testing particularly when salt sensitive crops are to be grown.

Salt levels were not determined in 2008.

Nutrient Levels Based on Tissue Analysis

Regarding macronutrients, in 2007 nitrogen levels were lower in plants grown with no supplemental nutrients than with all other treatments (Table 10). Potassium levels were lower when plants were supplied nutrients with ammonium nitrate versus by all other treatments including the unamended control. Magnesium levels were generally higher when

levels were not affected by the treatments.

In 2008, nitrogen levels were highest when ammonium nitrate was used compared to any other treatment except SMS assuming a 10 percent mineralization rate applied at planting (Table 11). Potassium levels were higher when SMS was applied three weeks prior to planting regardless of mineralization rate assumed compared to applying ammonium nitrate or using no supplemental nutrients. All other treatments resulted in intermediate potassium levels. Magnesium levels were higher when ammonium nitrate was applied three weeks prior to planting than applying SMS assuming a 10 percent mineralization rate at planting, applying SMS assuming a 40 percent mineralization rate and not applying supplemental nutrients. All other treatments resulted in intermediate magnesium levels. Phosphorus and calcium levels were not affected by the treatments.

Table 11: 2008 nutrient levels of pumpkins based on tissue analysis.

Treatment [1]	Leaf Nutrient Content											
	Macronutrients					Micronutrients						
	N[2]	P	K	Ca	Mg	Mn	Fe	Cu	B	Al	Zn	Na
	%					ug/g						
SMS, 10%, 3 weeks	4.84_{bc}	0.52	3.32_{a}	5.1	0.78_{abc}	105	957	12	36_{a}	921	45_{a}	4
SMS, 10%, 1 day	5.11_{ab}	0.55	3.16_{ab}	4.0	0.71_{c}	92	1380	12	34_{ab}	1248	46_{a}	6
SMS, 20%, 3 weeks	4.45_{c}	0.50	3.24_{a}	4.8	0.79_{abc}	106	1398	12	37_{a}	1272	43_{ab}	6
SMS, 20%, 1 day	4.54_{bc}	0.50	3.01_{ab}	5.4	0.82_{abc}	93	2015	12	35_{ab}	1819	45_{a}	8
SMS, 40%, 3 weeks	4.47_{bc}	0.48	3.09_{ab}	4.3	0.70_{c}	119	2837	12	34_{ab}	2298	39_{bc}	10
NH_4^+-NO_3^-, 3 weeks	5.47_{a}	0.50	2.62_{c}	5.5	0.88_{a}	134	1626	11	32_{bc}	1518	31_{de}	6
NH_4^+-NO_3^-, 1 day	5.59_{a}	0.49	2.63_{c}	4.6	0.85_{ab}	119	1920	12	30_{c}	1572	35_{cd}	6
unamended	4.71_{bc}	0.49	2.86_{bc}	4.3	0.72_{bc}	124	2073	10	37_{a}	1918	29_{e}	9
Significance[3]	*	NS	*	NS	*	NS	NS	NS	*	NS	*	NS

[1] SMS applied at 10, 20 or 40% mineralization rates two weeks preplant or at planting; ammonium nitrate applied two weeks preplant or at planting; unamended control

[2] N = nitrogen; P = phosphorus; K = potassium; Ca = calcium; Mg = magnesium; Mn = manganese; Fe = iron; Cu = copper; B = boron; Al = aluminum; Zn = zinc; Na = sodium; Values followed by different letters within a column are significantly different using Duncan's least significant difference test at the 5% level.

[3] * = significantly different at $P \leq 0.05$; NS = no significant differences

In 2007, several differences in leaf tissue micronutrient levels were observed. Applying SMS, regardless of mineralization rate or timing, resulted in lower iron and aluminum levels than all other treatments. Also, the unamended control resulted in the highest levels of iron and aluminum. The reverse was observed with zinc; applying SMS resulted in the highest levels followed by the ammonium nitrate treatments and then the unamended control. Copper levels were higher when SMS was applied using a 10 or 20 percent mineralization rate compared to the other treatments. The unamended treatment resulted in excessive iron levels, applying ammonium nitrate or SMS using a 40 percent mineralization rate and SMS using a 20 percent mineralization rate and applied at planting resulted in high levels. The remaining treatments resulted in normal zinc levels. Boron and sodium levels were not affected by the treatments.


Contol plot: no fertilizer or soil amendment

In 2008, boron levels were higher in the unamended control, when SMS was applied three weeks prior to planting assuming a 10 percent mineralization rate and applying SMS three weeks prior to planting assuming a 20 percent mineralization rate than applying ammonium nitrate. Zinc levels were generally higher when SMS was applied assuming a 10 or 20 percent mineralization rate regardless of timing than all other treatments. Manganese, iron, copper, aluminum and sodium levels were not affected by the treatments.

In general, macro- and micro-nutrient levels were within normal ranges for pumpkins. **mn**

Mineralization rate: The rate at which organic materials are returned to their inorganic form.