COMPOSTED MUNICIPAL SOLID WASTE APPLICATION IMPACTS ON COTTON YIELD AND SOIL PROPERTIES

By

Ahmad Khalilian, Professor
Mike J. Sullivan, Professor
John D. Mueller, Associate Professor
Edisto Research & Education Center
Blackville, South Carolina

Francis J. Wolak, Professor
Robert E. Williamson, Professor
Agricultural & Biological Engineering Department
Clemson University
Clemson, South Carolina

Robert M. Lippert, Assistant Professor
Agronomy Department
Clemson University
Clemson, South Carolina

INTRODUCTION

Municipalities are facing a growing problem of how to safely dispose of their solid waste. A possible solution to this problem is composting the organic fraction of municipal solid waste (MSW). Biosolids are entering composting facilities to turn a waste byproduct into a valuable resource. Industry is looking to expand towards composting of the organic fraction of the municipal solid waste stream as evidenced by the development of Bedminster BioConversion Corporation in Sieverville, Tennessee and Cobb County Georgia. The largest potential user of MSW compost is the agricultural industry (Parr and Hornick, 1992; Slivka et al., 1992). Application of MSW compost usually increases yields of agronomic and horticultural crops, under both field and greenhouse conditions. Agricultural uses of composted MSW have shown promise for a variety of field crops (sorghum, maize, forage grasses) and vegetables sold for human consumption (lettuce, cabbage, beans, potatoes). Responses by plant systems have ranged from none to over twofold increases in yield (Shiralipour et al., 1992). According to research at Louisiana State University (Hallmark et al., 1994) application of 22.4 Mg/ha of composted MSW to opened sugarcane rows prior to planting resulted in an 808 kg/ha increase in sugarcane yields. Addition of 25 Mg/ha compost increased ryegrass yields compared to untreated plots but did not excessively increase the trace metal concentration in the soil (Bauduin et al., 1987). In other studies application of 8, 16, 32, or 64 Mg/ha compost to a sandy soil increased heights and weights of two successive sorghum crops (Hortenstine and Rothwell, 1973).

Soil hard pans can reduce crop yields and are a significant problem in many soils in the Southeast. A high-energy input is required via in-row subsoiling to break up the compaction to promote improved root development and subsequent nutrient and water utilization. Composted MSW has the potential to increase organic matter content of sandy coastal plain soils. Under laboratory conditions values of bulk density, penetration resistance and peak shear strength decreased with increasing organic matter contents in sandy loam and clay soils (Ekwue and Stone, 1995).

Seedling cotton (cotyledon - 4 true leaves) is attacked by various thrips species, western flower thrips (Frankliniella occidentalis), tobacco thrips (F. fusca) and eastern flower thrips (F. tritici) with the first two being most prevalent in South Carolina. Over 99% of South Carolina cotton acreage is treated with an at-planting, in-furrow insecticide to control early season thrips. The effects of different rates and application methods of municipal compost on early season thrips populations needs to be determined. Plant-parasitic nematodes cause over $250,000,000 in yield losses on cotton in the United States each year (Blasingame, 1996). Yield losses in individual fields may reach 30-50%. At the present, nematode management relies heavily on the use of nematicides, such as aldicarb applied in-furrow at-planting at a cost of approximately $52.00/ha. Higher organic matter content tends to increase the populations of many soil microorganisms, including those that are naturally antagonistic or pathogenic to plant-parasitic nematodes.

Research is needed to determine whether compost can be used economically to replace or supplement commercial fertilizers for cotton production. Quantitative data on the effects of compost on soil and plant characteristics are needed as a means of understanding benefits and problems associated with utilization of composted municipal solid waste in coastal plain soils. Determination of the best methods of applying MSW composts to land (broadcast, banded, etc.) is needed. In addition, the effects of compost on pest management decisions needs to be determined.

OBJECTIVES

The objectives of this project were to develop and test equipment for broadcast, banded or injection applications of composted municipal solid waste at selected rates to agricultural lands for cotton production; and determine the effects of compost on soil parameters (organic matter, soil compaction, soil fertility and additive effects over years), plant responses (yield, nutrition) and pest management.

METHODS AND MATERIALS

Tests were conducted at the Edisto Research and Education Center near Blackville, SC on a Faceville loamy sand soil. A randomized complete block design with four replications was the statistical model selected for comparing different treatments. Two application methods (broadcast and banded), three application rates 11.2, 22.4, and 33.6 Mg/ha (5, 10, and 15 tons/acre), and a control (no compost) were used in 1995. The same treatments were used in 1996 and 97, except the broadcast application plots were split in half to determine the additive effects of compost over the years. No additional compost was applied to one half while the other half received the same rate as in 1995. Cotton was planted and carried to yield using recommended practices for seedbed preparations, seeding, fertilization, insect and weed control. Plots consisted of 12 30-m rows on 96-cm centers. The two middle rows of each plot were machine harvested for yield determinations.

A commercially available spreader (Knight Pro Twin Slinger, model 8024) was used for broadcast application of compost in 1995. The spreader was adjusted to apply different rates of compost. With this system, swinging hammers deliver the material to the side resulting in a uniform coverage over 7.5-m width of the test plots. A 4-shank subsoiler-bedder was used to disrupt the hardpan and incorporate the composted material. Drift was a problem with this spreader under windy conditions. In 1996 and 97, a conventional flatbed, chain conveyer type manure spreader was used for broadcast application to eliminate drift problems associated with the side delivering system. An adjustable gate was added to the spreader to control the application rates.

A 4-row device for band application of the MSW compost was developed and mounted behind a John Deere MaxEmerge2 cotton planter. The unit consisted of a hopper with four fluted-wheel-metering devices at the bottom of the hopper. A hydraulic motor was used to run the metering system. Compost application rates were adjusted by changing speed of the motor using a flow control valve. This system dispensed the material, 20-cm wide, behind the cotton planter.

To determine the effects of compost on soil compaction, a tractor-mounted, hydraulically-operated, microcomputer-based, digital recording penetrometer system was used to quantify soil resistance to penetration. Soil cone index values were calculated from the measured force required to push a 3.2 cm^2 base area, 30° cone into the soil at a constant velocity. Penetrometer data (four probes per plot) was taken before compost application and immediately after cotton harvest in 1996. Penetrometer readings were taken to a depth of 45 cm from crop rows and row middles).

Each plot was sampled for Columbia lance nematodes, soil organic matter, ammonium and nitrate contents at planting, 6-weeks-after planting and 14-weeks-after planting. Twelve cores 20-cm deep and 2.5-cm in diameter were taken from each plot on each date. Plant tissue samples (35 leaves/plot) were collected and analyzed for nitrogen.

INJECTION TEST, 1997

The trials were expanded for the 1997 season by including a site with subsurface application. Equipment was

constructed for injecting MSW compost under the seed row at sufficient depth to place it in the compacted subsoil layer at different application rates. Tests were conducted on a Varina sandy loam soil. Two application methods (injection and broadcast), three application rates 9, 18 and 27 Mg/ha (4, 8, and 12 tons/acre), and a control (no compost) were used in a randomized complete block design. Briefly, the equipment was configured for two rows and consisted of subsoiler shanks which had been modified by attaching a 10-cm x 20-cm thin-wall rectangular tubing to the back of each subsoiler shank. These extended from the lower end of the shank to a position above the soil surface. The trailing edge of the rectangular tubing was cut away from the lower end of the tubing to allow the MSW compost to be deposited into the slot created by the subsoiler shank. Compost was funneled into the top of the rectangular tubing and fell by gravity flow to the bottom, filling the tube. As the tool moved through the soil, the MSW compost was placed into the bottom of the subsoil.

For preparing the test plots, the MSW was carried on the subsoiler. A hopper was constructed and attached to the subsoiler frame. This hopper was fitted with a drag chain which pulled the MSW material toward a drop point above the injection tubes. Material dropped by gravity from the hopper floor and was directed into the top of the injection tubes with transitions constructed from sheet metal.

RESULTS AND DISCUSSION

Cone index values before tillage and compost application indicated that the field had a hardpan in the E horizon at a depth of 17 to 25 cm. All rates of compost significantly reduced formation of the hardpan in the top 30-cm of soil for cotton rows compared to no compost application (Table 1). In addition, all rates of broadcast application significantly reduced soil compaction in the top 30 cm of the row middles compared to no compost application (Table 2). Banded application did not affect the compaction in the row middles. Similar results were obtained in 1997.

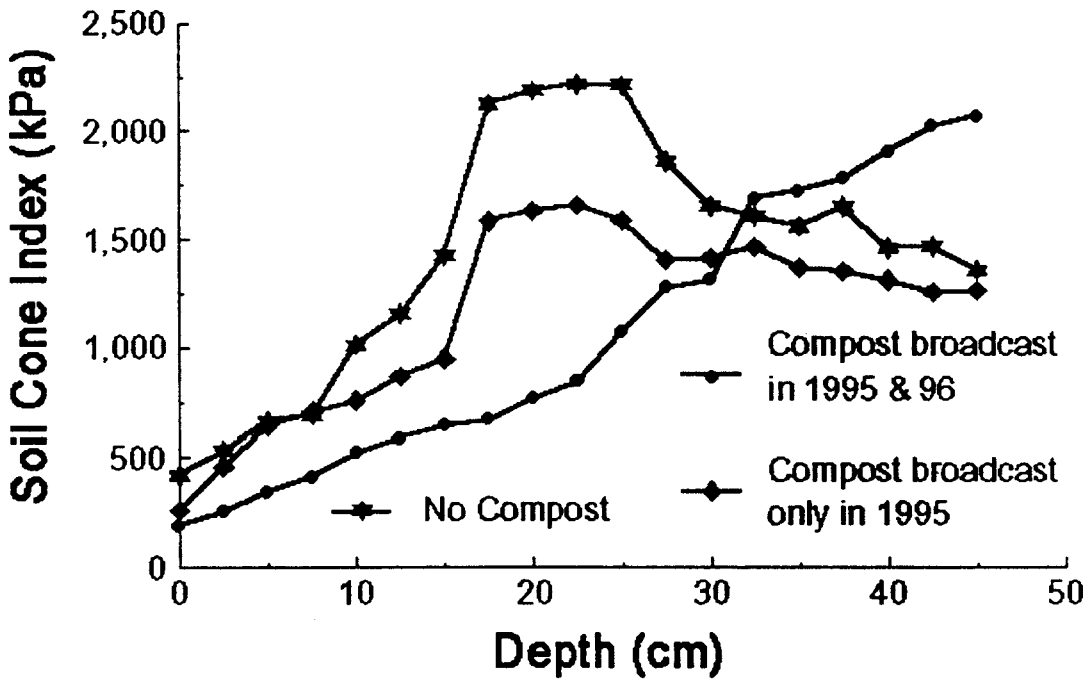

Figure 1. Effects of multiple compost application on formation of hardpan from crop rows after cotton harvest in 1996 (33.6 Mg/ha).

Table 1. Effect of compost application methods and rate on formation of hardpan under cotton rows at harvest, 1996. Clemson University, Edisto Research and Education Center, Blackville, SC.

Compost (Mg/ha)	Application Method	Cone index (kPa)			
		0-7.5 cm Depth	7.5-15 cm Depth	15-22.5 cm Depth	22.5-30 cm Depth
11.2	Broadcast	409 bc	605 b	706 b	1253 bc
22.4	Broadcast	302 c	549 b	754 b	808 c
33.6	Broadcast	301 c	586 b	760 b	1286 b
11.2	Band	536 ab	644 b	1146 b	1236 bc
22.4	Band	495 ab	691 b	1097 b	1155 bc
33.6	Band	510 ab	675 b	1030 b	1218 bc
None	-------	578 a	1198 a	2176 a	1909 a

Means within a column followed with a letter in common are not significantly different (Duncan's Multiple Range Test, $\alpha = 0.05$).

Multiple broadcast applications of compost (1995 and 96) significantly reduced formation of the hardpan in the top 30 cm of cotton row compared to no compost application (Figure 1). Also, there were significant differences in cone index values between no compost application and one year application of compost. In row middles both one-year application and multiple applications of compost significantly reduced soil compaction in the top 22.5-cm of soil compared to no compost application. Also, there was a significant difference in cone index values in the 7.5 to 15 cm depth of soil between compost applied only in 1995 versus 1995 and 1996 applications (Figure 2).

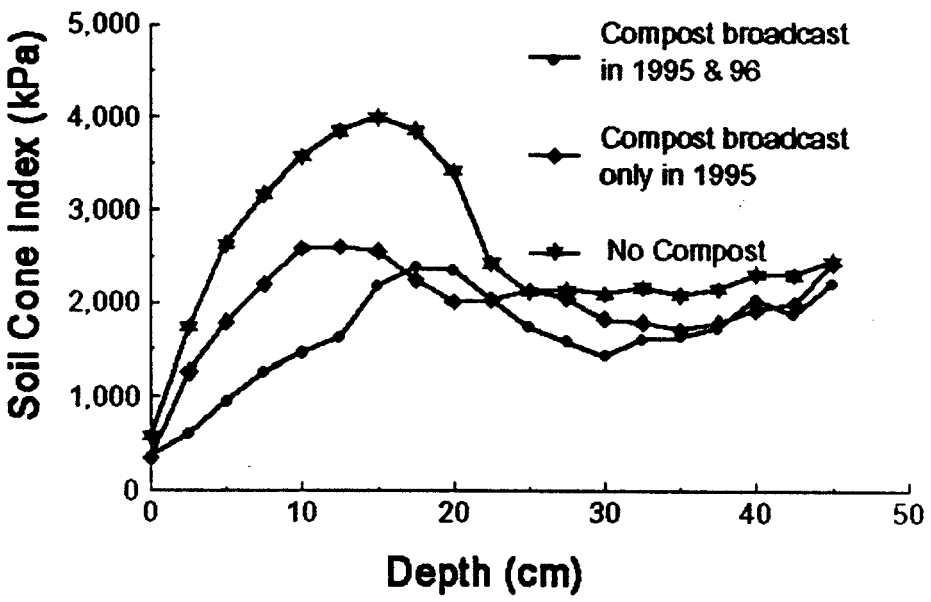

Figure 2. Effects of multiple compost application on soil compaction from row middles after cotton harvestin 1996.(33.6 Mg/ha)

All application rates of banded municipal compost reduced early season thrips populations in 1995 and 1996. However, it showed no effect on thrips in 1997. Recovery of Columbia lance nematodes (*Hoplolaimus columbus*) prior to planting in 1995 was minimal. By midseason reproduction in the untreated check plots was more than double that in all treatments except the 22.4 Mg/ha (10 tons/acre) broadcast application (Table 3). Columbia lance nematode levels decreased in all treatments between harvest in 1995 and planting in 1996. By harvest in 1996, nematode population densities had again increased significantly, especially in the check that had almost triple the density of any of the other treatments. Several of the compost treatments had nematode densities comparable to those found in the Temik 15G treatment. Temik 15G was applied at the rate of 1.18 kg a.i./ha. At midseason in 1997, only the broadcast applications provided level of control comparable to that provided by Temik 15G.

Table 2. Effect of compost application methods and rate on soil compaction for row middles at harvest, 1996. Clemson University, Edisto Research and Education Center, Blackville, SC.

Compost (Mg/ha)	Application Method	Cone index (kPa)			
		0-7.5 cm Depth	7.5-15 cm Depth	15-22.5 cm Depth	22.5-30 cm Depth
11.2	Broadcast	1017 b	1870 b	2374 b	1757 c
22.4	Broadcast	858 b	2010 b	2331 b	1859 bc
33.6	Broadcast	791 b	1752 b	2292 b	1580 c
11.2	Band	1884 a	3143 a	3264 a	2214 a
22.4	Band	2019 a	3337 a	2631 ab	2086 ab
33.6	Band	1544 a	3073 a	2664 a	1897 ab
None	-------	2024 a	3807 a	3234 a	2121 a

Means within a column followed with a letter in common are not significantly different (Duncan's Multiple Range Test, $\alpha = 0.05$).

Figure 3 shows soil organic matter content averaged over top 20 cm of the soil for 1996. Application of MSW compost significantly increased the soil organic matter content and soil nitrogen content (Figure 4) 6-weeks-after planting proportional to compost application rate. However, these differences did not affect the leaf nitrogen content of cotton plants during the same sampling period (Figure 5). Similar results were obtained in 1995 and 1997.

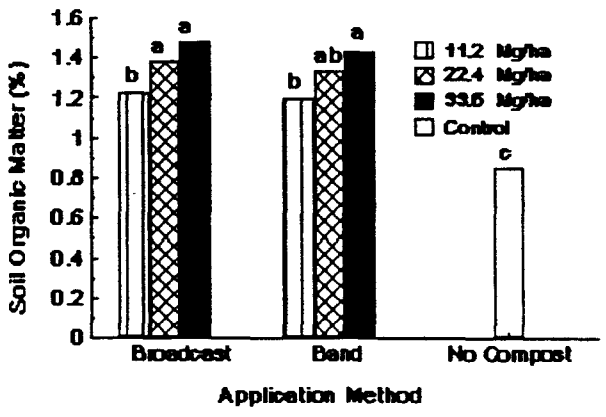

Figure 3. % Soil Organic Matter 6 Weeks after planting

Table 3. Effects of compost on recovery of Columbia lance nematodes from soil.

Compost (Mg/ha)	Application Method	Columbia lance nematodes/100 cm^3 soil			
		1995 Midseason	1996 Preplant	1996 Harvest	1997 Midseason
11.2	Broadcast	31	11	24	11
22.4	Broadcast	22	5	13	8
33.6	Broadcast	3	5	0	24
11.2	Band	13	1	5	52
22.4	Band	71	15	13	41
33.6	Band	52	8	16	66
None	------	125	18	61	61
Temik 15G	In-furrow	19	19	13	39

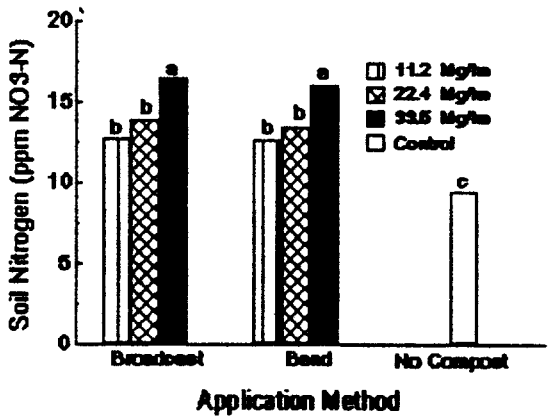

Figure 4. Soil Nitrogen Content 6 Weeks after planting

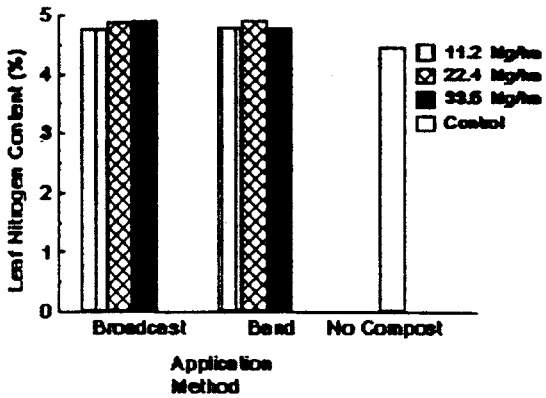

Figure 5. Leaf Nitrogen Content 6 Weeks after planting

Table 4. Effects of compost on seed cotton yield.

Trt. No.	Compost (Mg/ha)	Application Method	Yield (kg/ha) 1995	1996	1997
1	11.2	Broadcast	2063 b	2323 c	2814 c
2	22.4	Broadcast	2213 b	2400 bc	3093 b
3	33.6	Broadcast	2375 a	2633 a	3406 a
4	11.2	Band	2084 b	2306 c	2831 c
5	22.4	Band	2216 b	2353 bc	3064 b
6	33.6	Band	2396 a	2495 ab	3361 a
7	None	-------	2208 b	2135 d	2617 d

Means within a column followed with a letter in common are not significantly different (Duncan's Multiple Range Test, $\alpha = 0.05$).

- Figure 6 shows soil organic matter content 14-weeks-after planting. Except for 11.2 Mg/ha (5 tons/acre) banded application rate, MSW compost significantly increased soil organic matter compared to no compost application. Only application of 33.6 Mg/ha (15/acre) compost (broadcast or banded) statistically increased soil nitrogen content averaged over the top 20 cm of the soil (Figure 7).

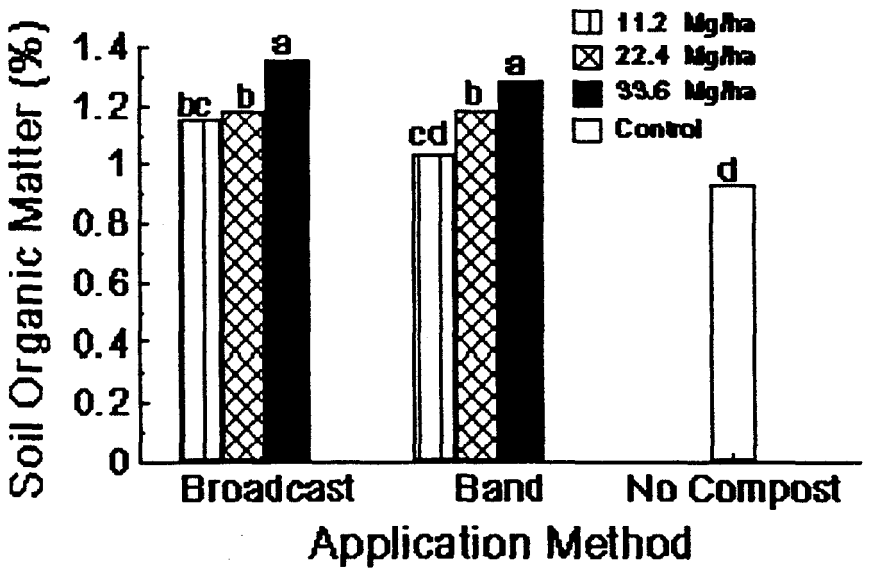

Figure 6. Soil Organic matter content 14 weeks after planting

Table 5. Carryover and additive effects of compost on soil nitrogen and organic matter contents and seed cotton yield 1996.

Trt. No.	Compost (Mg/ha) 1995	Compost (Mg/ha) 1996	No3-N (ppm) 6 W*	No3-N (ppm) 14 W	Organic Matter (%) 6 W	Organic Matter (%) 14 W	Yield (Mg/ha)
1a	11.2	11.2	12.7b	2.1ab	1.23b	1.15b	2323 b
1b	11.2	None	8.4c	1.6 b	0.95cd	0.95c	2131 c
2a	22.4	22.4	13.8b	2.4ab	1.38b	1.18b	2400 b
2b	22.4	None	7.2c	1.6 b	1.0cd	0.88c	2143 c
3a	33.6	33.6	16.4a	3.0 a	1.48a	1.35a	2633 a
3b	33.6	None	9.5c	2.0ab	1.05c	0.98c	2057 c
7	None (control)		7.7c	1.5 b	0.90d	0.93c	2137 c

- . 6 W and 14 W = 6- and 14-weeks after planting.
- Means within a column followed with a letter in common are not significantly different (Duncan's Multiple Range Test, $\alpha = 0.05$).

Table 4 shows seed cotton yields for the 1995, 96, and 97 tests. Application of 33.6 Mg/ha (15 tons/acre) of MSW compost (broadcast or banded) significantly increased seed cotton yield (187 kg/ha) compared to no compost application in 1995. There were no significant differences in yield among the rest of the treatments. In 1996 and 97, all rates of MSW compost significantly increased seed cotton yield. Yield increase was proportional to application rate. In 1996, for 33.6 Mg/ha broadcast application treatment, the yield increase was 498 kg/ha or 23% more compared to no compost application. In 1997, yield increase at this level of application rate was 30% higher than no compost application. Similar results were obtained for the compost injection test in 1997. Yield increases were proportional to the application rates. Application of 27.0 Mg/ha increased seed cotton yield by 23% compared to no compost application.

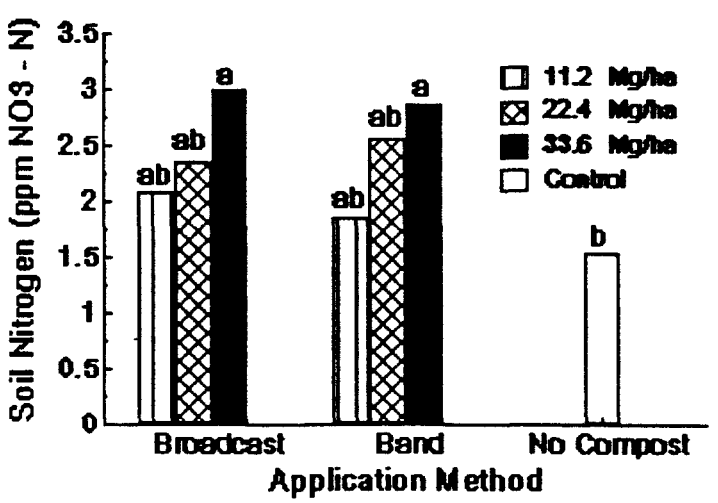

Figure 7. Soil nitrogen content 14 weeks after planting

Table 5 shows carryover and additive effects of compost on soil organic matter and soil nitrogen for both 6- and 14-weeks-after planting and seed cotton yield. There were very few carryover effects with all of these parameters except for soil organic matter contents 6-weeks-after planting at the 33.6 Mg/ha (15 tons/acre) application rate (treatment 3b, Table 5). Additive effects of compost were significant on soil organic matter, nitrogen content and seed cotton yield (treatments 1a, 2a and 3a as compared to 1b, 2b and 3b). Increased soil organic matter and nitrogen content combined with the potential increase in soil water-holding capacity and decreases in soil density associated with MSW compost, could be the contributing factors to yield increase.

Table 6. Effects of compost on seed cotton yield for compost injection test.

Compost (Mg/ha)	Application Method	Yield (kg/ha) 1997
9.0	Injected	3426 b
18.0	Injected	3624 ab
27.0	Injected	3787 a
9.0	Broadcast	3440 b
18.0	Broadcast	3592 ab
27.0	Broadcast	3763 a
None	-------	3091 c

Means within a column followed with a letter in common are not significantly different (Duncan's Multiple Range Test, $\alpha = 0.05$).

SUMMARY

Equipment was developed and tested for broadcast, band and injection application of MSW compost at selected rates to agricultural land for cotton production. Replicated tests were conducted to determine the effects of compost on soil parameters (organic matter, soil compaction, soil fertility and additive effects over years), plant growth, and pest population.

All rates of compost (broadcast application) significantly reduced soil compaction in the top 30 cm of soil for cotton rows and row middles compared to no compost application. Banded application did not affect the compaction in the row middles.

Multiple applications of compost (broadcast, 1995 and 96) significantly decreased soil compaction in the top 30 cm of cotton row and the top 22.5 cm of row middles compared to no compost application.

All rates of banded applications of compost reduced early season thrips populations in 1995 and 1996. However, it showed no effect on thrips in 1997. By midseason 1995, Columbia lance nematode density in the untreated check plots was more than double that in all treatments except the 22.4 Mg/ha (10 ton/acre) broadcast application. Columbia lance nematode levels decreased in all treatments between harvest in 1995 and planting in 1996. By harvest in 1996, nematode population densities had again increased significantly, especially in the check that had almost triple the density of any of the other treatments. Several of the compost treatments had nematode densities comparable to those found in the Temik 15G treatment.

All rates of compost significantly increased the soil organic matter content and soil nitrogen content 6-weeks-after planting. The increase was proportional to application rate. However, compost did not affect the leaf nitrogen content of the cotton plant during the same sampling period.

Except for the11.2 Mg/ha (5 tons/acre) banded application rate, MSW compost significantly increased soil organic matter 14-weeks-after planting. Only application of 33.6 Mg/ha (15 tons/acre) compost (broadcast or banded) statistically increased soil nitrogen content during this period.

In 1996 and 97, all rates of MSW compost significantly increased seed cotton yield. Yield increase was proportional to application rate. For the33.6 Mg/ha broadcast application treatment, yield increase was 23% and 30% more compared to no compost application respectively. There were very few carryover effects from previous year on soil organic matter, soil nitrogen and seed cotton yield.

ACKNOWLEDGMENTS

The authors acknowledge the support of the South Carolina Cotton Grower Association; the South Carolina Universities Research and Education Fund; and Bedminster Bioconversion Corporation. The significant contributions of Mr. Richard Hallman and Mr. Raul Garcia to this study are sincerely appreciated.

REFERENCES

Bauduin, M., E. Delcarte and R. Impens. 1987. Agronomic characterization and evaluation of two new municipal waste composts. In Compost: Production, Quality and Use (M. De Bertoldi, M. P. Ferranti et al.), pp. 479-486. Elsevier Applied Science, London.

Blasingame, D. 1996. Cotton disease loss estimate committee report. Pp. 227 *In* P. Dugger and D. A. Richter, eds. 1996 Proceedings Beltwide Cotton Conferences, National Cotton Council of America, Memphis, TN.

Ekwue, E. I. and R. J. Stone. 1995. Organic matter effects on the strength properties of compacted agricultural soils. Transactions of the ASAE 38(2): 357-365.

Hallmark, W. B., S. E. Feagley, X. Wan and L. P. Brown. 1994. Effects of composted MSW on sugarcane production and fertilizer requirements. Compost Quality Documentation, Bedminster Bioconversion Corporation, Cherry Hill, NJ.

Hortenstine, C. C. and D. F. Rothwell. 1973. Pelletized municipal refuse compost as a soil amendment and nutrient source for sorghum. J. Environ. Qual. 2(3): 343 - 344.

Parr, J. F. and S. B. Hornick. 1992. Utilization of municipal wastes. In Soil Microbial Ecology: Application in Agriculture, Forestry, and Environmental Management (B. Metting). Marcel Dekker, New York.

Shiralipour, A., D. B. McConnell and W. H. Smith. 1992. Uses and benefits of MSW compost: a review and assessment. Biomass and Bioenergy, Pergamon Press, N.Y., 3(3-4):267-279.

Slivka, D. C., T. a. McClure, a. R. Buhr and R. Albrecht. 1992. Compost: United States supply and demand potential. Biomass and Bioenergy 3, 281- 299.