SOIL AMENDMENTS TO INCREASE COTTON PRODUCTIVITY ON DROUGHT-STRESSSED SOILS

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ABSTRACT

Application of by-product waste-stream materials as soil amendments is an attractive alternative disposal method that could improve the productivity of drought-stressed soils. We conducted field experiments from 1996 through 1999 on Gigger-Gilbert silt loam (fine-silty, mixed, thermic, typic Fragiudalf-Glossaqualf) to determine if cotton *(Gossypium hirsutum L.)* yields could be increased by soil applications of organic and inorganic waste materials. The waste materials were applied using two methods of application, broadcast incorporated and as vertical mulch directly under the row. The waste materials were municipal biosolids (MB), composted sewage sludge (CSS), papermill sludge (PS), and papermill boiler ash. Applications were made with each material and with selected combinations of the materials. The rate of application for all treatments was 60 tons/A. Method of application had little or no consistent effect on response to the waste materials. Lint yield and plant height increased with application of MB, CSS, and boiler ash in the year of application and in the following 3 years. Yield increases ranged from 55% for MB applications and 40% for CSS applications. Application of PS decreased yield 70% and plant height 12 to 26% in the year of application and had no consistent residual effect on yield in the following 3 years. Waste materials with a low C:N applied as soil amendments were a fast and economic means of improving soil productivity and cotton yield. Papermill sludge with its high C:N should not be applied soil incorporated because of the potential for N immobilization.

INTRODUCTION

Loess soils of the southern U.S.A., which include large areas of cotton production, have low pH and organic matter content and natural shallow hardpans and fragipans that limit rooting depth. These problem soils are droughty and irrigation must be applied often to produce a profitable crop. The soils can be improved for cotton production by growing winter cover crops for green manure and using reduced (conservation) tillage practices (Boquet, et al., 1997; Hutchinson et al., 1991). This is a slow and expensive process requiring many years to increase soil organic matter. A faster and more economic means of improving soil productivity may be to utilize readily available organic materials from selected waste streams as soil amendments.

Each year in the U.S.A., a total of 400 million tons of organic wastes are generated (Korcak, 1998). Of these, about 208 million tons are municipal solid wastes (USEPA, 1996), 5 million tons are papermill sludge (PS) (Glenn, 1997) and 550,000 tons are biologically treated municipal biosolids (MB) (Millner et al., 1998). Additionally, paper mills produce large quantities of boiler ash. The cotton ginning industry produces approximately 800,000 tons of gin trash yearly. Historically, these waste products have been stored in lagoons and landfills or incinerated. These methods of disposal are no longer acceptable because they may cause environmental degradation. Beneficial use as soil amendments would be an attractive alternative disposal method for many by-product waste materials. This would recycle plant nutrients that would otherwise be lost and possibly enhance the productivity of land used for cotton production. The possibility of significant benefits to cotton from organic wastes applied as soil amendments has been recognized for more than 65 years (Reynolds, 1930). Waste-stream materials can be obtained at little or no cost but their value in agriculture is limited by transportation and application costs. To be practical and economic, waste products must be applied on agricultural land that is located within 50 miles of the production facility.

In recent years, the yield of dryland cotton grown on loess soils of the southern U.S.A. has been increased through the use of conservation tillage and green manure crops. The objective of this research was to determine whether cotton yields could be increased by soil applications of organic and other waste materials used in place of the green manure crop. If application of these materials proves beneficial, it will benefit not only cotton farmers but will also offer an economic and environmentally acceptable means of waste disposal.

MATERIALS AND METHODS

Field experiments were conducted from 1996 through 1999 on Gigger-Gilbert silt loam (fine-silty, mixed, thermic, typic fragiudalf-glossaqualf) at the Louisiana State University Agricultural Center Macon Ridge Research Station located near Winnsboro, Louisiana. The materials selected for evaluation were MB, composted sewage sludge (CSS), PS (primary, dewatered), paper mill boiler ash, and selected combinations of these materials. The composition of each of the waste materials is presented in Table 1. A complete list of treatments is shown in Table 2.

Methods of Application. The waste products were applied in two methods of application: i) broadcast on the soil surface and incorporated to a depth of 6 inches and ii) vertical mulch under the row in a 6-inch wide x 24-inch deep trench. The quantity of materials applied was dependent upon that needed to fill the vertical trenches, which varied from 40 to 60 tons of dry weight/A. The same rates were then used for the broadcast treatments. All of the treatments were applied in 1996 one week before planting. After application of the amendments the plots were prepared for planting by bedding with disk hippers (40-inch wide beds) and smoothing with a reel and harrow row conditioner. There were two control treatments: 1) plots that were bedded and prepared without amendments and 2) plots that were trenched and refilled without adding vertical mulch amendments.

Planting. In 1996, the plots were planted immediately after completing application of the soil amendments. After harvest in September 1996, the plots were left undisturbed except for stalk cutting. The plots were no-till planted in late April or early May 1997, 1998, and 1999 without re-applying amendments. ‘Deltapine NuCotton 33B’, ‘StonevilleLA887’, ‘Suregrow 125', and ‘Suregrow 125BR’ were planted in 1996, 1997, 1998, and 1999, respectively. Standard practices for the region were used to control diseases, weeds, and insects.

Fertilization. The N status of cotton plants in each treatment was monitored by weekly sampling of leaf petioles and blades (uppermost fully expanded leaf) for nitrate-N and total N content. Treatments that became N deficient were supplemented with inorganic N fertilizer. Supplemental fertilizer N was required by cotton in the papermill sludge and boiler ash treatments in each year. Fertilizer N was applied as surface-broadcast ammonium nitrate. Control treatments received the standard inorganic fertilization of 80 lb N/A.

Experimental design. The experiments were conducted in a randomized complete block design with four blocks. The arrangement of the treatments was a split plot with methods of application as the main plots and soil amendments as the sub plots. The experimental units were four 40-inch wide rows 50 ft long. Treatments were applied on and data collected from the two center rows of each plot.

Data collection. Data were collected on plant growth and development and yield. Plant height and node number per plant were determined 30 days after planting and at crop maturity by measuring 10 plants per plot. Node above white flower and internode length above white flower were determined at 8-day intervals during the 6-week period from bloom initiation to the end of effective bloom. Plots were harvested with a mechanical picker for seedcotton yield determination. Seedcotton sub samples were ginned in a laboratory 20-saw gin to determine lint percentage, which was used to calculate lint yield.

RESULTS

First-year effects. In the year applied, there were significant effects of the soil-amendment treatments on lint yield. Broadcast application of MB increased lint yield 22% compared with the standard fertilization practices (Control 1)(Table 2). Cotton in the vertically-mulched MB treatment produced a lower yield than with broadcast application. Combinations of MB with other wastes resulted in similar effects on lint yield as MB applied alone. None of the tested waste combinations produced higher yields than MB alone. In the year applied, CSS as a broadcast treatment did not increase yield but, as a vertical mulch treatment, CSS increased yield 25%. Application of PS decreased lint yield in the year applied (Table 2). Cotton plants in the PS treatments were N deficient throughout the growing season even though fertilizer N was applied when needed as dictated by plant N content. Papermill boiler ash had no effect on cotton yield in the year applied.

Plant growth responses to applications of amendments closely paralleled yield responses. The tallest plants were produced with application of MB, alone or in combination with PS or boiler ash (Table 3). In the initial year, the shortest plants were produced in the PS and PS plus boiler ash. With application of CSS, plant height was similar to the standard fertilizer practices.

Residual Effects. In the 3 years following application, there were significant lint yield responses to the soil amendment treatments. With broadcast application, all amendments increased lint yield above the standard fertilizer and liming practices (Table 2). Broadcast application of MB increased lint yield 55% in the year following application (first year residual) compared with the control. Averaged across the 3 residual years, broadcast-applied MB increased lint yield 264 lb/A (56%). Vertically-mulched MB had a larger residual effect on lint yield than broadcast MB, increasing lint yield 431 lb/A (57%) across 3 years. With both methods of application, the largest residual effects were from the treatments containing MB. As in the initial year, combinations of MB with other wastes resulted in lint yields similar to MB alone, and none of the residual waste combinations produced higher yields than MB alone.

The residual effect of CSS on yield from 1997 through 1999 was not as large as that of MB, but CSS did increase lint yield 41% when applied broadcast and 24% when applied as a vertical mulch. Average yield increases from residual CSS were about ¾ of the increase from MB with broadcast applications and only 1/3 of the increase from MB in the vertical mulch treatments. In contrast with 1996, when PS decreased yield as much as 70%, the residual effects of PS on cotton yield were neutral to positive. Averaged across all 4 years, PS did not significantly affect lint yield, and among the 3 residual years of 1997, 1998, and 1999, the effects of PS were inconsistent. Papermill sludge increased lint as a broadcast treatment only in 1997 and as a vertical mulch treatment only in 1998.

Although not affecting yield in the initial year, the residual effects of boiler ash significantly increased lint yield in years two through four. In some years, boiler ash was as effective as the organic amendments in increasing lint yield. The use of boiler ash in combination with other wastes did not provide any yield benefit above that obtained from organic amendments alone, but use of boiler ash in combination with MB was superior to MB and PS combinations or CSS alone. This was likely due to the fact that most of the amendment treatments contained high amounts of Ca and increased the soil pH without the addition of a liming agent (boiler ash).

As with plant height responses to waste applications in the initial year, plant height responses in the residual years closely paralleled the yield responses. In each year after the initial year, the tallest plants occurred in the MB treatments (Table 3). In the third-year residual, however, the MB combinations with PS or boiler ash no longer gave consistent increases in plant height when compared with the standard fertilizer control.

DISCUSSION

The application of waste materials as soil amendments had positive effects on cotton growth and yield and soil properties. Much of the benefits from the amendments were from the nutrients they contain, especially N. This was evident from plant analysis that showed up to a 1400% increase in plant N from application of MB (data not shown). Additionally, some of the amendments increased soil pH and the soil levels of P, K and Ca. Greater yield increases in the year following application rather than in the year of application were related to the mineralization of nutrients and increases in soil pH that occurred after the first year. Soil incorporated PS treatments, especially, required a reduction in C:N to release the N immobilized in the first year. In other experiments, applying PS as surface mulch with soil-injected fertilizer N has prevented N immobilization in the year of application (data not shown). Boiler ash proved to be, as expected, an effective liming material and raised the soil pH. This was particularly beneficial in the vertical mulch treatment because of the low pH of the subsoil that contained toxic levels of Al and Mn.

The waste treatments increased yield above that obtained with the control treatments that employed standard fertilizer and liming practices. A likely explanation for this is that, in addition to the nutritional benefits of the amendments, the organic components provided increased water holding capacity and water infiltration. The vertical mulch treatments also eliminated the shallow hardpan directly under the row, which allowed additional water storage and root development. Examination of root development patterns revealed that roots were limited primarily to the mulched area and did not grow into the undisturbed subsoil on either side of the mulch. The interface between the mulch and subsoil proved to be the area of greatest root development (data not shown).

SUMMARY

A comparison of broadcast and vertical mulch application for soil amendments revealed no consistent differences in cotton performance between the two methods. The less expensive and faster method of broadcast application would therefore be more economical. Application of organic materials with high amounts of N and narrow C:N increased plant growth and crop yield in the year of application and in the following years. Paper mill sludge with its wide C:N decreased yield in the year of application. In the year after application, the C:N in the PS treatments was narrowed by mineralization processes and cotton plant growth and yield increased, although not to the level of MB or CSS treatments. The use of these organic soil amendments appears to be a faster and more economical means of improving soil productivity and cotton yield than growing winter green-manure crops.

LITERATURE CITED

Boquet, D.J., R.L. Hutchinson, W.J. Thomas, and R.E.A. Brown. 1997. Tillage and cover crop effects on cotton growth, yield and soil organic matter. p. 639-641. In P. Dugger and D. A. Richter (Ed.) Proc. Beltwide Cotton Conf. 6-10 Jan. New Orleans, LA. National Cotton Council, Memphis TN.

Glenn, J. 1997. Paper mill sludge: Feedstock for tomorrow. BiocycIe. 38:30-36.

Hutchinson, R.L., R.C. Aycock, G.P. Boquet, S.M. Cruse, P.A. Miletello, C.L. PinnelI-Alison, R.L. Rogers, and W.W. Russell. 1991. An evaluation of conservation tillage systems for cotton on the Macon Ridge. Louisiana Agnc. Exp. Stn. Bull. 2460.

Korcak, R.F. 1998. Why co-utilization: p 1-7. *In* S. Brown, J.S. Angle, and L. Jacobs (eds.) Beneficial Co-Utilization of Agricultural, Municipal and Industrial By-products. Kluwer Academic Publishers, Dordrecht, The Netherlands.

Millner, P.D., L.J. Sikora, D.D. Kaufman, and M.E. Simpson. 1998. Agricultural uses of biosolids and other recyclable municipal residues. p. 9-27. In R.J. Wright et al. (Ed.) Agricultural Uses of Municipal, Animal and Industrial Byproducts. U.S.D.A.,A.R.S. Conservation Res. Rep. No. 44.

Reynolds, E.B. 1930. Activated sludge as a fertilizer for cotton and corn. J. Amer. Soc. Agron. 22:537-539.

U.S. Environmental Protection Agency, Office of Solid Waste Management. 1996. Characterization of Municipal Solid Wastes in the United States. EPA/530/R-96/001. U.S. Government Printing Office, Washington, D.C.

Table 1 Elemental composition of materials applied as soil amendments for cotton production.

Element	Paper mill sludge	Composted sewage sludge	Municipal biosolids	Paper mill boiler ash
	----------	mg/kg	----------	
C	42000	196000	257000	183000
N	1300	7700	45000	1800
A1	912	8230	13680	6471
As	0.0	3.0	2.9	2.6
B	84	49	73	37
Ba	49	257	295	308
Ca	3200	12170	13993	39527
Cd	0.6	5.1	6.9	1.9
Cr	28	25	38	7.7
Cu	14.8	110	317	28
Fe	844	11884	15918	2681
Hg	0.0	0.4	0.4	0.0
K	276	1758	3225	4693
Mg	417	2551	4917	2062
Mn	91	316	619	977
Na	2371	220	1883	4227
Ni	5.0	13	22	12
P	144	3213	12680	546
Pb	1.1	42	40	8.0
Se	1.1	0.0	0.0	0.0
Si	26	2024	107	64
Sr	20	73	112	282
Ti	13	80	29	115
Zn	29	191	323	75

Table 2. Yield response of cotton to broadcast-incorporated and vertical-mulch applications of organic and inorganic wastes on Gigger-Gilbert silt loam at Winnsboro LA.

Soil amendment	Lint Yield				
	1996	1997	1998	1999	Average
	------- lb/A -------				
			Broadcast Application		
Papermill sludge (PS)	178	807	397	479	465
Composted sewage sludge (CSS)	630	882	480	639	658
Municipal biosolids (MB)	736	936	588	686	737
Boiler ash (BA)	631	850	401	570	613
PS + BA 7:3	200	876	405	556	509
CSS + BA 7:3	692	970	470	652	696
MB +BA 3:2	821	991	555	724	773
PS + MB 3:1	716	855	429	614	654
PS + MB + BA 8:5:7	728	970	456	652	702
Control 1 †	605	603	378	436	510
			Vertical Mulch Application		
PS	330	648	470	534	496
CSS	650	870	541	560	655
MB	617	1137	664	689	777
BA	612	1025	470	621	682
PS + BA 7:3	364	818	508	653	586
CSS + BA 7:3	618	935	568	636	690
MB +BA 3:2	686	1164	703	783	834
PS + MB 3:1	575	1044	574	673	716
PS + MB + BA 8:5:7	662	1170	694	701	807
Control 2 ‡	519	755	378	452	526

†Standard management practice, 80 lb N/A. ‡Trenched and refilled, no amendment, 80 lb N/A.

Table 3. Plant height response ofcotton to broadcast-incorporated and vertical-mulch applications of organic and inorganic wastes on Gigger-Gilbert silt loam at Winnsboro, LA.

Soil amendment	Plant Height				
	1996	1997	1998	1999	Average
	---------- inches ----------				
			Broadcast Application		
Paper mill sludge (PS)	33.5	33.8	28.2	41.0	34.1
Composted sewage sludge (CSS)	37.0	33.1	30.0	40.9	35.2
Municipal biosolids (MB)	40.6	42.1	32.2	47.8	40.7
Boiler ash (BA)	40.9	32.3	25.5	38.4	34.3
PS +BA 7:3	29.5	33.9	26.1	38.0	31.9
CSS +BA 7:3	38.9	33.9	26.7	41.5	35.2
MB +BA 3:2	40.6	40.6	30.4	44.6	39.0
PS+MB 3:l	40.9	37.0	25.8	40.5	36.0
PS +MB +BA 8:5:7	41.3	39.0	27.1	41.0	37.1
Control 1†	37.4	27.6	24.4	42.3	32.9
			Vertical Mulch Application		
PS	28.7	27.6	25.6	41.7	30.9
CSS	38.9	31.5	26.3	40.7	34.3
MB	43.7	39.4	28.7	44.2	39.0
BA	35.0	32.3	24.6	37.7	32.4
PS+ BA 7:3	29.5	28.7	25.2	41.7	31.3
CSS + BA 7:3	38.2	30.7	25.8	41.5	34.0
MB +BA 3:2	38.6	41.3	29.3	45.6	38.7
PS + MB 3:l	34.6	37.0	26.8	43.2	35.4
PS + MB + BA 8:5:7	39.4	39.4	29.7	41.0	37.4
Control 2‡	38.9	30.3	24.9	42.1	34.0
LSD (0.05)		(within year) 3.7	3	(across year) 2.6	2

†Standard management practice, 80 Ib N/A. ‡Trenched and refilled, no amendment, 80 Ib N/A.