Beneficial Use of Municipal, Industrial and Agricultural Wastes in Cotton Production

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ABSTRACT

Most row-cropped soils of the southern USA are low in organic matter and must be limed frequently to maintain an acceptable pH. Industry, municipalities and agriculture produce organic and other waste materials that can be used as soil amendments to increase both soil organic matter and pH. Field experiments were conducted on Gigger-Gilbert silt loam complex (fine-silty, mixed, thermic, typic fragiudalf-glossaqualf) to assess the effects of municipal biosolids, composted sewage sludge, paper mill sludge and paper mill boiler ash.

Introduction

Loess soils of the southern USA, including 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 slow and expensive, requiring many years to increase soil organic matter. A faster and more economic means of improving soil productivity may be to utilize available organic materials from selected waste streams as soil amendments.

Each year in the USA, a total of 8 million tonnes of organic wastes are generated (Millner *et al.*, 1998). Of these, about 5 million tonnes are paper mill sludge (Glenn, 1997) and 545,000 tonnes are biologically treated municipal biosolids (Millner *et al.*, 1998). In addition, paper mills produce large quantities of boiler ash. The cotton ginning industry produces approximately 800,000 tonnes 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 otherwise 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 100 km of the production facility.

Recently, the yield of dryland cotton grown on loess soils of the southern USA has 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. If application of these materials proves beneficial, it will benefit not only cotton farmers but will also offer an economic, environmentally acceptable means of waste disposal.

Material and Methods

Field experiments were conducted in 1996 and 1997 on Gigger-Gilbert silt loam (fine-silty, mixed, thermic, typic fragiudalf-glossaqualf) at the Louisiana State University Agricultural Centre, Macon Ridge Research Station located near Winnsboro, Louisiana. The materials selected for evaluation were municipal biosolids, composted sewage sludge, papermill sludge (primary, dewatered), paper mill boiler ash and selected combinations of these materials. The composition of each waste material is presented in Table 1. A complete list of treatments is shown in Table 2.

The waste products were applied in two methods of application: i) broadcast on the soil surface and incorporated to a depth of 15 cm; and ii) vertical mulch under the row in a 15 cm wide x 60 cm deep trench. All the treatments were applied in 1996 one week before planting. After application of the amendments, plots were prepared for planting by bedding with disk hippers (1-m wide beds) and smoothing with a reel and harrow row conditioner. There were two control treatments - plots that were bedded and prepared without amendments and 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 May 1997 without re-applying amendments. Deltapine NuCotton 33B was planted in 1996 and Stoneville LA887 in 1997. 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 both 1996 and 1997. Fertilizer N was applied as surface-broadcast ammonium nitrate. Control treatments received the standard inorganic fertilization of 90 kg/ha N.

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 1-m wide rows 15 m long. Treatments were applied on, and data collected from, the two centre 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 seed cotton yield determination. Seed cotton sub samples were ginned in a laboratory 20-saw gin to determine the lint percentage to calculate lint yield.

Results

In the year of application there were significant effects of the treatments on plant growth and yield. Broadcast application of municipal biosolids increased plant height 16 % and lint yield 22% compared with the control (Table 2). As a vertical mulch, the effects of municipal biosolids were significant but less pronounced -- increases of only 10%. Composted sewage sludge was a less effective soil amendment than municipal biosolids. It increased yield when applied as a vertical mulch but not when applied broadcast. Application of papermill sludge decreased plant growth and yield. Cotton plants in these treatments were N deficient throughout the growing season even with fertilizer N application. Combinations of the amendments were no better than applications of a single material except for the combination of municipal biosolids and boiler ash. This combination increased yield an additional 12% over that with municipal biosolids alone, but there was no additional effect on plant growth.

In the year after application, there were significant plant growth and lint yield responses to the soil amendment treatments. With broadcast application, all amendments increased lint yield above the fertilized control (Table 2). With both methods of application, the highest yielding treatments were those containing municipal biosolids, that increased yield 50 to 55% above the control. Composted sewage sludge was not as beneficial to yield as municipal biosolids but did increase lint yield 46% when applied broadcast. In contrast with 1996, when papermill sludge decreased yield as much as 70%, these treatments had positive effects on cotton yield in 1997. Broadcast application of papermill sludge increased yield, and vertical mulch application produced yields similar to the control. Boiler ash applied alone was as effective as any of the organic amendments in increasing lint yield. Unlike 1996, addition of boiler ash to the amendments did not provide any yield benefit above that from organic amendments alone. This was probably due to the fact that most of the amendment treatments contained high amounts of Ca and had the added benefit of increasing the soil pH.

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 municipal biosolids. 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 during the two years. Soil incorporated paper mill sludge treatments, especially, required a reduction in C:N to release the N immobilized in the first year. Applying paper mill sludge as a surface mulch prevented most N immobilization in the year of application (data not shown). The inorganic 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.

In addition to the nutritional benefits of the amendments, the organic components provided increased water holding capacity and infiltration. Vertical mulching also eliminated the shallow hardpan directly under the row, which allowed additional water storage and root development. Root development out of the mulched area into the undisturbed subsoil was still limited, however. The interface between the mulch and subsoil proved to be the area of greatest root development.

Summary

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 the following year. Paper mill sludge with its wide C:N decreased yield in the year of application but the following year, the C:N in the paper mill sludge treatments was narrowed by mineralization and cotton plant growth and yield increased. Applying paper mill sludge as a surface mulch with soil-injected fertilizer N reduced the immobilization of N and resulted in yield increases in the year of application. The use of these organic soil amendments appears to be a faster and more economic means of improving soil productivity and cotton yield than growing winter green-manure crops.

References

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

Element mg/kg	Paper Mill Sludge	Composted Sewage Sludge	Sewage Sludge	Paper Mill Boiler Ash
C	420,000	196,000	257,000	183,000
N	1,300	7,700	45,000	1,800
Al	912	8,230	13,680	6,471
As	0.0	3.0	2.9	2.6
B	8.4	49	73	37
Ba	49	257	295	308
Ca	3,200	12,170	13,993	39,527
Cd	0.6	5.1	6.9	1.9
Cr	2.8	25	38	7.7
Cu	14.8	110	317	28
Fe	844	11,884	15,918	2,681
Hg	0.0	0.4	0.4	0.0
K	276	1,758	3,225	4,693
Mg	417	2,551	4,917	2,062
Mn	91	316	619	977
Na	2,371	220	1,883	4,227
Ni	5.0	13	22	12
P	144	3,213	12,680	546
Pb	1.1	42	40	8.0
Se	1.1	0.0	0.0	0.0
Si	26	2,024	107	64
Sr	20	73	112	282
Ti	13	8.0	29	115
Zn	29	191	323	75

Table 2. Yield and growth response of cotton to soil applications of organic wastes and boiler ash.

Soil amendment	Lint Yield kg/ha		Plant Height (cm)		NAWF, 64 DAP no	
Broadcast Application	1996	1997	1996	1997	1996	1997
Paper mill sludge (PS)	200	904	85	86	6.8	7.1
Composted sewage sludge (CS)	706	988	94	84	6.8	6.5
Municipal biosolids (MB)	824	1048	103	107	6.7	8.1
Boiler ash (BA)	707	952	104	82	7.0	7.2
PS + BA 7:3	223	981	75	86	6.7	7.1
CS + BA 7:3	775	1086	99	86	6.9	6.6
MB + BA 3:2	920	1110	103	103	7.2	6.9
PS + MB 3:1	802	958	104	94	7.0	7.6
PS + MB + BA 8:5:7	815	1087	105	99	7.0	7.5
Control 1 *	678	675	95	70	6.9	7.2
Vertical Mulch	1996	1997	1996	1997	1996	1997
PS	370	726	73	70	6.5	5.9
CS	728	974	99	80	7.2	7.6
MB	691	1273	111	100	7.2	8.8
BA	686	1146	89	82	6.8	7.2
PS + BA 7:3	408	916	75	73	6.1	6.7
CS + BA 7:3	692	1047	97	78	6.9	7.2
MB +BA 3:2	768	1304	98	105	7.2	8.4
PS + MB 3:1	644	1169	88	94	6.6	8.4
PS + MB + BA 8:5:7	741	1310	100	100	6.9	8.8
Control 2 **	581	846	99	77	6.6	7.1
LSD (0.05) =	115	211	10	9	0.8	1.0

* Standard management practice, 90 kg N/ha. ** Trenched and refilled, no amendment, 90 kg N/ha.