Sewage Sludge Effects on Soil Properties, Nitrogen Availability, and Yield at Marana, 1989.

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INTRODUCTION

Sewage sludge disposal is a problem for most metropolitan areas. Methods of sewage sludge disposal include dumping into oceans, rivers, or landfills or application onto agricultural lands. Application of sewage sludge onto agricultural land is a preferred method of disposal. Sewage sludge is valued in crop production as a source of plant nutrients, particularly nitrogen and phosphorus, and as a source of organic material. Liquid sludge from Tucson is currently being applied on agricultural land near Marana.

Previous work has demonstrated the value of Tucson sewage sludge as a source of plant nutrients for small grains and cotton (Unger and Fuller, 1985; Watson et al., 1985; Day et al., 1988; Ottman et al., 1989). However, the influence of Tucson sewage sludge on soil properties, nitrogen availability, and yield has not been reported in detail. The present study comprises the fourth year in a 5-year study designed to determine the long-term effects of Tucson sewage sludge in crop production.

MATERIALS AND METHODS

The study was conducted on a Pima clay loam soil at the Marana Agricultural Center during the 1989 growing season. The following treatments were applied before planting: (1) control - no sludge or inorganic fertilizer applied; (2) 1X sewage sludge - 1.86 tons/A sludge on a dry matter basis applied with one pass of the sludge injector on 7 Feb. 1989; (3) 1X inorganic fertilizer - 253 lbs N/A and 177 lbs P_2O_5/A as urea (46-0-0) and ammonium phosphate (16-20-0) broadcast and incorporated preplant on 30 March 1989, which is an amount approximately equivalent to the nutrient content of the sludge; and (4) 3X sewage sludge - 5.80 tons/A sludge on a dry matter basis applied in three passes of the sewage sludge injector on 7 Feb. 1989, 28 Feb. 1989, and 14 March 1989.

Anaerobically digested sewage sludge was obtained from the Pima County Treatment Plant at Ina Road and injected into the soil at a depth of 8 to 12 inches. The sludge is characterized as follows: approximately 2.4% dry matter, 17 to 34% organic carbon, nearly 6% available N (half as ammoniacal-N and half as readily mineralizable organic-N), and 27% phosphorus. Approximately 0.7 acre-inches of water per acre is applied with each pass of the sewage sludge injector in addition to nearly 2 tons dry matter.

The 1989 growing season was the fourth year of a 5-year study. Similar soil treatments were applied the previous 3 years on identical plots except for the control, which previously received inorganic fertilizer in amounts similar to treatment 3. In 1988, cotton was grown on the plots. The field was ripped after the treatments were applied in the winter of 1989.

Pima cotton cultivar S-6 and upland cotton cultivar DPL-41 were planted on 26 April 1989 in two separate experiments. The experimental design was a randomized complete block with four treatments replicated four times over two experiments. The plots were 20 feet wide and 565 feet long. Herbicides, insecticides, irrigations, and defoliants were applied as required to maintain optimum yields.

Soil was sampled in January for pre-treatment nitrate content in the first and second foot of soil. A 2-inch thick section of soil from the top of the bed was sampled for seedbed analysis on 1 May. The soil samples were airdried. Seedbed particle size distribution was determined by dry-sieving the soil through a series of screens with the following hole diameters: 1.0, 1.4, 2.0, 2.8, 4.0, 5.66, 8.0, 11.2, and 16.0 mm. A sub-sample of the seedbed soil was also analyzed for electrical conductivity (salt content). Initial plant stand was estimated on 15 June by counting ten 10-foot lengths of row. Water intake rate was determined on 22 June by measuring the decrease in height of water in furrows after 11 hours of irrigation and after the siphon tubes were removed. Cotton petioles were sampled on a weekly basis from 14 June to 19 September and analyzed for nitrate content. Upland cotton was harvested on 8 Nov. and picked a second time on 30 Nov. The Pima cotton was picked only once on 15 Nov. Two rows were picked by machine the length of each plot, the seed cotton was dumped into wagons, and the wagons were weighed on truck scales. Lint yield was determined using the gin turnout from the entire field since no difference in turnout was detected among treatments. At harvest, plant height and final plant stand were also determined.

RESULTS AND DISCUSSION

Reduced stands have been observed in previous years of this study in the 3X sludge treatment. This year, we measured seedbed particle size distribution and electrical conductivity to determine if these properties are related to stand establishment. Initial stand was reduced in the 1X fertilizer and 3X sludge treatments compared to the control and 1X sludge treatment (Table 1). Final stand at harvest was least for the 3X sludge treatments. No differences in seedbed particle size distribution were detected among treatments (Table 2, only 2 of 9 classes presented). This is in contrast to previous observations of increased clodiness in the 3X treatment after ripping. Apparently, any difference in clod size among treatments is eliminated by the various tillage implements after final seedbed preparation. Differences in the electroconductivity of the seedbed were detected, however. Electroconductivity was greatest for the 1X fertilizer treatment followed by the 3X sludge treatment. Although a relationship seems to exist between the electroconductivity of the seedbed and the reduced stand in the 1X fertilizer and 3X sludge treatments, the values of electroconductivity are 6 to 10 times lower than that which reduced germination would be expected. Presently, we cannot offer any explanation for differences in plant stand as affected by the treatments.

In the first year or two of this study, increased ponding of irrigation water was observed in plots treated with sludge, particularly the 3X sludge treatment. This was attributed to compaction from the sludge application. Consequently, the fields were routinely ripped after sludge application. In the present study, no differences in water intake rate were detected (Table 2). Apparently, ripping the field may have eliminated any negative effect of sludge application on water infiltration. Addition of organic material to the soil can improve water infiltration characteristics. However, in the case of this study, water intake rate was not increased possibly due to the relatively low amount of dry matter applied compared to typical manure applications or due to characteristics of the site.

A major benefit of sewage sludge in crop production is the nitrogen it supplies. Since the treatments have been applied to the plots continuously for 4 years, long-term effects on residual soil nitrate have accumulated, particularly in the case of the 3X sludge treatment (Table 2). The amount of nitrate-N in the top 2 feet of soil before the treatments were applied to this study is roughly equivalent to 135, 123, 121, and 356 lbs N/A for the control, 1X sludge, 1X fertilizer, and 3X sludge treatments, respectively. This amount of nitrogen in the soil could supply most of the needs of the crop if it were available during the growing season. The analysis of nitrates in the petioles (see Figs. 1 and 2) show that the control treatment bordered on nitrogen deficiency at the beginging of flowering (week 4) and at the first open boll stage (week 11) and the 3X treatment may have supplied excessive nitrogen to the crop near peak bloom (week 7). The major difference detected in petiole nitrate was between the control and the 3X sludge treatment from flowering (week 4) thru the end of the season. Plant height and lint yield of upland cotton were not influenced by the treatments (Table 1). However, lint yields of Pima cotton were decreased compared to the control for all treatments. Excessive nitrogen apparently contributed to decreased yield based upon our observations of increased plant height and the vegetative appearance of the plots.

Sewage sludge can be used successfully in crop production. However, for sludge to be used most effectively, the producer must consider sources of nitrogen such as the soil and irrigation water, potential for losses of nitrogen from the production system, and the nitrogen requirement of the crop.

REFERENCES

Day, A. D., M. J. Ottman, B. B. Taylor, I. L. Pepper, and R. S. Swingle. 1988. Liquid sewage sludge as fertilizer for wheat. Bio Cycle. 29(10):60-61.

Unger, M., and W. H. Fuller. 1985. Optimum utilization of sewage sludge of low and high metal content for grain production on arid lands. Plant Soil. 88:321-332.

Watson, J. E., I. L. Pepper, M. Unger, and W. H. Fuller. 1985. Yields and leaf elemental composition of cotton grown on sludge-amended soil. J. Environ. Qual. 14:174-177.

Ottman, M. J., A. D. Day, I. L. Pepper, and B. B. Taylor. 1989. The influence of sewage sludge on nitrogen availability, crop growth, and yield at Marana, 1988. p. 14-18 Cotton. Coop. Ext. Ag. Exp. Stn. Report Series P-77. Tucson, AZ.

Table 1. Plant growth and yield as affected by sewage sludge and inorganic fertilizer treatments.

Treatment	Plant Stand Initial	Plant Stand Final	Plant Height	Lint Yield
	-----plants/ft-----		inches	lbs/A
		Pima		
Control	2.96	2.80	45	1097
1X sludge	2.97	3.04	54	796
1X fertilizer	2.58	2.95	55	867
3X sludge	2.37	2.42	64	766
FLSD (10%)	.282	.243	5.8	229.6
		Upland		
Control	4.65	3.99	44	1646
1X sludge	4.75	3.19	49	1697
1X fertilizer	4.11	3.36	46	1544
3X sludge	3.93	2.99	49	1572
FLSD (10%)	.352	.144	NS	NS

Table 2. Soil properties as affected sewage sludge and inorganic fertilizer treatments.

Treatment	Pre-treatment Soil Nitrate 0-1 ft	Pre-treatment Soil Nitrate 1-2 ft	Seedbed <1.0 mm	Seedbed >16.0 mm	Seedbed EC	Water Intake Rate
	---------ppm-----------		%	%	1mho/cm	inches/hr
Control	19.4	14.3	23.0	25.1	668	1.47
1X sludge	16.1	14.6	23.8	24.3	742	1.52
1X fertilizer	14.4	15.8	24.5	23.6	1694	1.58
3X sludge	47.6	41.3	22.8	22.1	915	1.54
FLSD (10%)	9.33	7.59	NS	NS	161.3	NS

Fig. 1. Nitrate content in petioles of Pima cotton as affected by sludge and fertilizer treatments.

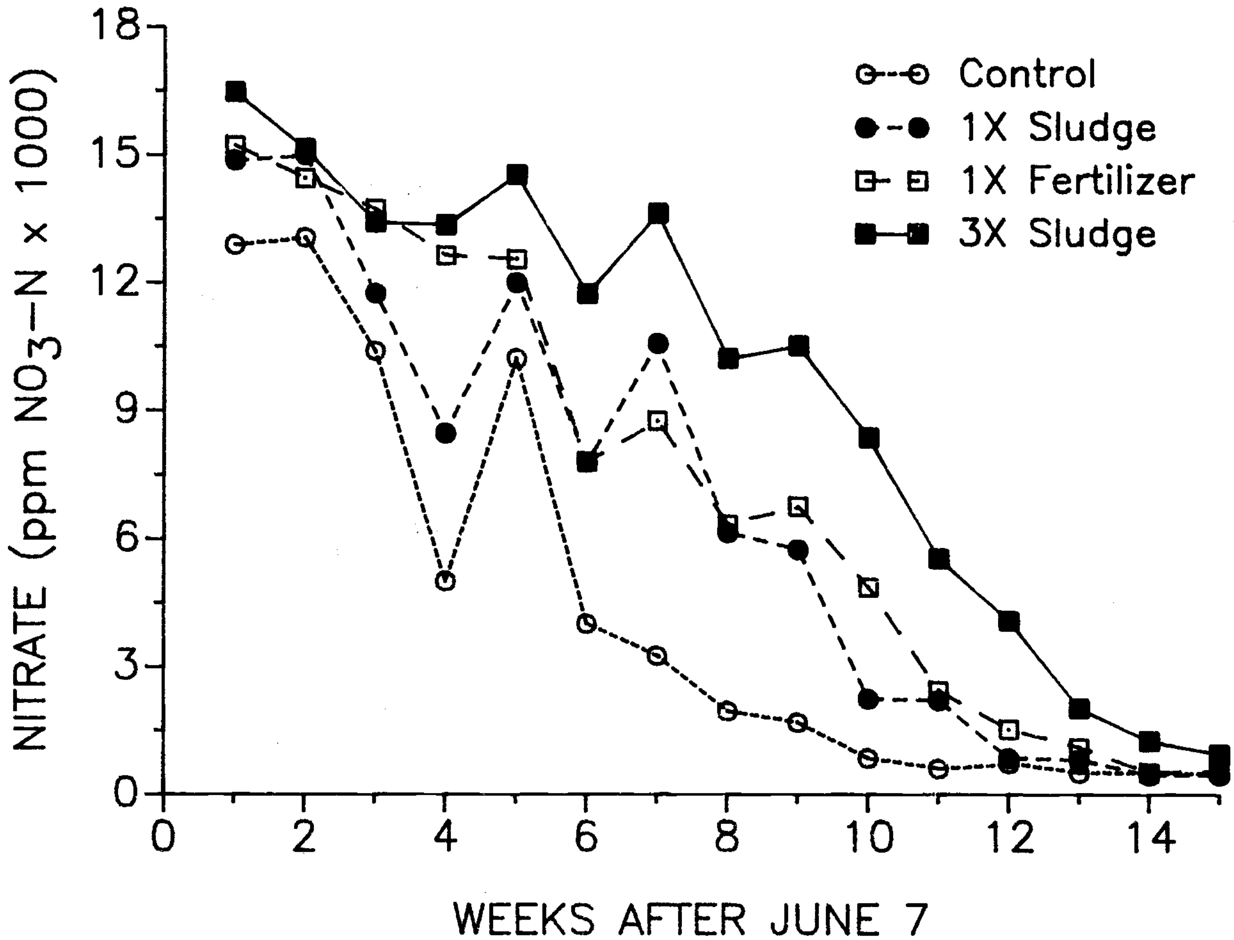

Fig. 2. Nitrate content in petioles of Upland cotton as affected by sludge and fertilizer treatments.