DENIM SLUDGE AS A SOIL AMENDMENT: EFFECTS ON COTTON GROWTH PARAMETERS

D.O. Porter and R.P. Porter
New Mexico State University
Las Cruces, NM

Abstract

Cotton garment finishing operations, which involve garment washing and drying, generate appreciable quantities of cellulosic wash solids. As a part of ongoing research to investigate waste disposal options for a major garment manufacturer, bench scale tests were conducted to determine if land application is a feasible option for wash solids utilization. Observations indicated that soil moisture retention, soil aggregation, and permeability were improved by the addition of wash solids. Plant emergence, growth, and fruiting were improved by low and moderate applications of wash solids, but were not improved by heavy application of wash solids.

Introduction

Denim garment finishing processes may require washing to condition the garments to a desired "weathered" finish. Through the washing process, some fibers and dyes are released from the garments to become a highly cellulosic sludge by-product, generally referred to as "wash solids".

Wash solids currently are disposed of in sanitary landfills. Utilization alternatives for the wash solids will reduce the volume of material placed into landfills. Further, wash solids can be "recycled" into a useful, and potentially marketable product.

Through natural biological stabilization, organic material is broken down, and nutrients are transformed into more plant-available forms. The natural biological treatment of the material can be enhanced through composting or through well-managed direct land application. Either method can transform wash solids into a soil amendment which may improve soil productivity.

An important aspect of alternative utilization of this or any by-product is demonstrating its safety and value to potential users. Bench scale tests were conducted to determine effects of the applied wash solids on soil conditions and on crop performance.

This bench scale study of direct land application of wash solids is part of a larger project to investigate several treatment and disposal alternatives, including direct land application and aerobic composting. Additional information about the project was reported in Porter and Porter (1995) and Wheeler and Porter (1995).

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1358-1361 (1996)
National Cotton Council, Memphis TN

Materials and Methods

Wash Solids

Wash solids were obtained from a denim garment manufacturer in El Paso, Texas. "Wash solids" refers to the mixture of solid materials removed from wash water through Dissolved Air Floatation and through screening (hydrosieving). Composition of the material is variable, due to periodic adjustments in product finishing operations. However, the material generally contains 10-30% solids and 70-90% water. The solids are made up primarily of cotton fibers and diatomaceous earth, and may also include dyes and detergent residues.

Soil Mixture

A soil mixture (in this document referred to as "soil") to provide a reasonably good growing medium, with respect to balancing water holding capacity and drainage, was developed. This soil was used as an experimental control. The mixture contained approximately equal parts of 1) Glendale clay loam, with a moderately slow permeability and low organic matter; 2) vermiculite; and 3) washed sand. The resulting mixture had a sandy texture with very low organic matter, relatively low water holding capacity, and a moderately high permeability.

Application of Wash Solids

Wash solids were applied to the soil (described above) according to the following procedure: Drain holes were drilled into 19-liter (5-gallon) plastic buckets. Gravel was placed in the bottom of the buckets to facilitate drainage. The buckets were filled with the soil-sand-vermiculite control soil mixture to approximately 15 cm (6 in) below the bucket rim. Soil and wash solids were combined in prescribed volumetric ratios through use of a cement mixer. The soil/wash solid mixture was applied to the buckets to a depth of approximately 10 cm (4 in) above the untreated soil. Buckets were placed in a lath house in a randomized complete block arrangement, and irrigation was applied to prepare the buckets for planting. Four treatments and four replications were used in this experiment.

Three treatment levels and an untreated control were selected according to the following ratios:

1. "0% Wash Solids": The control buckets received no wash solids. Additional soil was added to these buckets to match total depth of soil and wash solids in the treated buckets.

2. "16.7% Wash Solids": A light application of wash solids was achieved by mixing one part wash solids to five parts soil. This application rate represents a field application of 2.5 cm (1 in) washsolids in a 15 cm (6 in) tillage layer.

3. "33.3% Wash Solids": A moderate application of wash solids was achieved by mixing one part wash solids to two parts soil. This application rate represents a field application of 5 cm (2 in) wash solids in a 15 cm (6 in) tillage layer.

4. "66.7% Wash Solids": A heavy application of wash solids was achieved by mixing two parts wash solids to one part soil. This application rate represents a field application of 10 cm (4 in) wash solids in a 15 cm (6 in) tillage layer.

Plant Production, Management, and Observations

All buckets were seeded with Acala cotton (*Gossypium hirsutum*) two days after wash solids application. Because the wet soil/wash solids mixture had formed a soft, but continuous "block" on the surface of the soil, the surface was broken up before planting. In order to achieve a good "stand" of plants in all treatments, 10 seeds were planted in each bucket. As the plants grew larger, they were thinned for continued development. All buckets were irrigated as needed and fertilized with a dilute nutrient solution weekly.

Daily emergence counts were made through the first 28 days after planting. Plant height and morphological development were recorded weekly. Qualitative observations, including plant development and appearance, evidence of plant stress, and soil feel and appearance, were made daily during the early season, and 2-3 times per week throughout the season.

Soil Properties

Samples of the soil mixture, wash solids, and all treatment mixtures were collected at the time of mixing and placement into the buckets. Standard soil tests were conducted on the samples at the New Mexico State University Soil, Water, and Air Testing Laboratory. Physical properties for the soil and soil/wash solid mixtures were determined from samples extracted from the buckets one month after initial application. Bulk density, field soil moisture, and saturated hydraulic conductivity were determined for each treatment.

Results and Discussion

Analyses of Soil and Wash Solids

A partial listing of results from laboratory analyses conducted on the soil and wash solids is summarized in Table 1. The chemical analyses of the control soil indicated that the soil was slightly alkaline (pH = 7.77), and moderately saline (EC = 5.76 mmhos/cm). The soil organic matter was low (O.M. = 0.67%). Chemical analyses of the soil indicated a characteristic Southern New Mexico desert soil.

Wash solids composition is variable by lot, but the material used in this study contained approximately 10% solids (primarily cellulose and diatomaceous earth) and 90% water. This material was relatively high in phosphorus (1607 ppm), but low in available nitrogen (8.4 ppm NO_3-N). Total Kjeldahl Nitrogen was much higher (1400 ppm), much of which was bound in the organic material. Depending upon the quality of water used in wash operations, wash solids can contain elevated salt levels (4.27 mmhos/cm), which can damage sensitive crops (Brown, et al., 1983). The material was alkaline (pH = 12.36), due to additions of lime for improved dewatering of solids from the garment washing wastewater.

Plant Production Indicators

Germination rates of the crops under each treatment were determined from daily seedling emergence counts. Data from selected dates are summarized in Table 2. Analysis of Variance and Least Significant Difference tests indicated that there were differences (alpha = 0.05) between treatments on some sampling dates. The data indicate that the high level of wash solids application may delay seedling emergence. Total germination rates were shown to be increased at all levels of wash solids application.

Early plant growth was determined from weekly plant height measurements. Some of these data are summarized in Table 3. Analysis of Variance and Least Significant Difference tests indicated that there were differences (alpha = 0.05) between treatments on some sampling dates. The data indicate that application of the wash solids results in shorter plants on a given date early in the season. The high application rate was found to inhibit early plant growth significantly. The smaller size of the plants could be due, in part, to the delayed emergence of plants under high wash solids application rates. It is likely also that the high organic matter content in the wash solids bound nutrients, resulting in more severely nutrient-limiting conditions. Visual observations did not indicate higher nutrient stress, however.

Time to first flower data are summarized in Table 4. Analysis of Variance and Least Significant Difference tests indicated that there were differences (alpha = 0.05) between treatments with respect to flowering. Plants in buckets treated with a low application (16.7% wash solids) flowered earlier than those in higher application rate or zero application rate treatments.

Effects upon Soil Properties

Observations of general soil/wash solid media conditions within the pots were made daily during the first 28 days after planting and periodically throughout the remainder of the season. Visual and touch observations indicated that the media containing wash solids had a notable aggregation, while the untreated soil had essentially no aggregation. The low and moderate treatments (16.7% and 33.3% wash solids, respectively) had a fairly consistent distribution of stable granular aggregates less than 3 mm (0.1 in). The high treatment (66.7% wash solids) had many relatively large stable aggregates up to approximately

12 mm (0.5 in) in diameter. Irrigation applications indicated that the treated media had very high permeabilities. Daily observations also indicated that the treated media, especially those receiving heavy wash solids application, retained more water than the untreated soil.

Samples of soil/wash solids media extracted from the buckets one month after treatment were analyzed in the laboratory for physical characterization. Results of the analyses are summarized in Table 5. Mean hydraulic conductivity values increased substantially with application of the wash solids. The hydraulic conductivity of the heavily treated soil (66.7% wash solids) was especially high, due to large inter-aggregate macropores. Soil moisture determined from core samples indicated that the applied wash solids increased the water holding capacity of the soil media. Bulk density values did not indicate an effect of the wash solids at low application rates, but the heavily treated soil had a substantially reduced bulk density. In general, data were consistent with the daily observations.

Conclusions and Recommendations

Plant emergence, soil moisture retention, soil aggregation, and permeability were improved by the addition of wash solids. Plant growth seemed to be inhibited by heavy application of the wash solids.

Brown, et al., (1983), and Sposito (1989) allow us to speculate on the possible effects of wash solids upon the soil chemistry and soil fertility aspects of the study. According to Brown, microbial breakdown of organic matter may initially immobilize nitrogen. However, as organic matter decays over time, nitrogen can be mineralized. Organic compounds resistant to degradation may immobilize phosphorus, especially at high carbon:phosphorus ratios. Further, high pH conditions often contribute to a low availability of some micronutrients. Therefore, the plant growth inhibition observed in the tests, especially at the high application rate of 66.7% wash solids, may be due to nutrient limitations. It is expected that the plant growth environment will be improved as organic matter in the wash solids decomposes.

From observations in this bench scale study, direct land application of wash solids at low to moderate rates seems to be safe and beneficial for soils with low organic matter. Application rates of of 1-2 inches are recommended, but excessive application (over 2 inches) should be avoided. Since nutrients may be immobilized to some extent by the biological stabilization process, soil fertility should be closely monitored.

Future Work

This bench-scale experiment is part of an ongoing project to investigate treatment and disposal alternatives for wash solids produced in garment finishing operations. Other work in progress includes direct land application of wash solids to improve vegetation rates in surface mine reclamation and composting of the wash solids with dairy manure and other locally available agricultural by-products.

Acknowledgments

This project was supported by Muniz Aerospace, Inc., Eagle Environmental Division, and by Levi-Strauss & Co. Research facilities were provided by Mr. Brad Lewis, Department of Entomology, Plant Pathology, and Weed Science at New Mexico State University. Regina Wheeler, graduate research assistant, managed a related experiment to compost wash solids. Dr. Sammy Gabriel assisted with interpretation of chemical analyses in light of his expertise in garment manufacturing processes.

References

1. Brown, Kirk W., Gordon B. Evans, Jr., and Beth D. Frentrup. 1983.
HAZARDOUS WASTE LAND TREATMENT. Butterworth Publishers. Boston. 692 pp.

2. Porter, D.O., and R.P. Porter. 1995. Bench-Scale Investigation of Direct Application of Garment Finishing Wash Cycle Solids. ASAE Paper No. 952410. Presented at: 1995 Annual International Meeting of the American Society of Agricultural Engineers. Chicago, Illinois, June 18-23, 1995.

3. Sposito, Garrison. 1989. *THE CHEMISTRY OF SOILS*. Oxford University Press. New York. 277 pp.

4. Wheeler, R.A., and D.O. Porter. 1995. Physical and Chemical Properties of Cotton Wash Cycle Solids Compost. ASAE Paper No. 956111. Presented at: 1995 Annual International Meeting of the American Society of Agricultural Engineers. Chicago, Illinois, June 18-23, 1995.

Table 1. Chemical characteristics of soil and wash solids.

Parameter	Units	Soil	Wash Solids
pH		7.77	12.36
EC	mmhos/cm 5.76		4.27
Sodium	meq/L	24.52	18.75
SAR		4.82	5.51
Organic Matter	%	0.67	17.87
NO_3-N	ppm	56.7	8.4
TKN	mg/Kg	400	1400
Phosphorus	ppm	13.4	1606.9
Potassium ppm		96	10

Table 2. Germination of cotton by treatment (% wash solids) and number of days after planting.

7 Days		9 Days	
Treatment	**% Germination**	**Treatment**	**% Germination**
0.0	45.0 ab*	0.0	70.0 a
16.7	62.5 a	16.7	85.0 a
33.3	35.0 b	33.3	77.5 a
66.7	5.0 c	66.7	40.0 b

11 Days		16 Days	
Treatment	**% Germination**	**Treatment**	**% Germination**
0.0	70.0 a	0.0	72.5 b
16.7	87.5 a	16.7	92.5 a
33.3	87.5 a	33.3	92.5 a
66.7	77.5 a	66.7	95.0 a

* Column means within the same date not followed by the same letter were found to be significantly different at the 0.05 level of probability as determined by LSD procedures.

Table 3. Growth of cotton by treatment (% wash solids) and number of days after planting.

11 Days		21 Days	
Treatment	**Plant Ht. (cm)**	**Treatment**	**Plant Ht. (cm)**
0.0	2.6 a*	0.0	4.4 a
16.7	2.3 a	16.7	4.0 ab
33.3	2.2 b	33.3	3.6 b
66.7	1.3 b	66.7	2.4 c

28 Days		67 Days	
Treatment	**Plant Ht. (cm)**	**Treatment**	**Plant Ht. (cm)**
0.0	4.6 ab	0.0	13.1 b
16.7	5.2 a	16.7	16.4 a
33.3	4.3 b	33.3	14.2 b
66.7	2.9 c	66.7	9.9 c

* Column means within the same date not followed by the same letter were found to be significantly different at the 0.05 level of probability as determined by LSD procedures.

Table 4. Average number of days to first flower.

Wash Solid Content, (%)	Days to First Flower
0.0	107.8 b
16.7	96.0 a
33.3	101.2 ab
66.7	107.9 b

* Column means within the same date not followed by the same letter were found to be significantly different at the 0.05 level of probability as determined by LSD procedures.

Table 5. Physical characteristics of soil/wash solid media (mean values).

Wash Solid Content, (%)	Mean K (cm/day)	Soil Moisture (%)	Bulk Density (g/cm^3)
0.0	193	17.5	1.05
16.7	490	43.7	0.91
33.3	573	44.4	1.10
66.7	1317	72.6	0.69