Short-term effects of organic amendments on structural stability and fertility of a NSW grey-cracking clay

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Introduction

Soil quality is the capacity of a soil to produce and maintain its sustainability. The soil quality concept integrates soil biological, chemical and physical attributes to assess a soil's capacity to function (Karlen et al. 1997). While there are many indicators of soil quality, soil organic matter is considered to be of central importance. It plays an important role in influencing soil's different physical, chemical and biological properties. These properties, along with soil organic carbon, N and P, are considered critical indicators for the health and quality of soil. One management technique whereby soil organic matter content can be increased is the addition of organic waste materials (Reynolds 1930). Many landholders have been investigating options of using recycled organic material to improve soil properties and with a view to partially or fully replace inorganic fertilizers. Information on the effects of organic waste products on quality of heavy clay soils, such as the cracking clays used for irrigated cotton production systems in Australia is, however, sparse.

The possibility of significant benefits to cotton from organic wastes applied as soil amendments has been recognized for more than 65 years (Reynolds 1930). Soils amended with feedlot manure do not contain toxic elements (e.g. heavy metals) and generally have higher biological activity than those managed with mineral fertilizers (Fauci and Dick 1988; Marshall 1977; Dick 1992). Vermicompost, which is produced from the worm-composting of organic residues from animal and plants reputed to produce superior growth responses in plants. Edwards and Neuhauser (1988) reported increased plant growth in potting-media enhanced with vermicompost derived from animal manures. Substantial quantities of cotton processing waste, which had been used as a cattle-food supplement are presently dumped and left to degrade in stockpiles around the gins. Cotton-producers have recognized this waste as a potential source of organic matter which could be used to improve soil conditions.

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 which should be located near the production facility. In this study we examine the effects of a wide range of organic amendments on cotton soil and the associated changes due to their application. 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

A pot experiment was conducted at the temperature controlled growth chamber in the Department of Agronomy and Soil Science, UNE, Armidale. The experiment was conducted for 4 weeks in a

controlled temperature room where temperature was maintained at 30^0C. The soil used was a grey cracking clay (self-mulching, Grey Vertosol) from the Australian Cotton Research Institute, near Narrabri, NSW. It was collected from 0-0.1m depth and amended with four organic inputs collected from different local sources and one commercial product (Table 1). The treatments were laid in a randomized block design and replicated thrice. Water was added once a week to maintain the moisture level of the soil near field capacity (gravimetric soil water content of ~42%).

Table 1. Soil amendments and their application rates

Treatment		Rate
T_1	Control	
T_2	Cotton gin trash (Narrabri)	10t/ha (dry weight)
T_3	Biosolids (Armidale)	10t/ha (dry weight)
T_4	Local cattle manure (Narrabri)	10t/ha (dry weight)
T_5	Composted chicken manure (Laureldale, UNE)	3t/ha (dry weight)
T_6	Tryton Bio Starter	Tryton Bio Starter and Bio Balance were applied combined @50L/ha and 30L/ha in 400L/ha of water for soil
	Tryton Bio Balance	

The rates of the organic amendments were fixed according to the typical farmers' practice and we aimed to add about the same amount of N from the amendments. Tryton vermicast was applied at the manufacturers recommended rate (Table 1).

After 4 weeks of incubation, part of the moist soil was used for the analysis of microbial biomass and respiration and rest of the samples were air-dried and crushed to obtain a <2 mm and >2 mm fractions. Chemical properties viz., pH (1:5 soil: water), electrical conductivity ($EC_{1:5}$), free light fractions of organic matter and nutrient concentration (exchangeable cations and resin extractable anions) were measured using <2 mm fraction and the >2 mm fraction was used to determine the mean weight diameter, dispersion index of soil.

Statistical analysis

SAS 8e was used to perform the analysis of variance (ANOVA) as outlined for a randomized complete block design for the pot experiment. Mean comparisons were performed according to Fisher's least significant difference (LSD) test at P 0.05 and compared according to Duncan's multiple range test (DMRT).

Results and Discussion

Analysis of the organic amendments used in this experiment shows that K content of locally available cattle manure collected from Narrabri was higher (Table 2) and it contributes more K to the soil than the other amendments (Table 3). Biosolids from Armidale added highest amount of other nutrients, i.e., C, N, Ca, P and Mn to the soil (Table 3). Differences between treatments in soil pH, EC, K and Na were found to be highly significant ($p<0.001$).

Table 2. Nutrient concentrations of the amendments used

Treatment	C	N	K	Mg	Ca	Na	P	Mn
	%	%	%	%	%	µg/g	%	µg/g
CGT(N)	12.0	1.31	1.37	0.76	3.29	640	0.34	621
BS(A)	21.8	2.18	0.11	0.30	4.69	724	1.35	499
Manure(N)	24.1	2.33	2.26	0.97	3.03	4010	1.05	274
CM(UNE)	20.9	2.92	1.93	0.97	17.6	4378	4.39	506

Table 3. Nutrient added to soil by the amendments on a per hectare basis

Treatment	C	N	K	Mg	Ca	P	Mn
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
CGT(N)	1.26	0.14	144	80	344	36	6.5
BS(A)	6.93	0.70	36	96	1491	429	15.9
Manure(N)	2.58	0.25	241	103	324	112	2.9
CM(UNE)	0.75	0.11	69	35	633	158	1.8

**CGT(N) = Cotton gin trash (Narrabri)
BS(A) = Biosolids (Armidale)
Manure (N) = Local manure (Narrabri)
CM(UNE) = Composted chicken manure (Laureldale Farm, UNE)

Changes in soil properties

Soil pH (1:5 soil: water) ranged between 7.20 and 8.01. All amendments except cotton gin trash significantly increased soil pH (Table 4), but the treatments did not differ significantly among themselves. The electrical conductivity ($EC_{1:5}$) varied from 202 to 419 µS/cm (Table 4) for the samples and application of biosolids caused significantly highest increase in EC value as compared to control pot.

Table 4. Effect of different amendments on some important soil properties

Treatment	pH	EC (µS/cm)	Micro biomass (mg Microbial C/100 g DM soil)	Respiration (mg CO_2/h/100 g DM soil)	Organic matter light fraction (g)
T_1	7.20b	224d	28.4a	0.26bc	0.032b
T_2	7.23b	283c	24.5a	0.35ab	0.089b
T_3	7.59c	419a	30.0a	0.45a	0.079b
T_4	7.89cd	363b	28.9a	0.22bc	0.175a
T_5	7.79cd	312c	29.6a	0.18c	0.060b
T_6	8.01d	202d	23.2a	0.17c	0.061b

Means followed by the same letter within a parameter are not significantly different based on Duncan's multiple range test at p = 0.05

With respect to soil microbiological properties, there was no significant difference in microbial biomass, but biosolids application significantly increased microbial respiration over that for the unamended soil (Table 4). This may be due to the application of these amendments in fresh form which provided more substrate for the microbes. This has also been shown in some field

experiments where fresh feedlot manure applied in the field resulted in improved microbial properties. This result is similar to other studies which have examined effects on soil microbes after addition of organic amendments to cropping soil (Dick 1992; Fauci and Dick 1988; Gupta 1994; Paul and Beauchamp 1996).

The light fraction of organic matter was measured as the fraction of organic matter which floats in sodium iodide solution at a density of 1.6 gcm^{-3}, and is an indicator of the labile or more reactive component of organic matter. It provides a source of plant nutrients in soil due to its chemical composition and rapid turnover rate, and is responsible for temporary soil structural stability until it is further decomposed (Tisdall and Oades 1982). The light fraction (LF) of organic matter was measured using. Soil amended with cattle manure showed highest free light fractions (Table 4) of organic matter.

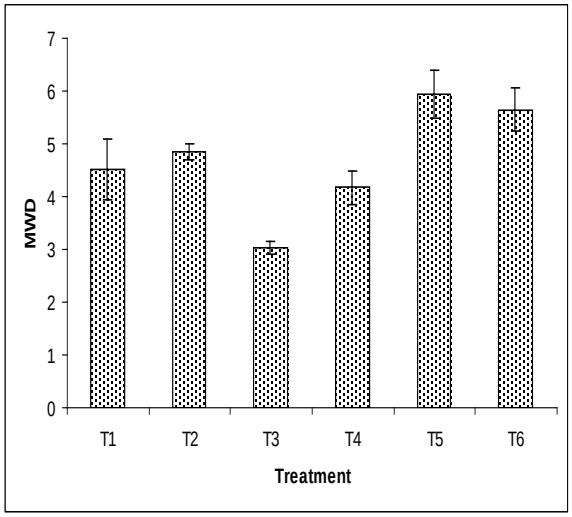

Figure1. Mean weight diameter of the samples by affected different organic inputs

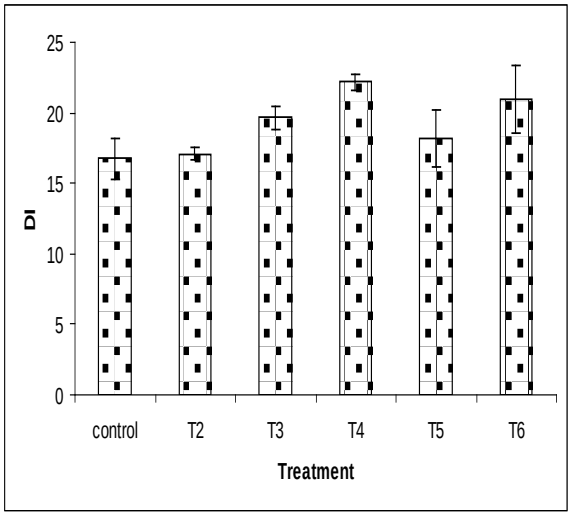

Figure2. Effect of different organic inputs on Dispersion index of the samples

Application of organic amendments resulted in some beneficial and some degrading effects on soil physical properties. Mean weight diameter (MWD), an indicator of aggregate formation and stability, increased significantly in pots amended with composted chicken manure (Fig 1) whereas addition of biosolids significantly decreased the MWD. In case of the dispersion index (DI), a measure of how easily the soil disperses, there was no significant difference among the treatments except cattle manure. Application of manure increased the dispersion index (Fig 2) significantly as compared to control pots. This is consistent with the high Na level found in this amendment (Table 2). Addition of this type of cattle manure at a too high rate could therefore result in a temporary effect on reducing infiltration and an increased run off risk.

Among the nutrients, the exchangeable K content varies from 1.50 to 1.91 cmole(p+)/kg (Table 5). There was significant increase in the K content due to application of Narrabri cattle manure as compared to the control.

Table 5. Effect of application of different amendments on nutrient concentration of the soil

Treatment	Ca	Mg	K	Na	Nitrate	Phosphate
	cmoles(p+)/kg	cmoles(p+)/kg	cmoles(p+)/kg	cmoles(p+)/kg	µg/g	µg/g
T_1	24.71b	11.66b	1.57bc	0.85d	130.26d	63.05b
T_2	25.21ab	11.65b	1.64b	0.91c	153.36c	52.50b
T_3	26.06a	11.67b	1.50c	0.94c	181.77b	105.67a
T_4	24.56b	12.15ab	1.91a	1.17a	130.45d	135.66a
T_5	25.25ab	12.22ab	1.66b	1.01b	228.49a	131.46a
T_6	25.83a	12.41a	1.59bc	1.05b	100.72e	60.31b

Means followed by the same letter within a parameter are not significantly different based on Duncan's multiple range test at p = 0.05

Ongoing research

The reported research is part of a wider study which also includes field experimentation at the Australian Cotton Research Institute, near Narrabri, NSW using three of these organic amendments since 2004. The aim is to correlate this experimental data with broad acre farming. Additionally, we conducted another pot experiment using fewer organic amendments but different rates with the aim to screen out the most suitable amendments for cotton production systems and to evaluate the appropriate rate for the amendments.

Conclusion

Organic amendments had both beneficial and detrimental effects on soil quality in this cotton soil. Application of biosolids has the potential to improve the microbial properties. It also improved one indicator of soil structure. However, the significant increase in exchangeable Na content due to application of the amendments needs more investigation, especially in the case of cattle manure, because this treatment caused an increase in soil dispersion. The potential of organic amendments for meeting crop nutrient demand will require further investigation. The improvement in overall soil quality may reduce the potential for nutrient contamination of ground and surface water and produce more vigorous-growing and high yielding crops. Our continuing study will determine whether long-term fertility, soil quality, and crop productivity can be enhanced with organic fertility sources.

Acknowledgments

We gratefully acknowledge financial support of University of New England and Cotton Research and Development Corporation. We would also like to thank Mrs. Leanne Lisle for her technical support and Dr. Kathy King for her help for measuring the microbiological properties.

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