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Cowdung and Poultry Litter as Soil Amendments and Extracts of Garlic and Pepper as Insecticides on Cotton (*Gossypium hirsutum* L.) Production in the Nigerian Savanna

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Abstract: The long-term sustainability of cotton-based systems is at risk in the Nigerian savanna because of its environmental effects. Presently, policies aimed at addressing the problems of soil fertility decline and insecticide contamination are being advanced. The effects of two organic materials (i.e. cowdung and poultry litter) as soil amendments and, two others (extracts of garlic and west African black pepper) as insecticidal materials on soil physical properties and upland cotton (*Gossypium hirsutum* L.) productivity were compared with the conventional method (mineral fertiliser and synthetic insecticide) in a 2 year field trial on a savanna Alfisols. Seed cotton yield under mineral fertiliser amendment was about 30% higher than were yields from the two organic amendments. However, the cotton lint yield from the three amendments were similar. Seed cotton, cotton seed and lint yields were similar for cotton that received garlic extract and karate (synthetic insecticide). Cotton sprayed with extract of west African black pepper produced significantly higher seed cotton and cotton lint yield than the synthetic insecticide. The treatments had no significant effect on soil physical properties. This result further confirms the usefulness of organic cotton cultivation, a viable alternative to the conventional method of cotton production in the savanna.

Key words: Organic materials, soil amendment, insecticide, cotton, savanna

INTRODUCTION

Soil fertility depletion is one fundamental biophysical constraint to increasing food and fibre crop production in small holder farms of the savanna[1]. Weathered, weakly aggregated Alfisols are often used for the expansion of food and fibre production in the savanna. Although degraded soil structure, compaction and loss of organic matter are the major fertility constraints in these soils, nutrient imbalance usually becomes the most limiting factor to crop productivity, particularly under continuous cultivation. Through a combination of the above factors, the available nutrient content decreases.

Fertilization with mineral fertilisers is one way of replenishing these nutrients. Increasing use of mineral fertilisers on these poorly buffered soils is not sustainable. This is because mineral fertilisers encourage soil acidification and facilitate deterioration of soil physical fertility. Continuous cultivation, which involves soil disturbance and vegetation removal, has been widely observed to cause losses of soil nutrients particularly, soil organic matter which is an indication of widespread soil degradation.

Currently, there is much interest in reducing soil nutrient losses through land use practices that increase plant nutrient availability in soils. These practices include greater cropping frequency, reduced tillage and application of organic amendments[2]. Organic materials are a major source of nutrient inputs to soils in small holder traditional system[3,4].

Cultivation of upland cotton (*Gossypium hirsutum*) is increasing in the savanna region of Nigeria. The crop is grown intensely as a sole crop, an intercrop and in rotation. Under the tropical condition of the savanna, polyphagous insect pests (Aphids, American bollworm and cotton whitefly) usually attack this crop resulting in decreased lint yield. Frequent use of synthetic insecticides lead to a destabilization of the ecosystem and to enhanced insecticide resistance[5]. Organic materials such as garlic (*Alium sativum* L.) and the west African black pepper (*Piper guinensis*) have potentials to help in this situation especially in the Nigerian savanna where

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these materials are abundant. Investigations on the effects of amendment on soil-and crop-productivity have been carried out by some researchers[4,6-8]. Not much attention has yet been placed on integration of organic materials as insecticides and soil amendments in crop production.

Cotton growers are gradually adopting organic cotton as a means of reducing costs of production, eliminating pesticide usage and increasing environmental safety[9]. It is assumed that the elimination of the two major inputs, i.e. synthetic fertilisers and insecticides, in cotton production could bring a drastic reduction in cost. Organic cotton production is new in the west African savanna. Available information on organic cotton is limited to justify any judgment on its potential as a viable alternative to the conventional method of cotton cultivation[10]. The objective of this study was to compare cotton yield and fibre properties under organic and conventional cultivation methods and to determine the best organic material that optimizes cotton lint yield in a savanna ecology.

MATERIALS AND METHODS

A Two year field trial involving organic materials as soil amendments and insecticides for upland cotton production was conducted at the experimental farm of the Institute for Agricultural Research at Samaru (11°11'N; 07°38'E; alt. 686 m) during 2002 and 2003 cropping seasons. Samaru is at the northern fringe of the Northern Guinea Savanna, i.e. at a transition zone of the Sudan and Northern Guinea Savanna. The area is characterized by a tropical climate with marked rainy and dry, harmattan seasons. Long term mean annual rainfall is about 1050 mm. Details of environmental conditions are presented in Table 1. The soils are Alfisols-Typic Haplustalf which is a loam, that has a pH (water) of 5.0, its cation exchange capacity was 5.3 cmol(+) kg^{-1} with a low total nitrogen of 0.7 g kg^{-1}. The treatments consisted of:

(i) Cowdung at 9.1 t ha^{-1} in the first year and 5.8 t ha^{-1} in the second year; poultry litter at 3.8 and 2.5 t ha^{-1} in the first and second year, respectively; mineral fertiliser at 60 kg N, 15 kg P_2O_5 and 15 kg K_2O ha^{-1} in both years.
(ii) Three insecticidal materials namely; garlic extract, extract of west African black pepper and karate 2.5 EC (25 g lambda-cyhalothrin per litre).
(iii) A check (i.e., absolute control).

This gives a total of ten treatment combinations involving cowdung plus-garlic (T_1), pepper (T_2) and Karate 2.5 EC (T_3), poultry litter plus-garlic (T_4), pepper (T_5) and Karate 2.5 EC (T_6), mineral fertiliser plus-garlic (T_7), pepper (T_8) and Karate 2.5 EC (T_9). Treatment T_{10} was no amendment and no insecticidal application. They were arranged in a Randomized Complete Block Design with three replications. This gives a total of 30 plots with a plot size of 36 m^2.

The extract of garlic was obtained by soaking 200 g of chopped garlic bulbs overnight in a 1 L of hot water (70°C), the extract of pepper was obtained by soaking 100 g seeds of the west African black pepper overnight in boiled water (100°C). Three hundred milliliter each, of the sieved solution were mixed with 7.5 L of water. For karate, 50 mL were mixed with 7.5 L of water (which is the recommended rate). Each of these insecticidal materials was used in spraying a cropped area of 324 m^2 (i.e. 9 plots).

Table 1: Agro-meteorological data of Samaru during the period (July-December) of the trial

		Temperature (°C)			
Months/Years	Rainfall (mm)	Maximum	Minimum	Relative humidity (%)	Sunshine (h)
July 2002	229.0	31.1	22.1	87.4	6.0
August 2002	201.4	29.8	22.3	90.6	5.5
September 2002	193.9	31.1	22.3	90.0	7.0
October 2002	125.2	31.6	21.2	86.1	6.2
November 2002	nil	30.6	17.4	55.5	7.4
December 2002	nil	31.6	15.4	38.4	8.4
July 2003	283.7	30.3	22.4	69.3	na
August 2003	427.1	29.5	22.2	72.9	na
September 2003	218.7	30.7	23.0	63.9	5.5
October 2003	67.7	32.6	22.2	49.7	6.1
November 2003	nil	33.6	18.4	22.9	na
December 2003	nil	31.1	15.6	14.8	na

na = non-available data, nil = no rainfall, Source: Meteorological Unit of the Institute for Agricultural Research, Ahmadu Bello University, Zaria

The nitrogen (N) contents of the cowdung and poultry litter used in the study were 10.5 and 24.5 g kg^{-1}, respectively, on a dry-weight basis. The N content for these organic materials was determined by the Kjeldahl wet digestion method[11]. The amounts of cowdung and poultry litter to supply 60 kg N ha^{-1} were calculated each year based on each N content of the amendment. A 60% adjustment factor was used to compensate for the N availability from poultry litter and cowdung during the first year[12]. The amendments were broadcast by hand and incorporated to a depth of 8 to 10 cm by disc harrowing. After the field was ridged, seeds of upland cotton (SAMCOT-9) were sown at 0.6 m spacing on 5th July, 2002 and 30th July, 2003. The mineral fertiliser treatment received 60, 15 and 15 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. The N rate was in two split dose; at 3 and 5 weeks after emergence.

Crop data collected include; seed cotton, cotton seed and lint yield. A digital Fibrograph (Fibrograph 530) and a Stelometer (Stelometer 154) produced by Spinlab (Tennessee, USA) were used to determine fibre span length and fibre strength, respectively. The micronaire value of the fibre was determined using a fibre-fineness meter called Portar 175, also a product of Spinlab.

The surface soil (0-10 cm) of each treatment plot was sampled at the end of the second year harvest for laboratory determination of pH[13]. Aggregate size distribution was determined by dry sieving 50 g of air-dried soil through a nest of sieves for 3 min. The nest consisted of 5.0, 2.0, 0.5, 0.25 and 0.16 mm mesh sieves. Soil water retention was determined using a pressure plate for matric potentials of 0, -10 and -100 kPa, while the pressure membrane was used for higher tensions (-500 and -1500 kPa. Plant available water was taken as the difference in water held at -10 and -1500 kPa.

The data were analyzed statistically using the General Linear Model procedures[14] of the Statistical Analysis System[15]. Contrast analysis procedure was used to determine main effects of treatment factors.

RESULTS

Crop performance: Early planting in year 2002 resulted in a fast growth rate and development of cotton. This is noticeable from the higher seed cotton recorded relative to year 2003. Combined analysis showed that treatment T_8 recorded the highest seed cotton, cotton seed and cotton lint yield (Table 2). The yields were, however, similar to those of T_5, T_1 and all treatments involving mineral fertiliser amendment. This is in agreement with the findings of Nyakatawa and Reddy[16], who reported similar cotton lint yield between plot that received poultry litter and those that received ammonium nitrate fertiliser in Alabama. The check treatment gave the lowest yield. In year 2002, seed cotton-, cotton seed and cotton lint yield in the treated plots were higher than those of the control (Table 2). The T_8 treatment still dominated with higher yields than all the others. This was also the same for yields in 2003.

Fibre properties: Significantly longer fibre and higher micronaire values were recorded in the 2002 trial. However, the fibre produced from the 2003 trial were significantly stronger ($p = 0.001$) than those from 2002 trial (Table 3). The treatments had no significant effect on the properties of the fibre except for the micronaire value.

Treatment effect was significant ($p<0.01$). Highest micronaire values were recorded in lint from T_1 and T_7 treatments. The lint from T_3 and check had the lowest value of micronaire (Table 4). However, lint from T_4 and T_5 treatments had a similar micronaire value with lint from all the other treatments (Table 3). In year 2002, treatment effect on 50% fibre length was significant. Lower length was recorded in lint from T_2, T_5 and T_9 treatments. The lint from all other treatments had similar fibre length. The treatments significantly affected the micronaire value of the fibre in the two years. In the 2002 trial, lint from T_1 and T_7 recorded the highest micronaire value. However, in 2003, lint from T_4 had the highest micronaire value (Table 3). The effect of fertility on fibre quality is still not very clear. Blaise *et al.*[17] reported no significant effect of fertility on fibre quality while Joubert *et al.*[18] showed that N had a positive effect on length, strength and micronaire.

Contrast analysis: Contrast analysis revealed no significant difference in seed cotton-, cotton seed and cotton lint yield between the two organic materials (i.e. cowdung and poultry litter). However, average seed cotton yield from the cowdung amendments was higher (657.6 kg ha^{-1}) than were those from poultry litter (640.8 kg ha^{-1}). Seed cotton yield was significantly higher in plots with mineral fertiliser (852.9 kg ha^{-1}) than in either cowdung or poultry litter treatments. This trend was same for cotton seed yield. For cotton lint, there was no significant difference between yields of the three soil amendments.

Extracts of garlic and West African black pepper (*Piper*) had a non-significant difference in seed cotton, cotton seed and lint yield. This trend was the same when yield averages between garlic extract and Karate (synthetic insecticide) were considered. However, yields of seed cotton, cotton seed and lint were significantly higher in plots receiving extract of black pepper (810 kg ha^{-1}) than those receiving Karate (638 kg ha^{-1}).

Table 2: Seed cotton, cotton seed and lint yields (kg ha^{-1}) as affected by organic material utilization in the savanna

	Combined analysis			Year 2002			Year 2003		
Treatments	Seed cotton	Cotton seed	Cotton lint	Seed cotton	Cotton seed	Cotton lint	Seed cotton	Cotton seed	Cotton lint
T_1	731.3ab	435.50ab	289.17ab	674.4ab	427.8ab	244.2ab	786.2ab	443.2ab	334.2
T_2	670.8b	401.82b	262.82ab	710.2ab	452.7ab	252.8ab	631.4ab	351.0ab	272.8
T_3	570.8b	330.65b	225.35b	572.0ab	363.0ab	201.9ab	569.5ab	298.3ab	248.8
T_4	587.3b	338.52b	244.80ab	519.7ab	323.8ab	187.8ab	655.9ab	353.3ab	301.8
T_5	704.3ab	410.08b	285.05ab	780.9ab	481.0ab	294.9ab	627.7ab	339.2ab	275.2
T_6	630.8b	375.35b	235.48b	693.2ab	432.0ab	255.9ab	568.3ab	318.7ab	215.1
T_7	790.7ab	478.10ab	303.00ab	849.8ab	547.7ab	294.3ab	731.6ab	408.5ab	311.6
T_8	1055.1a	643.72a	385.55a	1077.7a	700.0a	366.3a	1032.5a	587.5ab	404.8
T_9	713.0ab	418.93b	271.83ab	742.2ab	436.4ab	268.7ab	683.8ab	401.5ab	275.0
T_{10}	461.2b	268.60b	181.75b	427.5b	272.2b	149.1b	494.8b	265.0b	214.4
SE	114.64	70.68	44.30	167.6	107.2	61.66	156.6	92.3	63.7
Year 2002	704.95	443.63	251.61	-	-	-	-	-	-
Year 2003	678.17	376.62	285.36	-	-	-	-	-	-
SE	51.28	31.62	19.82	-	-	-	-	-	-

Values having the same or no alphabets within the same column are not significantly different at p = 0.05 by DMRT Test

Table 3: Fibre properties of upland cotton as affected by organic material utilization in the savanna

	Combined Analysis				Year 2002				Year 2003			
	Fibre length (mm)			Fibre strength	Fibre length (mm)			Fibre strength	Fibre length (mm)			Fibre strength
Treatments	50%	2.5%	Micronaire	(g tex^{-1})	50%	2.5%	Micronaire	(g tex^{-1})	50%	2.5%	Micronaire	(g tex^{-1})
T_1	11.90	22.82	3.60a	15.72	14.4a	26.1	4.17a	15.36	9.37	19.54	3.03ab	16.08
T_2	10.90	21.83	3.21bc	15.70	12.9b	25.1	3.53ab	15.16	8.87	18.56	2.88bcd	16.24
T_3	11.23	22.32	3.01c	15.95	13.7ab	25.9	3.21b	15.20	8.73	18.71	2.18bcd	16.70
T_4	11.00	22.21	3.30abc	15.98	13.3ab	25.5	3.39b	15.50	8.73	18.88	3.21a	16.46
T_5	10.88	22.07	3.38abc	16.05	12.3b	25.0	3.81ab	15.41	9.41	19.18	2.96abc	16.69
T_6	11.25	22.29	3.11bc	15.62	13.6ab	25.8	3.26b	14.72	8.90	18.78	2.95abc	16.51
T_7	10.87	22.41	3.64a	15.37	12.6b	25.7	4.16a	14.60	9.13	19.09	3.11ab	16.14
T_8	11.53	22.99	3.40ab	16.05	13.5ab	26.1	3.76ab	15.53	9.60	19.84	3.03ab	16.56
T_9	10.93	22.13	3.11bc	15.59	12.9b	25.5	3.48ab	15.28	9.00	18.79	2.73cd	15.89
T_{10}	10.87	21.98	3.22c	16.15	13.1ab	25.3	3.85ab	15.68	8.60	18.67	2.60d	16.62
SE	3.38	0.47	1.14	2.63	0.44	0.38	0.21	0.43	0.51	0.87	0.09	0.3
Year 2002	13.23a	25.61a	3.66a	15.24	-	-	-	-	-	-	-	-
Year 2003	9.04b	19.00b	2.93b	16.39	-	-	-	-	-	-	-	-
SE	0.15	0.2	0.05	0.12	-	-	-	-	-	-	-	-

Values having the same or no alphabet(s) within the same column are not significantly different at p = 0.05 by DMRT test

Table 4: Moisture retention at several tensions as affected by organic material utilization in a savanna Alfisol

	Moisture retained by weight (kg kg^{-1})				
Treatments	-10 kPa	-100 kPa	-500 kPa	-1500 kPa	Plant available water (-10 to -1500 kPa)
T_1	0.14ab	0.13	0.12a-c	0.04	0.092ab
T_2	0.17a	0.12	0.11bc	0.06	0.115a
T_3	0.16a	0.14	0.12a-c	0.05	0.11a
T_4	0.12b	0.11	0.11bc	0.09	0.03c
T_5	0.15ab	0.14	0.12a-c	0.05	0.10a
T_6	0.12b	0.11	0.10bc	0.07	0.05bc
T_7	0.11b	0.10	0.09c	0.08	0.03c
T_8	0.11b	0.10	0.09c	0.06	0.05bc
T_9	0.15ab	0.14	0.12a-c	0.08	0.07b
T_{10}	0.13ab	0.10	0.09c	0.07	0.06bc
SE	0.02	0.02	0.01	0.02	0.03

Values having the same or no alphabet(s) within the same column are non significantly different at p = 0.05 by DMRT Test

Soil properties: Soil moisture retention varied among the various treatments depending on the pressure potential applied to the soil. There was no consistent pattern in water retention along the various pressure potentials (Table 4). However, the cowdung amendments seems to improve water retention in soils. At field capacity (-10 kPa potential), soils under the T_2 treatment had the highest moisture content which was similar with soil under T_1 and T_3 treatments. This trend was same for plant available water. Contrast analysis (not shown here) revealed no significant difference in moisture retention among the various pressure potentials of soils under mineral fertiliser and those under organic amendment. However, significant differences in moisture retention were observed between soils with cowdung treatment and those that received poultry litter at -10 kPa pressure potential and plant available water.

There was no significant effect of treatments on soil pH. However, the soils having cowdung treatment were the most neutral in soil reaction (Table 5). The various treatments had no significant effect on soil aggregation. The cow dung treatment had the highest value for soil

Table 5: Soil pH and aggregation affected by organic material utilization in the savanna

Treatments	Macro aggregate (2-0.5 mm)	Micro-aggregate (0.25-<0.05 mm)	pH
T_1	1.63	0.033	6.83
T_2	1.82	0.030	6.70
T_3	1.85	0.023	6.80
T_4	1.63	0.033	6.80
T_5	1.57	0.033	6.80
T_6	1.78	0.027	6.77
T_7	1.68	0.033	6.67
T_8	1.68	0.27	6.77
T_9	1.81	0.030	6.77
T_{10}	1.78	0.033	6.67
SE	0.13	0.004	0.06

macro aggregates, this was followed by treatments with mineral fertiliser (Table 5). The higher macro aggregate values in cowdung treatment may not be unconnected with the binding of clay microaggregates by organic materials. While, the presence of Ca, which is added indirectly as an amendment (in P fertilisers), could further aggregate the smaller micro aggregates[19].

DISCUSSION

Soils that received mineral fertiliser amendments generally had the highest seed cotton and cotton seed yield. The ability of mineral fertilisers to supply readily available essential nutrients into the soil for plant utilization is probably one of the factors that facilitated yield increase in those treatments. However, the significant seed cotton yield increase observed in the mineral fertiliser treatments did not translate to significant cotton lint yield. In the cotton industry, the most important material is the lint, this is what the textile industries used as raw material. Cotton lint produced organically usually attract a premium price[9]. The extracts of garlic and piper look a likely alternative to use as insecticidal material rather than synthetic insecticide in cotton production; this is because yields under these products were comparable. There was also no significant departure in the fibre qualities of cotton produced with the various organic materials relative to the conventional method of cotton production. These results are clear indications that organic cotton production may produce similar yield and quality with the conventional method in the savanna.

The two years study was actually not long enough to cause significant changes in the soil physical properties. However, there is a possibility of the cowdung amendment favouring the process of macro aggregate formation thereby increasing the water holding capacity and plant available water content of such soils. However, long term study (45 years) on the use of cowdung as soil amendment in the savanna shows that it increases the fraction of large macro aggregate and increase the mean weight diameter of the soil[4].

CONCLUSIONS

From this study it is concluded that organic materials like cowdung and poultry litter has a high fertilizing value and may possess good potentials for improving the physical fertility of low activity clay soils of the savanna. In addition, extracts of garlic and west African black pepper have insecticidal potentials in cotton production in the savanna. The performance of these materials can be a basis for adoption of organic cotton production in the savanna regions of west Africa.

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