International Journal of Manures and Fertilizers Vol. 1 (12), pp. 233-239, December, 2012. Available online at www.internationalscholarsjournals.org

Full Length Research Paper

Effects of Anaerobically digested and undigested poultry manure on the growth and yield of maize (*Zea mays*, L)

Okpere R. Iyogun and Ariko Donatus

Department of Crop Science, Faculty of Agriculture, Ambrose Alli University, Nigeria. Ambrose Alli University, Edo State, Nigeria.

Accepted 16 November, 2012

A comparative study of the effects of undigested and anaerobically digested poultry manure and conventional inorganic fertilizer on the growth characteristics and yield of maize was investigated at Ibadan, Nigeria. The pot experiment consisted of sixty (60) nursery bags, set out in the greenhouse. The treatments, thoroughly mixed with soil, were: control (untreated soil), inorganic fertilizer, (NPK 20:10:10) applied at the 120 kgN/ha; air-dried undigested and anaerobically digested manure applied at 12.5 g/pot, or 25.0 g/pot or 37.5 g/pot, and or 50.0 g/pot. Plant height, stem girth, leaf area, number of leaves at 2, 4, 6 and 8 weeks after planting (WAP) and stover mass and grain yield were measured. Analysis of variance (ANOVA) at P 0.05 was used to further determine the relationships among the factors investigated. Generally, results in respect of crops treated with digested manure, were quite comparable with those treated with undigested manure and inorganic fertilizer, right from 2WAP to 6WAP. Stover yield was increased to as much as 1.58, 1.65 and 2.07 times by inorganic fertilizer, digested and undigested manure, respectively while grain yields were increased by only 200% with inorganic fertilizer, but by up to 812 and 933% by digested and undigested manure, respectively. In conclusion, digested poultry manure enhanced the growth characteristics of the treated plants for the maize variety used. As observed, the order of grain yield was undigested manure > digested manure > inorganic fertilizer.

Key words: Undigested poultry manure, digested manure, inorganic fertilizer, maize.

INTRODUCTION

Activities in livestock production facilities cause environmental problems such as odour nuisance and land pollution resulting from improperly discharged manure. In addition, some odorous substances from these facilities may present health hazards (Donham et al., 1982; Schiffman, 1998). Odour is caused by a large number of chemical components produced during animal growth and present in livestock manure and these may ordinarily be unavoidable (Spoelstra, 1980; Tanaka, 1988; O'Neill and Phillips, 1992). This potential for environmental pollution is gaining importance in Nigeria as the country's

*Corresponding author. E-mail: okpere61@yahoo.com

livestock industry expands. Federal Ministry of Agriculture and Natural Resources, FMA&NR (1997) estimated the populations of Nigeria's cattle, sheep, goat, pigs and poultry to be 18, 33.2, 53.8, 8.3 and 97.3 million, respectively. These livestock generate huge quantities of manure daily, which constitute a threat for polluting the environment, except these wastes can be managed in an environmentally safe and economically useful manner. One such way is to anaerobically digest manure in order to produce methane gas which is used to produce energy, as well as use the digested manure to fertilize crops and by so doing, lessen their risk of polluting the environment.

In view of Nigeria's annual livestock population growth rate of 3.2% (FMA & NR, 1997), it is obvious that the production of huge quantities of livestock manure is virtually assured in Nigeria for years to come along with their associated demerits. Options have to be investigated to turn manure into a more useful resource rather than being a mere pollutant which further burdens agriculture and the environment. This paper reports results obtained from one of those options currently under investigation in Nigeria.

There has been considerable interest in recent years in slurry treatment technologies and in particular anaerobic digestion (Pain et al., 1990; Doelle, 2001; Mer et al., 2002; Friends of the Earth, 2004; Cardiff University, 2005; Adelekan and Bamgboye, 2009; Adelekan et al., 2009). Much of this has been in the area of direct production and use of biogas. Using waste biomass to produce energy can reduce the use of fossil fuels, reduce greenhouse gas emissions and reduce pollution and waste management problems (Marshall, 2007; Inderwildi and King, 2009) . However, not much has been reported in the area of using the digested biomass for crop production. Specifically in the case of Nigeria, reported values of animal waste production range from 144 million tonnes/year (Energy Commission of Nigeria, 1997) to 285.1 million tonnes/year (Adelekan, 2002).

The foregoing suggests that Nigeria's farm animals no doubt produce huge quantities of manure. This is a ready source which can be exploited for energy in biogas production; while the digested biomass is used for crop fertilization. Biogas production from organic materials does not only generate energy, but also preserves nutrients in the digested effluent and this can be recycled back to land in form of slurry. Key advantages in respect of doing this as compared to dried, undigested manure are presented in this paper using maize as the crop of interest.

Organic manures play a direct role in plant growth as a source of all necessary macro and micronutrients in available forms during mineralization. Thereby, they improve both the physical and physiological properties of soil soil (El Shakweer et al., 1998), thus enhancing soil water holding capacity and aeration (Abou el Magd et al., 2005). Organic manures decompose to give organic matter which plays an important role in the chemical behavior of several metals in soil through the fulvic and humic acid contents which have the ability to retain metals in complex and chelate forms (Abou el Magd etal., 2006). They release nutrients rather slowly and steadily over a longer period and also improve soil fertility status by activating soil microbial biomass (Ayuso et al., 1996; Belay et al., 2001). They thus, ensure a longer residual effect (Sherma and Mittra, 1991), support better root development and this leads to higher crop yields (Abou el Magd et al., 2005). Improvement of environmental conditions and public health as well as the need to reduce cost of fertilizing crops are also important reasons for advocating increased use of organic manures (Seifritz, 1982).

Mathers and Stewart (1984) incorporated cattle manure into Pullman clay loam soil for 14 years and found that annual applications of 22 Mg/ha were adequate for maintaining high nitrate levels. Application of cattle manure increased soil organic matter and hydraulic conductivity, but decreased bulk density. This work also found that sunflower yields from plots which received cattle manure were similar to those plots which received comparable amounts of inorganic nitrogen. Safely et al. (1985) characterized fresh dairy cattle manure and found that it can be used as a substitute for commercial fertilizer for growing corn silage. The study found that fresh dairy manure contained approximately 30% more nitrogen than previously documented. Another study of nitrogen in soil receiving cattle manure revealed that overall soil N distribution levels increased with increasing applications of manure (Smith et al., 1980).

Wolt et al. (1984) evaluated the potential of pig manure as a source of N for corn silage production. Optimum corn silage yield was obtained with manurial N application in excess of 480 kg/ha. In another study, Safley and Westerman (1989) applied pig lagoon effluent on a weekly basis to coastal Bermuda grass (*Cynodon dactylon*) plots for a 6–year period. Application rates ranged from 335 to 1340 kg/ha/yr. Elevated nitrate levels were noticed in the higher application rates. Sharpley et al. (1984) applied cattle manure at rates of 176 to 1614 Mg/ha to irrigated continuous–grain sorghum over an 8–year period. It was found that applications of the manure increased soil P content. The soil P contents decreased when manure applications stopped. However, in order to apply manure to fulfill the nutrient requirements of a crop, knowledge of the amount of nutrients mineralized following application is needed (Eghball et al., 2002). It has been variously reported that poultry manure performs better than other animal manures in improving crop performance and soil properties (Ano and Agwu, 2005; Adeniyan and Ojeniyi, 2005).

MATERIALS AND METHODS

Sources and collection of manure, anaerobic digestate

Fresh manure was collected from the poultry of Federal College of Agriculture, (IAR&T), Moor Plantation, Ibadan. 12 kg of it was air-dried in the laboratory for 2 days. 15 kg of the remaining portion was mixed with 15 kg of clean water and anaerobically digested in a batch type digester in a biogas production process over a 30-day retention period. Stirring of the charge in the digester was done twice daily at 8 am and 6 pm to free the trapped gases. Anaerobic digestion is a process through which organic materials are decomposed by bacteria in the absence of air to produce biogas. Both the air-dried manure and the digested manure were used for this experiment.

Experimental set-up

The experiment consisted of ten (10) treatments replicated thrice and doubled for destructive sampling; amounting to an aggregate of sixty (60) polythene nursery bags, each of 4-litre capacity and perforated at the base, set out in the greenhouse. The treatments were: control (untreated soil), inorganic fertilizer, F (Nitrogen, Phosphorous and Potassium, NPK 20:10:10) applied at the 120 kgN/ha; undigested (U) and anaerobically digested (D) manure slurries applied at 2.5 t/ha or 12.5 g/pot(L1), 5.0 t/ha or 25.0 g/pot(L2), 7.5 t/ha or 37.5 g/pot(L3) and 10.0 t/ha or 50.0 g/pot(L4). Each treatment was thoroughly mixed with 10 kg of soil in its allotted pot at the beginning of the experiment.

Analytical methods

Physical and chemical analyses of soil were conducted prior to planting. Methods of analyses used were those given by AOAC (1990). Samples (200 g) of both the air-dried (undigested) and digested manures were collected and analyzed for important nutrient elements such as carbon, nitrogen, phosphorous, potassium, zinc, copper and manganese using standard laboratory procedures (AOAC, 1990) .

Agronomic practice and measurements of agronomic characteristics

Two litres of water was sprinkled on each bag at planting and afterwards, 500 ml was added to each bag every other day by 5 pm to ensure adequate supply of water to the plants. The DMR-LSR-Y maize variety (obtained from IAR&T seed store) was planted and thinned to one plant per pot at 2 weeks after planting (WAP). Weeding was done at 2 WAP and the plants were sprayed with MONO CROWN, a brand of monocrotophos (20 ml was mixed in 12 litres of water) at 5WAP to eliminate insect pests. The manufacturer of MONO CROWN is African Agro Products Ltd with address at No. 37, Niger Street, Kano, Nigeria. Plant height, stem girth, leaf area and number of leaves were measured during growth at 2, 4, 6 and 8 WAP. Harvesting of stover biomass was done at 10 WAP. Grain yield was measured at maturity. Plant height was determined with metre rule (brand RUMOLD, Nr. 659 ZEICHEN-UND SCHNEIDELINEAL), while stem girth was measured with micrometer screw gauge (brand DRAPER, Made in Japan). Leaf area was measured with graph paper and number of leaves was determined by counting. Harvested stover was weighed with electronic balance (brand METTLER E2000).

RESULTS AND DISCUSSION

Physical and chemical properties of soil, undigested and digested poultry manure before planting

From the results of analyses conducted on the experimental soil before planting presented in Table 1, the values of percent organic carbon, N, P and K in the soil were quite low. Other exchangeable bases (Na and Ca) were also very low, indicating that the soil would be improved by manure addition, so as to adequately support plant growth. The soil pH value of 7.6 is adequate to support plant growth. This finding is consistent with the literature to the effect that organic matter contributed by manure leads to improvement of soil physical properties (Obi and Ebo, 1995; Akanni et al., 2005). Benefits which should be expected as a result of addition of organic matter to soil include increase in porosity, infiltration rate and water retention capacity as well as reduction in soil bulk density (Kingery et al., 1993; Agbede et al., 2008).

From Table 2 which shows some chemical properties of undigested and digested poultry manure. Undigested poultry manure appears to contain slightly higher values of several nutrients of importance to crop production (N, P, K, Zn, Cu, etc), than the digested form. This observation finds support in the findings of Van Horn et al. (1994), Deluca and Deluca (1997) and Thomsen (2000). These studies agree that only small differences of between 0.5 and 2.0% are usually measurable in the aggregate nutrient concentrations when digested manure is compared to the undigested form.

Agronomical characteristics of maize plant grown on planting soil, and on soil with undigested and digested poultry manure

Number of leaves

Table 3 shows the effects of applied treatments on average number of leaves of maize plant. These results revealed notable positive response of maize to both digested and undigested poultry manure, even as early as at 2 WAP. Only the undigested manure at 2.5 t/ha did not significantly increase number of leaves at 2WAP. Lower rates of 2.5 and 5.0 t/ha of digested manure, proved sufficient to increase leaf production significantly.

Table 1. Pre–planting soil analysis.

Parameters	Soil
pH	7.6
% Organic carbon	1.2
% Total Nitrogen	0.1
K (cmol/kg)	0.4
P (ppm)	3.0
% $N0_3$	0.02
Zn (mg/kg)	21.2
Cu (mg/kg)	6.4
Mn (mg/kg)	163.0
Na (cmol/kg)	0.2
Ca (mg/kg)	0.3
Pb (mg/kg)	0.1

Table 2. Chemical analyses of undigested and digested poultry manure.

Parameters	Undigested	Digested
pH	7.20	6.70
%Organic carbon	38.9	29.7
%Total nitrogen	3.56	2.36
C/N ratio	10.9	11.0
K (cmol/kg)	1.42	0.89
P(ppm)	20.6	11.4
%NO_3	0.83	0.64
Zn (mg/kg)	486	362
Cu (mg/kg)	82	52
Mn (mg/kg)	638	442
Na (cmol/kg)	0.63	0.30
Ca (mg/kg)	3.04	1.89
Pb (mg/kg)	25.4	14.3
%Ash	28.97	24.87

Effects of planting soil, undigested and digested poultry manure on agronomical characteristics of maize plants.

This same effect was produced by digested manure but only at rates in excess of 5 t/ha (that is, 7.5 and 10 t/ha), indicating the superiority of undigested over digested manure. At 4 and 6 WAP, there was no significant difference between number of leaves produced by lower rates of digested and undigested poultry manure. The highest number of leaves was obtained with 10 t/ha undigested manure (UL4). However by 8 WAP, the effect of all the treatments was statistically similar. These results are similar to those obtained for growth parameters of sorghum in a study by Agbede et al. (2008). The paper commented that its finding to the effect that poultry manure significantly increased the growth and grain yield of sorghum was attributed to improved soil physical and chemical properties. It noted further that increased porosity and moisture content enhanced root growth and water and nutrient uptake, apart from the fact that nutrients released from poultry manure had direct influence on growth and grain yield.

Leaf area

Maize leaf area relationship in the treatments (Table 4) appeared to follow a trend somewhat different from that observed for the number of leaves. Undigested poultry manure at 10 t/ha gave the highest leaf area values both at 4 and 8 WAP, which differed significantly from digested manure irrespective of rate of application. The highest value of leaf area obtained with undigested manure was 686.50 cm^2 at 10 t/ha while that of digested manure was only 548.26 cm^2 at 2.5 t/ha. These observations are consistent with what was found in Table 2 to the effect that undigested manure contained somewhat more nutrient than the digested form. These extra nutrients translated to more vigorous growth evidenced by larger leaf areas. However, digested manure gave significantly higher values than inorganic fertilizer at 4 WAP. There also certain notably higher values (DL1 and DL2), although by 8 WAP, this noticeable difference had somewhat reduced. Agbede et al. (2008) found that in the case of sorghum, undigested manure significantly ($P > 0.05$) increased plant height, leaf area, stem girth and grain yield. As noted above and in the following subsections, this finding is consistent with what was observed in this study for maize crop.

Mean plant height

At the early growth stage (2 WAP), the tallest plants were obtained with digested manure at 5.0 t/ha, followed by higher rates of undigested manure (7.5 and 10 t/ha). There was however no significant difference between all rates of digested and higher rates of undigested manure between 2 and 8 WAP. At 8 WAP, the plants treated with 7.5 t/ha undigested manure were the tallest, closely followed by 2.5 t/ha digested manure. This is an indication that both the undigested manure and the digested manure produced similar effects on plant height. Generally, as can be seen in Table 5, plant heights observed with both digested and undigested manure were statistically similar to those obtained with inorganic fertilizer. These results agree with those reported by Agbede et al. (2008) for sorghum (*Sorghum vulgare*), Akanni (2005) for tomato (*Lycopersicon esculentum*) and Adenawoola and Adejoro (2005) for jute (*Corchorus*

Table 3. Effect of treatments on mean number of leaves.

Treatments	2 WAP	4 WAP	6 WAP	8 WAP
C	$5.17^{b.c}$	8.67^{bc}	$9.85^{b.c}$	13.67
F	5.0^{c}	7.50^{c}	$10.17^{a.b.c}$	13.00
DL_1	6.00^{a}	9.00^{b}	$10.83^{a.b}$	13.33
DL_2	6.00^{a}	9.00^{b}	$10.83^{a.b}$	14.17
DL_3	5.67^{abc}	8.17^{c}	8.83^{c}	12.17
DL_4	5.83^{ab}	8.83^{bc}	$10.33^{a.b.c}$	13.00
UL_1	5.17^{bc}	8.50^{bc}	$11.17^{a.b}$	12.83
UL_2	5.67^{abc}	9.17^{ab}	$10.67^{a.b}$	14.00
UL_3	6.00^{a}	$9.17^{a.b}$	$11.33^{a.b}$	13.17
UL_4	6.00^{a}	10.17^{a}	11.83^{a}	13.50

Within a column means followed by the same letter are not significantly different at p 0.05 (DMRT).

Table 4. Effect of treatments on leaf area (cm^2).

Treatments	4 WAP	8 WAP
C	$276.73^{d.e}$	$448.84^{e.d}$
F	218.85^{e}	$502.15^{c.d.e}$
DL_1	$334.67^{d.c}$	$548.26^{b.c.d}$
DL_2	$355.83^{b.c}$	$519.64^{b.c.d}$
DL_3	$311.28^{b.c}$	398.05^{e}.
DL_4	$296.68^{d.c}$	$462.83^{d.e}$
UL_1	$279.55^{d.e}$	$614.03^{a,b}$
UL_2	$410.77^{a,b}$	$584.54^{a,b,c}$
UL_3	$357.81^{b,c}$	682.59^{a}
UL_4	432.20^{a}	686.50^{a}

Within a column means followed by the same letter are not significantly different at p 0.05 Duncan Multiple Regression Test (DMRT).

olitorus L.).

Stem girth

As was observed in the case of plant height, the thickest stem girths were obtained with undigested manure as shown in Table 6. Girth in plants treated with 2.5 and 5.0 t/ha digested manure was not statistically different from 5.0 and 7.5 t/ha undigested manure at 4 WAP. The highest values of stem girth were obtained with undigested manure at the rate of 10 t/ha at 4 and 6 WAP. Digested manure at 7.5 t/ha and above did not translate to noticeably higher girths of the plants at both 4 and 6 WAP. This finding agrees with that of Agbede et al. (2008) which concluded that application of raw poultry manure resulted in increase in stem girth for sorghum crop.

Stover yield

As shown in Table 7, there was no significant difference in the mass of stover produced by inorganic fertilizer, digested manure and undigested manure. Stover yield (computed in kg/ha), increased with increasing quantity of applied undigested manure. The highest yield was 5,915.2 kg/ha obtained with 10 t/ha undigested manure. However, an optimum yield of 4,695.20 kg/ha was obtained with 5.0 t/ha digested manure. Quantities of straw produced by undigested manure were generally higher than digested manure. It has been mentioned earlier that the quantity of tissue building nutrients in undigested manure are higher than the digested form (Table 2).Even though the differences were not statistically significant, maximum stover yields obtained by applying undigested manure, digested manure and conventional inorganic fertilizer were approximately 2.07, 1.65 and 1.58 times of the control. A study of soil amendment effects on soil quality, nutrients and yield by University of Minnesota (2004) suggested that there were no yield differences among amendments. The reason suggested to account for this was the lack of a pattern in the rank of order of treatment. As that study noted, the only differences observed in grain or stover yield were for an annual application in a particular field where raw manure yielded less than inorganic fertilizer and digested manure.

Grain yield

The highest grain yield was obtained with 10 t/ha undigested manure. Values of grain yield obtained with quantities of undigested manure higher than 2.5 t/ha were distinctly higher than the values obtained with all rates of digested manure except when the latter was

Table 5. Effect of treatments on mean plant height (cm).

Treatments	2 WAP	4 WAP	6 WAP	8 WAP
C	38.12$^{a.b.}$	46.77^{b}	85.28$^{b.c}$	155.52^{c}
F	37.08$^{a.b}$	46.07^{b}	68.53^{c}	167.43$^{a.b.c}$
DL$_1$	39.57$^{a.b}$	54.37^{b}	113.22$^{a.b}$	203.73$^{a.b}$
DL$_2$	44.67^{a}	64.37^{a}	107.48 $^{a.b}$	177.90$^{a.b.c}$
DL$_3$	42.55$^{a.b}$	53.90^{b}	84.95$^{b.c}$	153.13^{c}
DL$_4$	43.10^{a}	54.67^{b}	97.17$^{a.b.c}$	157.70$^{b.c}$
UL$_1$	33.25^{b}	51.12^{b}	102.18$^{a.b}$	182.17^{a,b,c}
UL$_2$	37.32^{a,b}	67.60^{a}	119.77^{a}	189.62^{a,b,c}
UL$_3$	43.10^{a}	67.10^{a}	129.70^{a}	205.95^{a}
UL$_4$	44.32^{a}	65.08^{a}	127.20^{a}	196.95 $^{a.b.c}$

Within a column means followed by the same letter are not significantly different at p 0.05 (DMRT).

Table 6. Stem girth (mm) of treated maize plants.

Treatments	2 WAP	4 WAP	6 WAP	8 WAP
C	5.82$^{d.}$	14.13^{c}	17.98^{c}	17.70^{d,e}
F	6.00^{ef}	14.80^{c}	17.87^{c}	18.10$^{d.e}$
DL$_1$	8.35^{a,bc}	18.18^{b}	20.58^{a,b}	19.20$^{e.d}$
DL$_2$	7.77$_{b,c.d}$	17.77^{b}	19.68$^{b.c}$	19.00$^{c.d}$
DL$_3$	7.22$_{c,d,e}$	15.92^{c}	17.77^{c}	15.90^{f}
DL$_4$	6.88^{def}	15.83^{c}	17.35^{c}	17.20$^{e.f}$
UL$_1$	7.30$_{c.d.e}$	15.58^{c}	20.74^{a,b}	20.00$^{b.c}$
UL$_2$	9.02 $^{a.b}$	19.28$^{a.b}$	22.44^{a}	20.50^{a,b,c}
UL$_3$	8.68$^{a.b}$	18.93^{b}	21.27$^{a.b}$	21.68^{a}
UL$_4$	9.45^{a}	20.75^{a}	22.87^{a}	21.00^{a,b}

Within a column means followed by the same letter are not significantly different at p 0.05 (DMRT).

Table 7. Stover mass and grain yield of maize (kg/ha).

Treatments	Stover mass	Grain yield
C	2,850.80 ^{b}	368.40 ^{d}
F	4,505.20 ^{ab}	726.60 ^{c}
DL1	3,666.40 ^{ab}	2,314.00 ^{bc}
DL2	4,695.20 ^{ab}	2,445.60 ^{bc}
DL3	4,557.60 ^{ab}	2,989.60 ^{ab}
DL4	4,250.80 ^{ab}	1,876.40 ^{c}
UL1	4,240.80 ^{ab}	2,020.40 ^{c}
UL2	4,979.60 ^{ab}	3,227.60 ^{a}
UL3	5,445.60 ^{ab}	3,361.60 ^{a}
UL4	5,915.20 ^{a}	3,438.00 ^{a}

Within a column means followed by the same letter are not significantly different at p 0.05 (DMRT).

applied at 7.5 t/ha, which was also the optimum rate. At that rate, digested manure performed significantly better than inorganic fertilizer and 2.5 t/ha undigested manure.

While inorganic fertilizer produced grain yield to the tune of almost 200% of the control, yield obtained with undigested manure ranged between 548 and 933% and digested manure between 509 and 812% of the control. Thus, the order of grain yield production was undigested manure > digested manure > inorganic fertilizer. The findings in this study agree with those of a previous study conducted by the University of Minnesota (2004) at Haubenschild Farms, Inc. Princeton, Minnesota (T36N R26W) which compared effects of anaerobically digested and undigested manure sources on soil properties and yields of alfafa (a temperate crop). Although soil variability was high on the site used, yet results obtained suggested that the use of digested manure would produce yields equivalent to undigested manure or fertilizer. Neither, the potentially mineralizable N, total C, total N, nor the microbial biomass differed in the soil samples taken from field plots treated with these amendments.

Results showed that the digested poultry manure produced from anaerobic digestion is an effective fertilizer for the maize variety used as evidenced by its positive effects on growth characteristics of the treated plants. Experiments which involved the application of digested manure vis–à-vis undigested manure, using mineral fertilizer as standard on maize crop, indicated that digested and undigested manures performed better, to various degrees, than the mineral fertilizer used. Higher rates of digested manure compared favourably well with undigested manure in its effect on the growth (number of leaves, leaf area, plant height, stem girth) and yield parameters (stover mass and grain yield) measured. Though grain yields obtained from use of undigested manure are somewhat higher than the digested form, the superior performance of the latter over conventional fertilizer makes it worthwhile to further investigate its potential as a nutrient source for production of other crops.

Part of the results obtained from this greenhouse study are comparable to those reported by Agbede et al. (2008) which applied undigested poultry manure on sorghum crop in field trials. That work found that manure significantly ($P > 0.05$) increased plant height, leaf area, stem girth, number of roots, root weight and shoot weight and grain yield. The work did not investigate the effects of the digested manure on that crop however.

While the practice of anaerobic digestion of biomass for energy production is increasing, particularly in developing regions of the world of which Nigeria and other African nations are a part, the use of the digested manure for crop production should be encouraged, judging by its potential to enhance the growth and yield of crops.

REFERENCES

Abou el Magd MM, Hoda Mohammed A, Fawz ZF (2005). Relationship Growth and Yield of Broccoli with increasing N, P or K Ratio in a Mixture of NPK fertilizers. Ann. Agric. Sci. Moshto 43(2): 791-805.

Abou el Magd MM, El Bassiony M, Fawzy ZF (2006). Effect of Organic Manures with or without Chemical Fertilizers on Growth, Yield and Quality of some Varieties of Broccoli Plants. J. Appl. Sci. Res. 2(10): 791-798.

Adelekan BA (2002). Assessing Nigeria's Agricultural Biomass Potential as a Potential Energy Source through Adoption of Biogas Technology. Niger. J. Renewable Energy Sokoto Energy Res. Centre, 10(2): 145-150.

Adelekan BA, Bamgboye AI (2009). Effect of Mixing Ratio of Slurry on Biogas Productivity of Major Farm Animal Waste Types. J. Appl. Biosci., 22: 1333-1343, October 7. Published online at www.biosciences.elewa.org/JABS.

Adelekan BA, Bamgboye AI Oradugba OB (2009). Comparison of Biogas Productivities of Major Livestock Waste Types Using Selected Mixing Ratios of Slurry, Proceedings of 3rd Int. Conference of West Africa Society for Agricultural. Engineer (WASAE) and 9th National Conference of Nigeria Institutution Agricultural Engineering. (NIAE), Obafemi Awolowo University, Ile-Ife, Nigeria, Jan. 25-29. Conference Proceedings.

Adenawoola AR, Adejoro SA (2005). Residual Effects of Poultry Manure and NPK Fertilizer Residues on Soil Nutrient and Performance of Jute (*Corchorus olitorus*, L.). Niger. J. Soil Sci. 15: 133-135.

Adeniyan ON, Ojeniyi SO (2005). Effect of Poultry Manure, NPK 15-15-15 and Combinations of their Reduced Levels on Maize Growth and Soil Chemical Properties. Niger. J. Soil Sci. 15: 34-41.

Agbede TM, Ojeniyi SO, Adeyemo AJ (2008). Effect of Poultry Manure on Soil Physical and Chemical Properties, Growth and Grain Yield of Sorghum in South West Nigeria. Am. Eurasian J. Sustain. Agric., 2(1): 72-77.

Akanni DI (2005). Response of Nutrient Composition and Yield Components of Tomato (*Lycopersicon esculentum*, M.) to Livestock Manure. Ph.D thesis, Department of Crop, Soil and Pest Manage., Federal University of Technology, Akure, Nigeria p.120.

Ano AO, Agwu JA (2005). Effect of Animal Manures on Selected Soil Chemical Properties. Niger. J. Soil Sci. 15: 14-19.

AOAC (1990). Standard Methods for Laboratory Determination of Soil Parameters. Association Official Analytical Chemists. 15th Edition, Wash. D.C, USA.

Ayuso M, Paschal, JA Garcia C, Hernandez T (1996). Evaluation of Urban Wastes for Agric. Use. Soil Sci. Plant Nutr. 142(1): 105-111.

Belay A, Classens AS, Wehner FC, De Beer JM (2001). Influence of Residual Manure on Selected Nutrient Elements and Microbial Composition of Soil under Long Term Crop Rotation. S. Afr. J. Plant Soil 18: 1-16.

Cardiff University (2005). Anaerobic Digestion Page. (http://www.wasteresearch.co.uk/ ade/efw/anaerbic .htm) Accessed April 19, 2009.DeLuca TH, DeLuca DK (1997) .Contemporary Issues: Composting for Feedlot Manure Management and Soil Quality. J. Prod. Agric. 10: 235-241.

Doelle HW (2001). Biotechnology and Human development in Developing Countries (http://www.ejbiotechnology.info/content/vol4 /issue3/issues/02/) Accessed April 19, 2009.

Donham KJ, Knapp LW, Monson R, Gustafson K (1982). Acute Toxic Exposure to Gases from Liquid Manure. J. Occupat. Med. 24(2): 142-145.

Egball B, Wienhold BJ, Gilley JE, Eigenberg RA (2002) Mineralization of Manure Nutrients. J. Soil Water Conserv. 57(6): 470-472.

El Shakweer MHA, El Sayad EA, Ewees MSA (1998). Soil and Plant Analysis as a Guide for Interpretation of the Improvement Efficiency of Organic Conditioners added to different Soils in Egypt. Commun. Soil Sci. Plant Anal. 29: 2067-2088.

Energy Commission of Nigeria (ECN) (1997). Potentials for Renewable Energy Application in Nigeria. Energy Commission of Nigeria, Lagos, p.21.

Federal Ministry of Agriculture and Natural Resources (FMA&NR) (1997). Nigeria Agricultural Statistics Time Series Data. A Publication of Agricultural Statistics and Information Systems, Dept. Planning, Res. Statistics FMA&NR Abuja 2nd Edition; Nov.

Friends of the Earth (2004). Anaerobic Digestion Briefing Paper. (http://www.foe.co.uk/resource/briefings/anaerobic_digestion.pdf) Accessed April 19, 2009.

Inderwildi OR, King DA (2009). Quo Vadis Biofuels. J. Energy and Environ. Sci. 2: 343. Doi:10.1039/b822951c. (http://www.dx.doi.org/10.1039/b822951c).

Kingery WL, Wood CW, Delaney DP (1993). Impact of Longterm Application of Broiler Litter on Environmentally related Soil Properties. J. Environ. Qual. 23:139-147.

Marshall AT (2007). Bioenergy from Waste: A Growing Source of Power Waste Management World Magazine, April 34-37. (http://www.waste-management-world-magazine/)

Mathers AC, Stewart BA (1984). Manure Effects on Crop Yields and Soil Properties. TRANS of the ASAE 27: 1022.

Mer HB, Sommer SG, Ahring BK (2002). Separation Efficiency and Particle Size Distribution in Relation to Manure Type and Storage Conditions. Bioresour. Technol. 85 (3): 189-196.

O'Neill DH, Philips VR (1992). A Review of the Control of Odour Nuisance from Livestock Buildings, Part 3. Properties of the Odorous Substances which have Been Identified in Livestock Wastes or in the Air Around Them. J. Agric. Eng. Res. 53(1): 23-50.

Pain BF, Misselbrook TH, Clarkson CR, Rees YJ (1990). Odour and Ammonia Emissions following the Spreading of Anaerobically-Digested Pig Slurry on Grassland. Biol. Wastes 34 (3): 259-267.

Safley Jr. LM, Westerman PW, Barker JC (1989). Fresh Dairy Manure Characteristics and Barnlot Nutrient Losses. 5th Int. Symp. Agric. Wastes, ASAE pp.191-199.

Safley Jr. LM, Westerman PW (1989). Anaerobic Lagoon Biogas Recovery Systems, J. Biol. Wastes 27: 43-62.

Schiffman SS (1998). Livestock Odours: Implications for Human Health and Wellbeing. J. Anim. Sci. 76(5): 1343-1355.

Seifritz W (1982). Alternative and Renewable Sources of Energy in Optimizing Yields: The Role of Fertilizers. In: Proceedings of 12th IPI Congress pp.153-163.

Sharpley A, Smith SJ, Stewart BA, Mathers AC (1984). Forms of Phosphorous in Soil Receiving Cattle Feedlot Waste. J. Environ. Qual. 13: 211-215.

Sherma AR, Mittra BN (1991). Effect of Different Rates of Application of Organic and N Fertilizers in a rice based Cropping System. J. Agric Sci. (Cambridge) 117: 313-318.

Smith SJ, Mathers AC, Stewart, BA (1980). Distribution of Nitrogen Formsin Soil Receiving Cattle Feedlot Waste. J. Environ. Qual. 9: 215-218.

Spoelstra SF (1980). Origin of Objectionable Odourous Components in Piggery Wastes and the Possibility of Applying Indicator Components for Studying Odour Dev. J. Agric. Environ. 5(3): 241-260.

Tanaka H (1988). Characteristics of Odours from Animal Industry (in Japanese). J. Agric. Machin. Assoc. 51(4): 99-104.

Thomsen IK (2000). C and N Transformations in ^{15}N Cross-Labeled Solid Ruminant Manure During Anaerobic Storage., Bioresource Technol. 73(3): 267-274.

University of Minnesota (2004). Soil Amendment Effects on Soil Quality, Nutrients and Yield. Part A: Manure/Soil/Crop/Interactions. www.mnproject.org/pdf/Part%20A%20Soil-Crop20Interactions-2004%20final.pdf Accessed July 18, 2009.

Wolt JD, Safley Jr. LM, Lessman GM, Smith MC (1984). Influence of Time on Silage Yield and Nutrient Content of Corn. Trans. ASAE 27: 1135-1139.