Research Paper

Fecal sludge-derived pellet fertilizer in maize cultivation

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ABSTRACT

Fecal sludge (FS) contains significant amounts of plant nutrients and organic matter although it also contains pathogens. Therefore, FS can be used as fertilizer after proper sanitization. This study was designed to test dried fecal sludge (DFS)-based pellet fertilizers on maize cultivation. The DFS fertilizers were produced by composting, co-composting with sawdust, or irradiated by gamma-irradiation, and then nitrogen-enriched and pelletized using gelatinized or gamma-irradiated cassava starch. These DFS pellet fertilizers were compared to each other and to no-fertilization, mineral fertilizer, and agro-industrial waste compost. The fertilizer applications were 150 or 210 kgN/ha. Maize was cultivated in pots containing Cambisol and Ferric Lixisol growth media. The EC-SDFS-PG pellet (DFS + sawdust co-composted, enriched with nitrogen and pelletized) at a rate of 210 kgN/ha produced the highest maize yield (4.4 ton/ha) among all other treatments, while mineral fertilizer produced 3.9 ton/ha. It is concluded that the EC-SDFS-PG pellet produces similar or higher maize yields than mineral fertilizer and more than the agro-industrial compost in both growth media types.

Key words | fecal sludge, fertilizer, maize, pellets, sanitation

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INTRODUCTION

Fecal sludge (FS) is rich with organic matter and plant nutrients N (nitrogen), P (phosphorus), and K (potassium) (Vinnerås 2002; Jönsson *et al.* 2004) but it also contains high levels of pathogens (Schönning & Stenström 2004). Therefore, disposal or reuse of untreated FS is a serious threat to public health and the environment. Installation, operation, and maintenance of fecal sludge treatment plants (FSTP) is expensive and not easily affordable, mainly for developing countries. It is important to find new methods for FS treatment to make such FSTP sustainable. Composting is the aerobic mineralization process of organic matter, and co-composting is the composting of other organic matter with fecal matter. Composting of dried fecal sludge (DFS) reduces enteric pathogens efficiently due to the high temperature and antibiotic compounds formed during composting (Adeleye *et al.* 2004; Koné *et al.* 2007; Germer *et al.* 2010). Composting mineralizes nutrients, increasing their plant uptake in agriculture (Sánchez-Monedero *et al.* 2001).

Untreated/partially treated/treated FS has been used as fertilizer or soil amendment for several decades (Cofie *et al.* 2005). Conventional composting or co-composting of DFS are simple methods to treat DFS. Further treatments, for example, gamma irradiation, N-enrichment, and pelletizing increase the production costs, although N-enrichment of DFS composts improves its fertilizing value by increasing readily plant-available N. Pelletizing is a simple compacting process, which reduces the volume of compost, increases its commercial value and makes nutrients release slowly. Pelletizing makes spreading the DFS compost more accurate and

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safer, as compost powder dust can be a potential occupational risk (Tolvanen *et al.* 1998).

Although DFS-based fertilizer can be produced using different methods, its potential feasibility should be studied for sustainability and commercialization. Enrichment of N into DFS-based fertilizers can make new organo-mineral fertilizers (mixtures of organic and mineral fertilizing components) that improve its fertilization value. The main objective of this study is to test if FS products enriched with mineral fertilizers would have fertilizer value for maize cultivated in Ferric Lixisol and Cambisol media. This testing was done by comparing different types of DFS-based pellet fertilizers with (1) a commercial agro-industrial waste compost, (2) mineral NPK fertilizer, and (3) non-fertilization (control), and to evaluate the chemical quality of maize grains fertilized with those different types of fertilizer. Maize was selected because it is the most important cereal crop for more than 1.2 billion people in sub-Saharan Africa (IITA report) and maize stalks are used as animal feed.

MATERIALS AND METHODS

Dewatered and DFS compost pellet materials

Several trucks of FS were poured into a sand filter drying bed in Nungua, Accra (5 ° 33′N). The sludge was dewatered and dried under equatorial sunlight for 2–3 weeks. The DFS was processed as follows: (1) DFS irradiated by gamma radiation (20 kGy for 48 h), (2) DFS composted alone, and (3) DFS co-composted with sawdust (SD) (1:3). Composting time was allowed to continue until the compost temperature dropped to ambient temperature, which took 60 days for DFS composting and 100 days for DFS with SD co-composting. After composting, the mature composts were ground and enriched with NH_4NO_3 to achieve 3% N content and mixed with gamma-radiated starch or pre-gelatinized starch (3%), and finally pelletized. The pellets were sun-dried and nutrient contents were analyzed (Table 1). The formulations and procedure are described in detail by Nikiema *et al.* (2013).

Cultivation experiment and yield analyses

The cultivation experiment was carried out in a greenhouse at Valley View University Accra (5 ° 33′N). This greenhouse has a transparent polyvinyl chloride roof allowing daily, almost 12 h, solar radiation and mosquito netting covering all four walls protecting plants against animal damage. The greenhouse did not have climate-control; thus indoor and ambient temperatures were similar. Ferric Lixisol (a sandy loam soil) was collected from the University of Ghana Crop Science Research Farm at Legon (Greater Accra Region, Ghana) and Cambisol from the University of Ghana Forest and Horticultural Crops Research Centre-Kade (Eastern

Table 1 | Chemical properties of ECO-F (agro-industrial waste compost), IN-F (mineral fertilizer as NH_4NO_3), I-DFS-IR (gamma-irradiated DFS, not composted, pelletized with gamma-irradiated cassava starch), EC-DFS-IR/PG (N-enriched DFS compost pelletized either with irradiated cassava starch or with pre-gelatinized cassava starch), and EC-SDFS-PG (N-enriched DFS + SD compost pelletized with pre-gelatinized cassava starch)

	Different types of fertilizers				
Parameters	**ECO-F**	**IN-F**	**I-DFS-IR**	**EC-DFS-IR/PG**	**EC-SDFS-PG**
Total-N (%)	3.2	35	2.8	2.6	2.5–3
NH_4 (%)	NK	17.5	1.02	0.88	0.05
NO_3 (%)	NK	17.5	0.48	0.61	0.03
Available-P (%)	3.3 (P_2O_5)	NK	0.07	0.02	0.01
Total-P (%)	1.45	NK	2.74	1.38	0.33
Total-K (%)	3.2	NK	0.46	0.68	0.25
Organic C (%)	30.6	0	70.2	65.1	71.3
pH	7.00	NK	7.34	6.62	8.66
EC (μS/cm)	NK	NK	1,690	1,100	3,050

NK, not known.

Region, Ghana) from the top soils of 0–15 cm. The soil samples were air-dried and sieved with a mesh size of 2 mm. Pots (surface area 0.07 m^2) were filled with 15 kg of the sieved samples, which will be further considered as cultivation/growing media.

The cultivation of maize (*Zea mays* L. Ver. Abelehii) was conducted using no-fertilization (control) and six fertilization treatments: (1) mineral fertilizer as NH_4NO_3 (IN-F); (2) agro-industrial waste compost (ECO-F); (3) gamma-irradiated DFS (not composted) pelletized with gamma-irradiated cassava starch (I-DFS-IR); (4) N-enriched DFS compost pelletized with irradiated cassava starch (EC-DFS-IR); (5) N-enriched DFS compost pelletized with pre-gelatinized cassava starch (EC-DFS-PG); and (6) N-enriched DFS + SD compost pelletized with pre-gelatinized cassava starch (EC-SDFS-PG). The DFS-based fertilizers were fortified with NH_4NO_3 to 3% N. In addition, P was applied as triple superphosphate (TSP containing 20% P) and K was applied as KCl (muriate of potash containing 50% K) (Table 2). The fertilizations were adjusted to correspond to NPK 150-150-170 kg/ha and 210-204-240 kg/ha. All pots were placed on the tables as a completely randomized block design with three replicates.

Maize was seeded on 03/08/2012 and harvested on 15/11/2012. The temperature varied from 26.9 °C to 33.7 °C. Pots were irrigated to maintain moisture at 40–60% of field capacity. Plant height, girth circle at the lower end, number of leaves, and leaf area were recorded at the flowering stage. Harvested maize grains, cobs, and other shoot and root biomasses were dried under direct sun for about 7 days and weighed. Total-N, ammonium-N, nitrate-N, total-P, and total-K were analyzed from crops and maize grains. The total-N, ammonium-N, nitrate-N, total-P, P_2O_5, total-K, K_2O and pH, OM and organic carbon (OC) of growth media were analyzed before and after harvesting (Table 3).

Total-N was determined by the Kjeldahl method and the OC by the wet oxidation method (Walkley & Black 1934). The soil OM content was estimated by multiplying the OC by a factor of 1.724 (Baldock & Skjemstad 1999). Total-P was determined by acid digestion and determined with a spectrophotometer (Perkin Elmer Lambda 45) using Bray 1 method (Okalebo *et al.* 2002). Total-K was determined after digestion with a ternary mixture (20 mL $HClO_4$ + 500 mL HNO_3 + 50 mL H_2SO_4) using a flame photometer (Jenway PFP7).

Data analysis

The basic data calculations were performed with Microsoft Office Excel 2010. SPSS 19 was used for the statistical analyses. The data were analyzed for normality and the normally-distributed data were analyzed using one-way ANOVA combined with the Tukey test or LSD; the non-normally distributed data were analyzed using the Mann–Whitney test.

The N-enriched DFS compost pelletized using gamma-irradiated starch (EC-DFS-IR) and pre-gelatinized starch (EC-DFS-PG) gave similar results. Therefore, these two treatments were merged and named as EC-DFS-PG/IR. The maize yields results are presented as tons per hectare; this calculation is based on the number of maize plants per hectare (Koli 1971).

Table 2 | Applied amounts of fertilizers in both growth media

	Ferric Lixisol and Cambisol	
Treatments g/pot	**150 kgN/ha**	**210 kgN/ha**
Control	None	None
IN-F mineral fertilizer (NH_4NO_3 + P + K)	3.06 g (+ TSP 5 g + KCl 2.3 g)	4.3 (+ TSP 7 g + KCl 3.2 g)
ECO-F	36 (+ TSP 2.2 g)	50 (+ TSP 3 g)
I-DFS-IR	36 (+ KCl 2 g)	50 (+ KCl 2.7 g)
EC-DFS-IR/PG	36 (+ TSP 2.4 g + KCl 1.8 g)	50 (+ TSP 3.4 g +KCl 2.5 g)
EC-SDFS-PG	36 (+ TSP 4.3 g + KCl 2.1 g)	50 (+ TSP 6 g + KCl 3 g)

For the application rate of 150 kgN/ha, each pot received 1.07 gN. For the application rate of 210 kgN/ha each pot received 1.5 gN.
See abbreviations in Table 1.
TSP, triple superphosphate.

Table 3 | Chemical properties counted for dry weight of Ferric Lixisol and Cambisol growth media before cultivation and after maize harvesting

		After maize harvesting					
	Before cultivation	Control (no fertilization)	IN-F	ECO-F	I-DFS-IR	EC-DFS-IR/PG	EC-SDFS-PG
Ferric Lixisol							
Total-N (g/kg)	1 ± 0.1	0.7 ± 0.1a	1 ± 0.1bc	0.9ab	1.1 ± 0.1bc	1.1c	1.1 ± 0.1bc
Total-P (g/kg)	ND	1.9 ± 0.3a	2.3 ± 0.2ab	2.8 ± 0.4abc	3.6 ± 0.4c	3.0 ± 0.4c	3 ± 0.2abc
Total-K (g/kg)	0.5	0.3	0.3 ± 0.1	0.4 ± 0.1	0.5	0.4	0.4 ± 0.1
NH_4-N (mg/kg)	175 ± 9	262 ± 37a	327 ± 19bc	311 ± 24ab	383 ± 31cd	353 ± 18bcd	401 ± 24d
NO_3-N (mg/kg)	11.5 ± 1	22.9 ± 1.8a	38.1 ± 10.3b	33.7 ± 5.9ab	28.1 ± 2.8ab	37 ± 6ab	36.9 ± 4.1ab
OM%	1.6 ± 0.08	ND	ND	ND	ND	ND	ND
C%	0.93 ± 0.05	ND	ND	ND	ND	ND	ND
pH	6.7	ND	ND	ND	ND	ND	ND
Cambisol							
Total-N (g/kg)	2 ± 0.2	0.8 ± 1a	0.9a	1.3 ± 0.1b	1.4 ± 0.1b	1.53 ± 0.1b	1.4 ± 0.1b
Total-P (g/kg)	ND	2.7 ± 0.1a	3.7 ± 0.3ab	3.5 ± 0.3ab	4.2 ± 0.4ab	4.9 ± 0.5b	4.2 ± 0.2ab
Total-K (g/kg)	2	0.4	0.4	0.5	0.5	0.6 ± 0.1	0.5
NH_4-N (mg/kg)	194.4 ± 10	287 ± 24a	354 ± 28ab	343 ± 14ab	391 ± 17b	375 ± 26b	394 ± 48b
NO_3-N (mg/kg)	14.6 ± 2	28.8 ± 2.7ac	31.3 ± 1.8cd	38 ± 2.1b	33.4 ± 3.6d	36 ± 3d	39.9 ± 1.1b
OM%	1.78 ± 0.17	ND	ND	ND	ND	ND	ND
C%	1.03 ± 0.1	ND	ND	ND	ND	ND	ND
pH	7.2	ND	ND	ND	ND	ND	ND

Pooled data of both fertilizer application rates (i.e., 150 kgN/ha and 210 kgN/ha) ($N = 3$).
See the abbreviations in Table 1. ND, not determined.
Different letters in the same parameter in the same rows after harvesting are significantly different to each other in both growth media.

RESULTS AND DISCUSSION

Maize plant growth and grain yield

The height of maize plants grown with DFS compost pellet fertilizers and mineral fertilizer were highest and similar to each other in both N-application rates in Ferric Lixisol and Cambisol media. The similar plant height can be attributed to the similar availability of nutrients from these fertilizers (Vanlauwe *et al.* 2001; Adamtey 2010). The maize plant heights averaged 105 vs. 88 cm, leaf numbers averaged 13 vs. 10, leaf area averaged 908 vs. 707 cm^2, and girth circle averaged 7 vs. 6 cm in the Cambisol and Ferric Lixisol media, respectively. The fertilizer value of DFS-based fertilizer is better in the Cambisol than in the Ferric Lixisol for maize cultivation, when growth parameters were analyzed without considering the fertilizer treatments and N-application rates. The better growth in the Cambisol might be caused by its higher nutrient content (Table 3).

The grain yields of this study (4.4 tons/ha for the Cambisol and 3.1 tons/ha for the Ferric Lixisol) for the co-composted DFS pellets at 210 kgN/ha (Table 4) were higher than the yield produced by compost or mineral fertilizer (Adamtey 2010; Pradhan *et al.* 2013). This might be because the nutrition release pattern of organo-mineral pellets is better (Alemi *et al.* 2010) than the non-pelleted compost used by Adamtey (2010) and Pradhan *et al.* (2013). The co-composted DFS produced 2 tons/ha (almost two times) more maize grains than the agro-industrial waste compost (ECO-F) in both soils and at both N-application rates (Table 4). This result showed that co-composted DFS can be used instead of ECO-F, and it can produce even higher maize yields. The high yield in co-composted DFS might be because of its organo-mineral compared to organic fertilizer alone (Soumaré *et al.* 2003; Mkhabela & Warman

Table 4 | Maize grain yield (DW tons/ha), total biomass (DW tons/ha) and percentages of N, P, and K in maize grains produced using different fertilizer treatments and difference in N-application rates in both growth media ($N = 3$)

Fertilizers	N-application rates	Control	IN-F	ECO-F	I-DFS-IR	EC-DFS-IR/PG	EC-SDFS-PG
Ferric Lixisol							
Grain yield	150 kgN/ha	0.5 ± 0.2a	1.7 ± 0.2b	0.4 ± 0.1a	0.7 ± 0.2a	0.7 ± 0.1a	1.1 ± 0.2c
	210 kgN/ha	0.4 ± 0.2a	1.8 ± 0.6b	0.5 ± 0.2a	1.0 ± 0.2ab	1.2 ± 0.1ab	3.1 ± 0.6c
Total biomass	150 kgN/ha	1.2 ± 0.2a	6.4 ± 1.5bd	2.1 ± 0.3ac	3.4 ± 0.1ce	5.5 ± 0.8de	7.7 ± 0.5d
	210 kgN/ha	1.4 ± 0.2a	6.3 ± 0.4b	2.3 ± 0.2ac	3.3 ± 0.6cd	5.6 ± 0.4b	4.8 ± 0.9d
N%	150 kgN/ha	0.8 ± 0.03	0.9 ± 0.06	0.9 ± 0.1	0.9 ± 0.03	0.8 ± 0.3	1.0 ± 0.1
	210 kgN/ha	0.9 ± 0.1	0.9 ± 0.1	0.8	0.8 ± 0.03	0.8 ± 0.03	1.0 ± 0.03
P%	150 kgN/ha	0.4 ± 0.03a	0.5 ± 0.02b	0.7 ± 0.02c	0.8 ± 0.02d	0.7 ± 0.02c	0.8 ± 0.02d
	210 kgN/ha	0.4 ± 0.02a	0.6 ± 0.01b	0.8 ± 0.03c	0.9 ± 0.02c	0.8 ± 0.05c	0.8 ± 0.03c
K%	150 kgN/ha	2.2 ± 0.2ab	2.0 ± 0.13a	2.1 ± 0.12ab	2.3 ± 0.2ab	2.5 ± 0.2b	2.1 ± 0.16ab
	210 kgN/ha	2.0 ± 0.14a	2.5 ± 0.2bc	2.1 ± 0.14ab	2.8 ± 0.2c	2.9 ± 0.2c	1.8 ± 0.05a
Cambisol							
Grain yield	150 kgN/ha	1.7 ± 0.4a	3.3 ± 0.1b	2.4 ± 0.5ab	2.7 ± 0.1b	3 ± 0.1b	4.4 ± 0.2c
	210 kgN/ha	1.9 ± 0.1a	3.9 ± 0.7bc	2.2 ± 0.5ab	2.1 ± 0.3ab	3.8 ± 0.4abc	4.4 ± 1.5c
Total biomass	150 kgN/ha	6.5 ± 0.5a	7.8 ± 0.5ab	7.4 ± 1.0ab	9.4 ± 1.1ab	9.9 ± 1.7ab	11.6 ± 1.9b
	210 kgN/ha	13.5 ± 1.9a	15.1 ± 0.6ab	12.5 ± 3.9a	12.8 ± 3.2ab	18.4 ± 1b	15.3 ± 0.2ab
N%	150 kgN/ha	0.8 ± 0.02	0.9 ± 0.05	1.0 ± 0.04	0.8 ± 0.1	1.1 ± 0.1	0.9 ± 0.05
	210 kgN/ha	0.8 ± 0.02	1.0 ± 0.03	0.8 ± 0.1	1.0 ± 0.05	1.1 ± 0.1	1.0 ± 0.1
P%	150 kgN/ha	0.3 ± 0.02a	0.5 ± 0.03b	0.5 ± 0.02b	0.6 ± 0.04c	0.6 ± 0.01c	0.8 ± 0.01d
	210 kgN/ha	0.3 ± 0.01a	0.7 ± 0.02b	0.8 ± 0.02c	0.9 ± 0.03d	0.9 ± 0.01d	0.9 ± 0.02d
K%	150 kgN/ha	1.6 ± 0.2a	2.2 ± 0.2b	2.7 ± 0.3b	2.4 ± 0.2b	2.2 ± 0.2b	2.6 ± 0.3b
	210 kgN/ha	1.5 ± 0.03a	1.8 ± 0.2ac	2.5 ± 0.2d	1.7 ± 0.2a	2.2 ± 0.2dc	1.9 ± 0.1a

See the abbreviations in Table 1.
Different letters in the same rows show significant differences ($P < 0.05$) for grain yield, total biomass, and P and K.

2005; Makinde & Ayoola 2010). Another reason for the lower maize yield produced from agro-industrial waste compost may be that the agro-industrial waste compost used might have contained some chemical compounds that could inhibit the growth of maize. This result indicates that product control authorities should conduct cultivation tests as done in this work to ensure that the fertilizer value of commercial compost products compares to mineral fertilizer and non-fertilized controls.

The co-composted DFS produced similar or slightly higher maize yields than the mineral fertilizer and higher maize grain yields than the composted DFS fertilizer in both growth media (Table 4). Our results thus confirm the similar results of Makinde & Ayoola (2010). Bagheri *et al.* (2011) reported that organo-mineral pellet fertilizer produced a higher maize yield than if fertilized only with urea. This might be attributable to the nutrient-release pattern, i.e., the N-enrichment of the co-composted DFS may improve N-availability during the whole growth period (Mugendi *et al.* 1999). In addition, the co-composted DFS contained more NH_4NO_3 (1.8% N) compared to the composted DFS (1.2% N) (Nikiema *et al.* 2013), and the longer composting time of the co-composted DFS might have mineralized the nutrients better than the DFS-composted fertilizer. This result can be presented in another way, i.e., co-composted DFS produced 1.3 ton/ha (77%) more maize grains than the mineral fertilizer when applied at 210 kgN/ha in the Ferric Lixisol. Similarly, co-composted DFS produced 25% more maize grains than the mineral fertilizer when applied at 150 kgN/ha in the Cambisol.

Irradiated DFS produced similar maize grain yields to the composted DFS. A similar result is also presented by Rathod *et al.* (2009), who reported that the fertilizer quality of the gamma-irradiated sludge and farmyard manure were similar in onion cultivation. In contrast, Chmielewski *et al.* (1995) and Wen *et al.* (1995) showed that irradiated sludge produced a lower vegetable yield than non-irradiated sewage sludge. Although gamma irradiation might disinfect DFS rapidly, this method is not practical as it is expensive and seldom available.

In this experiment, the maize grain biomass and total biomass obtained from the Cambisol were significantly ($P < 0.01$) higher than those produced in the Ferric Lixisol (Table 4). When the fertilization treatments and N-application rates are disregarded, the Cambisol and Ferric Lixisol produced grain biomasses of 2.9 ± 1 and 1.2 ± 0.9 ton/ha and total biomasses of 11.7 ± 5 and 4 ± 2 ton/ha, respectively. The contents of aluminum or iron of the Ferric Lixisol were not measured but usually they tend to be rich in highly weathering soils. Therefore, these soils can fix phosphorus by sorption so that plant-availability of phosphorus is low (Dossa *et al.* 2008). Evidently, such poor soils need higher amounts of N-enriched compost/co-compost to achieve significantly higher yields. As fertilizers were more effective in the Cambisol, it would be essential to improve the fertility of the Ferric Lixisol to improve the yields. The P-availability of organic fertilizers can be higher than that of mineral fertilizers, since organic matter can hinder the P-sorption to too-high soil iron and thus be better (Kahiluoto *et al.* 2015). It would be useful to apply N-enriched compost or co-compost for several growth seasons to reduce P-sorption capacity and to improve soil fertility for a longer duration.

Chemical quality of maize grains

The N-concentrations in maize grains produced by DFS-based fertilizers and mineral fertilizers in both soils were similar (Table 4). This result confirmed that the chemical quality of maize grain produced by DFS or mineral fertilizer is similar. Although the N percentage in maize grain varies due to several factors, the N percentages of maize in this study were lower than in maize variety TZEE-W (Hussaini *et al.* 2008). Crop response to N-fertilizer is also influenced by growth media, crop sequence, and the supply of nitrogen. The differences in percentages of P and K were small in spite of the fact that there were some statistically significant differences (Table 4) according to the nutrient content in the fertilizer (Table 1), application rates, and growth media (Table 4).

Residual nutrients in growth media

If one neglects the growth media types and N-application rates, the residual N in composted DFS and co-composted DFS-treated growth media were similar and significantly higher ($P < 0.05$) compared to mineral fertilizer. This might be because DFS-based fertilizer contains readily available mineral-N and slow release organic-N. Furthermore, DFS-based fertilizer supplies organic matter to soil, increasing N-concentrations in the growth media. The residual N, P, and K were significantly higher in the Cambisol than in the Ferric Lixisol (Table 3), evidently because the richer Cambisol can hold nutrients better than the Ferric Lixisol. In both growth media, the residual NH_4-N was higher when DFS fertilizers were used compared to agro-industrial waste compost and mineral fertilizer. This might be because of the slow release of nutrients in pellet fertilizers (Alemi *et al.* 2010). These results showed that there can be significant amounts of residual nutrients, especially phosphorus (Table 3), when fertilization employs DFS pellets in the Lixisol, and these nutrients might be available for subsequent crops.

CONCLUSIONS

Nitrogen-enriched DFS compost and co-compost pellets are good maize fertilizers. The application rate of DFS compost pellets should be 210 kgN/ha in poor Ferric Lixisol and 150 kgN/ha in richer Cambisol to achieve similar or greater yields than using the same N-application rates of mineral fertilizer. The co-composted DFS pellets were better than the composted DFS pellets. The N-content in maize grain fertilized with DFS-based products was similar to that of maize grain fertilized with mineral fertilizer. In fact, DFS-based organo-mineral compost/co-compost pellets are complete fertilizers, meaning that these products can be applied as lone fertilizers for maize. Furthermore, the N-contents of the pellet fertilizers can be manipulated according to the nutrient demands of different crops. This result will encourage people to use N-enriched DFS compost/co-compost pellets, contributing to increased food security and improved sanitary conditions.

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