

Research Application Summary

Efficacy of selected crop residues and rock phosphate in improving the quality of cattle manure

Essel, B.^{1*}, Ewusi-Mensah, N.¹, Opoku, A.¹ & Abaidoo, R.^{2,3}

¹Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

²Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi, Ghana

³International Institute of Tropical Agriculture, PMB 5320, Oyo Road, Ibadan

Corresponding author: esselbenedicta@yahoo.com

Abstract

Cattle manure is noted for its poor nutrient quality especially in Ghana where most cattle are fed on a free range. There is therefore a need to improve its quality since it is a vital nutrient resource for smallholder farmers. An experiment was thus carried out by composting cocoa pod husk (CPH), palm kernel cake (PKC) and rock phosphate (RP) to investigate their effectiveness for use as nutrient sources for improving the fertilizer value of cattle manure (CM). Four compost ratios (CM + PKC (3:1), CM + CPH (3:1), CM + RP (3:1) and CM + PKC + CPH + RP (3:1:1:1)) replicated three times in a Randomized Complete Block Design (RCBD) were formulated. The results showed that the addition of CPH, PKC and RP to CM improved the fertilizer value of cattle manure. The CM + PKC + CPH + RP (3:1:1:1) compost increased the N, P and K contents of cattle manure by 73 %, 145 % and 50 %, respectively and was therefore considered the most effective in enhancing the nutrient value of cattle manure. Hence, cocoa pod husk, palm kernel cake and rock phosphate can be used for improving the fertilizer value of cattle manure.

Keywords: cattle manure, cocoa pod husk, enriched compost, fertilizer value, palm kernel cake

Resume

Le fumier de vache est connu pour sa mauvaise qualité nutritive, en particulier au Ghana où la plupart des bovins sont nourris en plein air. Il est donc essentiel d'améliorer sa qualité puisqu'il constitue une ressource vitale en nutriments pour les petits agriculteurs. Une expérience a donc été réalisée en compostant des coques de cabosses de cacao (CPH), des tourteaux de palmiste (PKC) et du phosphate naturel (RP) pour étudier leur efficacité en tant que sources de nutriments pour améliorer la valeur fertilisante du fumier de bovin (CM). Quatre ratios de compost (CM + PKC (3:1), CM + CPH (3:1), CM + RP (3:1) et CM + PKC + CPH + RP (3:1:1:1)) étaient placés sous dispositif en blocs complets randomisés (RCBD) sur trois répétitions. Les résultats ont montré que l'ajout de CPH, PKC et RP au CM améliorait la valeur fertilisante du fumier de bovin. Le compost CM + PKC + CPH + RP (3:1:1:1) a augmenté les teneurs en N, P et K du fumier bovin de 73 %, 145 % et 50 % respectivement et a donc été considéré comme le plus efficace pour améliorer la valeur nutritive du fumier de bovin. Par conséquent, la coque de cabosse de cacao, le tourteau de palmiste et le phosphate naturel peuvent être utilisés pour améliorer la valeur fertilisante du fumier de bétail.

Mots clés : fumier de bovin, cosses de cabosses de cacao, compost enrichi, valeur fertilisante, tourteau de palmiste

Introduction

Ghana, like many other countries in Africa, has been facing an escalating soil fertility crisis over decades with predicted losses of 35, 4 and 20 kg/ha, respectively, for N, P and K annually (Jayne *et al.*, 2015). This has often occurred through drivers such as nutrient mining by crops, leaching of soil nutrients and inappropriate management practices resulting from lack of fallow periods, deforestation, and land degradation (Morris *et al.*, 2007). In view of this, Morris *et al.* (2007) suggested that intensive agriculture cannot be sustained unless mineral or organic or both nutrient sources are applied to the soil to replace the ones removed through increased crop production.

The use of organic fertilizers in the form of agricultural residues, manures and composts for soil fertility improvement is paramount (Omotayo and Chukwuka, 2009). The commonly used organic manures in Ghana are cattle and poultry manures. Out of these two manures, cattle manure has a relatively low nutrient content (1.20 % N, 0.07 % P, 0.09 % K, 0.25 % Ca, and 0.08 % Mg) as compared to poultry manure (2.20 % N, 0.77 % P, 0.91 % K, 1.70 % Ca and 0.42 % Mg) (FAO, 2005). The poor quality of cattle manure significantly impedes its adoption for application (Vanlauwe and Giller, 2006) resulting in high quantities needed for application. These problems associated with its use call for research aimed at optimizing cattle manure to enhance its quality. Most studies have attempted improving the N content of manure using crop residues (Kolade *et al.*, 2006; Ewusi-Mensah, 2009) and P using agro-minerals (Mahimairaja *et al.*, 1995) by composting. However, such studies did not simultaneously address other major macronutrients which are essential for plant growth.

Agricultural wastes are readily available in Ghana. Common agricultural wastes which have the potential of being used as sources of organic fertilizer include: cocoa pod husk (CPH), palm kernel cake (PKC), cattle manure (CM), poultry manure (PM), among many others. Cocoa pod husk contains approximately 1.47 % N, 0.19 % P and 3.35 % K (Adamtey, 2005) and thus, can serve as a rich source of potassium. Similarly, the burning of PKC in agro-processing industries has become an environmental concern that could be resolved by composting and application to the soil as a rich source of nitrogen (2.88 %) (Kolade *et al.*, 2006). Rock phosphate has a relatively high P content (28 —30 %). However, it cannot be used directly as a fertilizer due its slow P release for plant use (Reddy *et al.*, 2002). Cattle manure also contains approximately 0.52 - 1.40 % N and 0.28 — 0.76 % P (Fening *et al.*, 2005). Different agricultural wastes have varying concentrations of nutrients and thus, will supply relatively different quantities of nutrients following mineralization. Their mineral composition gives an indication of their potential for use as a soil amendment. The use of agricultural wastes will therefore be of immense benefit to farmers, as it is a sustainable and environmentally friendly way of restoring and maintaining soil fertility and productivity (Agbeniyi *et al.*, 2011). Composting agricultural wastes as a means of improving soil fertility and enhancing soil carbon sequestration (Ganunga *et al.*, 1998) acts as a long-term reserve and a slow-release source of soil nutrients (N, P, K) (Sullivan *et al.*, 2002). It was therefore envisaged in this study that when agricultural wastes are fully exploited, they could bridge the food security gap.

Based on the hypothesis that composting cattle manure with rock phosphate, cocoa pod husk and palm kernel cake can increase fertilizer value of manure, this study was carried out to assess the effectiveness of using rock phosphate, cocoa pod husk and palm kernel cake for improving the fertilizer value of cattle manure.

Research Approach.

This study was conducted at the experimental farm of the Department of Crop and Soil Sciences, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology (KNUST), Kumasi-Ghana. The resource materials used in the compost preparation were cattle manure (CM), palm kernel cake (PKC), cocoa pod husk (CPH) and rock phosphate (RP). The different resource combinations and their respective ratios (w/w) were: CM + PKC, 3:1; CM + CPH, 3: 1; CM + RP, 3:1 and CM + PKC + CPH + RP, 3:1:1:1. The compost combinations which constituted the treatments were arranged in RCBD with three replications. The parameters determined prior to and after composting were organic C, total N, total P, total K, dry matter content, lignin, polyphenol, and C:N ratio. Organic carbon, total N, total P and total K were determined using standard procedures as described by Motsara and Roy (2008). Lignin and polyphenol contents were also determined using the acid detergent fibre method and Folin-Denis method, respectively, as described by Anderson and Ingram (1998). All data collected during composting were subjected to One-way Analysis of Variance (ANOVA) using a General Statistical Software Package (GenStat, 2009). Results were then presented as means for each treatment while Fischer's protected Least Significance Difference (LSD) method was used for means separation at $p < 0.05$.

Results

Selected chemical characteristics of resources used. The chemical characteristics of the organic resources used for the compost are reported in Table 1. The CPH had the highest OC content (45.4 %), while CM had the least (31.2 %). The total N contents of CM, CPH and PKC was 1.5 ± 0.2 , 1.7 ± 0.4 , and 2.5 ± 1.1 , respectively. The highest C:N ratio of 29.2 was recorded in CPH. Cocoa pod husk contained the highest dry matter content, whereas CM had the least N content.

Table 1. Selected chemical characteristics of resources used in composting

Parameter	CM	CPH Mean $\pm$ SD	PKC
Organic C (%)	31.2 $\pm$ 12.9	45.4 $\pm$ 4.2	43.2 $\pm$ 14.8
Total N (%)	1.5 $\pm$ 0.2	1.7 $\pm$ 0.4	2.5 $\pm$ 1.1
Total P (%)	1.1 $\pm$ 0.8	1.0 $\pm$ 0.9	1.4 $\pm$ 1.6
Total K (%)	0.4 $\pm$ 0.1	0.3 $\pm$ 0.3	2.0 $\pm$ 1.6
Lignin (%)	12 $\pm$ 12.7	20.5 $\pm$ 3.5	8.5 $\pm$ 2.1
Polyphenol (%)	0.4 $\pm$ 1 0.2	0.5 $\pm$ 0.0	0.3 $\pm$ 0.0
Dry matter (%)	85.3 $\pm$ 12.4	91.0 $\pm$ 4.8	87.1 $\pm$ 7.2
C: N	20.9 $\pm$ 6.4	29.2 $\pm$ 11.3	22.4 $\pm$ 16.6

Values are means for three replicates; *Rock phosphate contains 30 % P₂₀₅ (13.2% P) CPH: cocoa pod husk, CM: cattle manure, PKC: palm kernel cake, SD: standard deviation

Potential of the resources used in enhancing the fertilizer value of cattle manure. Table 2 shows that the addition of the different resources (CPH, PKC and RP) to cattle manure (CM) increased its nutrient content after composting. The additives significantly ($p < 0.001$) increased the total N and P of the four compost types with CM + PKC + CPH + RP producing a significantly higher N followed by CM + PKC. The addition of RP to CM through composting relatively increased the P content of cattle manure by 155 %. The addition of PKC to CM also resulted in relatively increasing the N and K contents of CM by 33 and 25 %, respectively. Furthermore, cattle manure plus CPH combination also increased the K content of the CM by 50 %. Composting cattle manure with CPH, PKC and RP resulted in a tremendous increase in the fertilizer value of cattle manure. Generally, the addition of PKC, RP and CPH to cattle manure and composting resulted in simultaneously increasing the N, P and K contents of cattle manure by 73, 145 and 50 %, respectively.

Table 2. Contribution of cocoa pod husk, palm kernel cake and rock phosphate to the nutrient content of cattle manure

Resource material	Nutrient concentration		
	Total N	Total P	Total K
CM + RP (3:1)	1.2	2.8	0.5
CM + PKC (3:1)	2.0	0.5	0.5
CM + CPH (3:1)	1.6	0.3	0.6
CM+PKC+CPH+RP(3:1:1:1)	2.6	2.7	0.6
Fpr.	< 0.001	< 0.001	0.240
LSD (0.05)	0.21	0.14	0.20
CV (%)	5.6	4.4	17.9

CPH: cocoa pod husk, CM: cattle manure, PKC: palm kernel cake, RP: rock phosphate, CV: coefficient of variation, LSD: least significant difference

Discussion

Chemical characteristics of the selected resource materials. The quality of agricultural resource materials is largely determined by their chemical characteristics. The total N, P and dry matter content of CPH determined were greater than those stated by Adamtey (2005) that CPH contained 1.47 % N, 0.19 % P and 3.35 % K for CPH. Also, with PKC, the total K content was greater (2.0 %) than the 0.06 % value reported by Adamtey (2005) and Kolade *et al.* (2006). With the low percentage of total N recorded in CM and CPH, it is probable that when they are applied to the soil directly without composting, there would be immobilization of soil nutrients. Hence, the need for fortification. It was also observed that, among the other organic resources, PKC had the highest total N and K (Table 1). Similar observation was made by Roy *et al.* (2006) who reported greater nutrient content in processed residues like oilcakes than conventional crop residues. The C:N ratio of CPH (29.2: 1) and CM (20.9: 1) and PKC (22.4: 1) were above the critical value of 20 - 25 and hence their application will immobilize soil N (Burgess *et al.*, 2002). The greater C: N of CPH was due to its relatively low N and higher C content relative to PKC and CM. Each of the organic resource materials is unique with respect to their chemical characteristics. Since applying them individually to the soil may result in immobilization of soil nutrients due to poor quality, there was the need to exploit the nutrients in them by composting with cattle manure and quantifying the contribution of each additive to the fertilizer value of cattle manure.

Contribution of the resource materials to improving the fertilizer value of cattle manure. The addition of rock phosphate, cocoa pod husk and palm kernel cake to cattle manure increased the fertilizer value of cattle manure after the composting process (Table 2). This confirms an assertion by Roy *et al.* (2006) that composting can improve the value of crop residues as sources of nutrients. Kolade *et al.* (2006) and Fening *et al.* (2010) recorded the use of crop residues to increase the fertilizer value of goat manure, poultry manure and cattle manure. However, the nutrient increase observed in this study is greater than the ones observed by earlier researchers. Earlier studies only increased the N content of the manures in question. However, the CM + PKC + CPH + RP (3:1:1:1) compost produced in this study increased the N, P and K content of cattle manure. Kolade *et al.* (2006) increased the N content of poultry manure (PM) by 24 % by composting with palm kernel cake (PKC) in a PKC + PM compost (3:1). Similarly, the N content of goat manure (GM) was increased by 28 % by composting with palm kernel cake in PKC + GM compost (3:1) (Kolade *et al.*, 2006). Unlike Fening *et al.* (2010) who registered a rise in the N content of cattle manure compost by 53 %, the addition of PKC, CPH and RP to CM by composting in this study increased the N, P and K contents of CM by approximately 73, 145 and 50 %, respectively.

Conclusion

In order for any organic resource material to satisfy conditions as a soil fertilizing agent, it must have adequate nutrient concentrations and a low C:N ratio to enhance mineralization rate and possible nutrient release to support plant growth. At the end of the study, it was observed that, addition of cocoa pod husk, palm kernel cake and rock phosphate to cattle manure and composting improved the fertilizer value of cattle manure. The addition of palm kernel cake to cattle manure increased the nitrogen content of cattle manure. Rock phosphate and cocoa pod husk contributed to an increase in the phosphorus and potassium contents of the cattle manure, respectively. The CM + PKC + CPH + RP (3:1:1:1) compost resulted in the best combination, confirming the null hypothesis that, composting cattle manure with rock phosphate, cocoa pod husk and palm kernel cake increases the fertilizer value of manure. The CM + PKC + CPH + RP (3:1:1:1) compost increased the N, P and K contents of cattle manure by 73, 145 and 50 %, respectively. This implies that, rock phosphate, cocoa pod husk and palm kernel cake can potentially be exploited for use as nutrient amendments for improving the nutrient contents of cattle manure and for subsequent soil fertility improvement.

Acknowledgements

Kwame Nkrumah University of Science and Technology (KNUST) funded the research activities through a sub-agreement with the Alliance for Green Revolution in Africa (AGRA) under the AGRA Ph.D. Training in Soil Science in West Africa funded by Bill and Melinda Gates Foundation (USA) (i.e. Grant Number 2009 SHP 028). This paper is a contribution to the Fifteenth RUFORUM Annual General Meeting held 2-6 December 2019 in Cape Coast, Ghana.

References

- Adamtey, N. 2005. Evaluation of agricultural and agro- industrial residues for composting for agricultural use in Ghana: A case study in the Kwaebibirem District. MPhil Thesis, University of Ghana, Legon. 171 pp.
- Agbeniyi, S.O., Oluyole, K.A. and Ogunlade, M.O. 2011. Impact of cocoa pod husk fertilizer on cocoa production in Nigeria. *World J. Agric. Sci* 7 (2): 113-116.
- Anderson, J. M. and Ingram, J. S. I. (eds). 1998. Tropical Soil Biology and Fertility. A handbook of methods. 2nd edition. Oxford University Press.
- Burgess, M. S., Mehuys, G. R. and Madramootoo, C. A. 2002. Nitrogen dynamics of decomposing corn residue components under three tillage systems. *Soil Science Society of America Journal* 66 (4): 1350-1358.
- Ewusi-Mensah, N. 2009. Optimizing manure quality for increased food production on small holder farms in the Upper East Region of Ghana. PhD Thesis, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana. 205 pp.
- Food and Agriculture Organization (FAO). 2005. Fertilizer use by crop in Ghana. Land and Plant Nutrition management Service, Land and Water Development Division, Food and Agriculture Organization of the United Nations, Rome. 39pp.
- Fening, J. O., Adjei-Adjapong, T., Yeboah, E., Ampontuah, E. O., Quansah, G. and Danso, S.K.A. 2005. Soil fertility and potential organic inputs for improving smallholder crop production in the interior savanna zone of Ghana. *J. Sustain. Agric* 25:69-92.
- Fening, J.O., Ewusi-Mensah, N. and Safo, E. Y. 2010. Improving the fertilizer value of cattle manure for sustaining small holder crop production in Ghana. *Journal of Agronomy* 9: 92 - 101.
- Ganunga, R. P., Yerokun, O. and Kumwenda, J. D. T. 1998. Tithonia diversifolia: An organic source of nitrogen and phosphorus for maize in Malawi. *Journal of Soil Science and Environmental Management* 6 (3): 58-67.
- GenStat. 2009. GenStat Release 12.1 (PC/Windows Vista), GenStat Procedure Library Release PL20.1, VSN International Ltd.

- Jayne, T. S., Kolavalli, S., Debrah, K., Ariga, J., Brunache, P., Kabaghe, C., Rodriguez, W.N., Baah, K.O., Bationo, A.A., Huising, E.J. and Lambrecht, I. 2015. Towards a Sustainable Soil Fertility Strategy in Ghana. Report submitted to the Ghana, Ministry of Food and Agriculture, Accra, Ghana. 30 pp.
- Kolade, O. O., Coker, A. O., Sridhar, M. K. C. and Adeoye, G. O. 2006. Palm kernel waste management through composting and crop production. *Journal of Environmental Health Research* 5 (2): 81-86.
- Mahimairaja, S., Bolan, N.S. and Hedley, M.J. 1995. Agronomic effectiveness of poultry manure composts. *Commun. Soil Sci. Plant Anal* 26: 1843- 1861.
- Morris, M., Kelly, V. A., Kopicki, R. J. and Byerlee, D. 2007. Fertilizer use in African agriculture: Lessons learned and good practice guidelines. World Bank Publications. ISBN 0-8213-6880-X. 162pp.
- Motsara, M. R. and Roy, R. N. 2008. Guide to laboratory establishment for plant nutrient analysis. Food and Agriculture Organization of the United Nations. FAO Fertilizer and Plant Nutrition Bulletin No. 19. ISBN 978-92-5-105981-4. 204pp
- Omotayo, O. E. and Chukwuka, K. S. 2009. Soil fertility restoration techniques in sub-Saharan Africa using organic resources. *African Journal of Agricultural Research* 4 (3): 144-150.
- Reddy, M. S., Kumar, S. and Khosla, B. 2002. Bio solubilization of poorly soluble rock phosphates by *Aspergillus niger*. *Biores. Technol* 84:187 - 189.
- Roy, R. N., Finck, A., Blair, G. J. and Tandon, H. L. S. 2006. Plant nutrition for food security. A guide for integrated nutrient management. Food and Agriculture Organization of the United Nations. FAO Fertilizer and Plant Nutrition Bulletin No. 16. 368pp.
- Sullivan, D. M., Bary, A. I., Thomas, D. R., Fransen, S. C. and Cogger, C. G. 2002. Food waste compost effects on fertilizer nitrogen efficiency, available nitrogen, and tall fescue yield. *Soil Science Society of America Journal* 66 (1): 154-161.
- Vanlauwe, B. and Gillet . E. 2006. Pop41ar myths around soil fertility management in sub-Saharan Africa. *Agriculture, Ecosystems and Environment* 116 (1-2): 34-46.