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Use of soil amendments for urban horticulture in the savannah and forest areas of Ghana

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The search for suitable alternatives to loam, manure and sand based growing media in Ghana has generated a substantial body of literature on potential amendments akin to the peat based media in developed countries. The objectives of this study were to review literature on potential soil amendments in Ghana, determine the reasons for farmer choice of amendments and determine factors influencing farmer adoption of these amendments. Document review and survey were the main methods used in data collection. The review of literature indicates that the research and discourse on soil amendment over the last two decades have largely been limited to land management and nutrient recovery from waste. Although these have largely been reported as successful, they have not addressed the quality issues of soil amendments as finished product for application in specific production systems. As the amendments are not standardized, farmers adopt varying application rates based on their own experiences. Barriers in the use of amendments were found to be the technology to collect, funds to purchase and labour employment. The agro-ecology and the farmers' level of education largely determined the use of particular amendment. The study found wide scale acceptance and adoption of sawdust based poultry litter by urban vegetable farmers, hence the co-composting of sawdust and poultry manure would be the best option that can be developed and standardised for application in urban horticulture. Future research in soil amendment should therefore focus on net N mineralisation, stability indices and the responses of vegetable and ornamental plants to different ratios of co-composting of sawdust and poultry manure.

Key words: Growing media, soil amendment, urban horticulture, composting, organic waste, urban farmers.

INTRODUCTION

The need to recover nutrients from organic waste has generated a lot of research interest in Ghana and composting of crop residues and municipal solid waste have dominated such studies (Drechsel and Gyiele, 1998; Kindness, 1999; Cofie et al., 2003; Drechsel et al., 2004; Cofie et al., 2005; Danso et al., 2006; Cofie et al., 2008; Adamatey et al., 2009). Nutrient recovery and the use of manure to improve soil physical properties have also been given some research attention (Boateng et al., 2007; Agyarko, 2007). The recommendations contained

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in the works cited so far have relevant application in land management, nutrient recovery and recycling. However, quality standards and technological issues limit the safe use of organic materials especially for urban vegetable production and landscaping in Ghana.

Over the last two decades, rapid urbanisation resulting from increasing population pressure and estate development is generally believed to have reduced land available for primary horticultural production in urban and peri-urban areas of Ghana, leading to horticultural intensification (Appeaning Addo, 2010). Horticultural intensification has included putting the urban land under continuous cultivation, use of inorganic fertilizers, reuse of wastewater and landfill soil (Jim, 1998; Amarchey, 2000; Omotayo and Chukwuka 2009; Abdul et al., 2011). Application of heavy doses of inorganic fertilizers has been widely reported to increase production, but it has also been shown to lead to eutrophication, greenhouse gas emissions and nitrate leaching (Bationo et al., 2006; Barbanti et al., 2010). Fertilizer use per farmer is projected to decline owing to the removal of subsidies in Ghana and hence the need to find alternatives to the fertilizer based farming (Boateng et al., 2007). Organic soil amendments are critical in the development of sustainable urban production systems because they are important sources of carbon and nitrogen (Liang et al., 2012; De Lucia et al., 2013a; Rinaldi et al., 2014). They are known to be important in regulating pH and contaminants transport in the soil. In contrast, excessive use of inorganic fertilizers have been shown to decouple C, N and P cycles in agro ecosystems (Yadav et al., 2011).

Poultry manure of varying qualities is used as an amendment in urban horticulture and it is reported to have lower N use efficiency especially in the first year of application (Boateng et al., 2007). Fening et al. (2008) identified cow dung and refuse dump soil (land fill soil) as soil amendments that have potential for use in the interior savannah zone of Ghana. But cattle manure is also popular among rural farmers, but when composted it takes a longer period to stabilised and release nutrients (Gomez-Brandon et al., 2008). Furthermore, farmer field level of N and P (0.52 - 1.14 and 0.28 - 0.76 respectively) in cattle manure was found to be too low for net N mineralisation (Janssen, 1993). Although Fening et al. (2008) found refuse soils to contain less contaminants and have adequate nutrient needed by plants in northern Ghana, Agyarko et al. (2010) found that refuse soils in southern Ghana were loaded with significant levels of heavy metals higher than background soils.

Fening et al. (2008) studied potential materials that could be mixed with manure and loamy based soils for safe application in both rural and urban horticulture. The studies by Fening et al. (2008) identified *Cassia absus, Daniallia oliveri* (tree legumes); *Icacina senegalensis*, and *Syzygium guineense* (shrubs); *Chromolaena odorata* (herb) and *Crotalaria spectabilis* (herbaceous legume) as plant species with high mineralization and nutrient release rates for co-composting and soil amendment development. The N and P values of these materials were found to be higher than values required for net mineralisation. *C. odorata, Panicum maximum* and P*ueraria phaseoloides* were also found to be important nutrient sources for composting and maintenance of soil fertility in Ghana (Quansah et al., 2001). In addition, crop residues such as maize stover were found to improve the fertilizer value of cattle manure (Fening et al., 2010). The composting of industrial by-products such as cocoa pod husk, coconut coir, and sawdust and rice husks has only been the subject of a few research studies (Ahenkorah and Halm, 1976; Ofosu-Budu et al., 2009; Agyarko and Aseidu, 2012). Although recommendations of the above research work have been incorporated in to farmer training programmes, availability and technical barriers have prevented further development and up scaling of the recommendations and farmers in Ghana have generally not been able to adopt the recommendations.

Despite the widely acknowledged importance of organic amendments in safe and sustainable urban production systems, there are no documented national standards in Ghana for compost and for formulations of soil amendments to guide both farmers and private companies interested in soil amendments development. As a result, there are highly variable qualities of amendments in the market and farmers arbitrarily adopt varying application rates. It is important to standardised amendment used in urban horticulture (Bakry et al., 2012). Standardising means producing amendments with consistent physical and chemical qualities and adoption of optimum and economically feasible rates of application. In order to develop standards for soil amendments, it is important to determine and document the kind of amendments urban farmers are using, why they use them and how they prepare or obtain them for use. This study therefore sort to assess the current practices in the use of amendments in Tamale (savannah area) and Kumasi (forest area). The specific objectives include to:

1. Determine awareness and adoption of common soil amendments;
2. Determine the reasons for farmers' choice of amendments;
3. Document farmers' knowledge about user challenges and determine whether factors such as location, farmer's age and educational level influence the use of amendments.

METHODOLOGY

Two main methods used to collect data for this research include document review and survey involving farmers in Tamale and Kumasi:

1. The document review: This included review of published papers on soil amendments in Ghana especially over the last two decades.

Table 1. Urban farmers' awareness of proper use of different organic manures.

Organic material	Awareness	District response (%)		Chi-square value	p-value
		Tamale	Kumasi		
Compost	Yes	50	83.3	7.5	0.006
	No	50	16.7		
Cow manure	Yes	86.7	53.3	7.937	0.005
	No	13.3	46.7		
Refuse soil	Yes	3.3	66.7	26.447	0.001
	No	96.7	33.3		
Topsoil soil	Yes	36.7	100	27.805	0.001
	No	63.3	0		
Sawdust	Yes	26.7	100	34.737	0.001
	No	73.3	0		
Rice hull	Yes	36.7	40	0.071	0.791
	No	63.3	60		

2. Survey on the use of soil amendments by farmers in Tamale and Kumasi: A preliminary survey was conducted in Tamale and Kumasi and vegetable farmers and nursery operators who were using soil amendments identified.

Questionnaire design and sampling

Sixty semi-structured questionnaires were designed and administered to 30 farmers each from Tamale and Kumasi. The questionnaire captured the profile of farmers, the types of amendments and the level of usage of soil amendments. The farmer's knowledge of the use of soil amendments as well as the challenges facing farmers in using soil amendments was documented. In both Tamale and Kumasi, vegetable production areas were soil amendments are intensively used was selected. In Tamale, urban farmers within 5 km radius of the city centre were selected and 30 farmers in all interviewed using the snowball sampling method (one farmer leads the researcher to another farmer). In Kumasi, 30 farmers cultivating vegetables within 5 km radius of Kwame Nkrumah University of Science and Technology (KNUST) were interviewed using same sampling.
Tamale was chosen to represent the savannah area because it is has the highest population (371,351) and is the most urbanised town in the savannah areas of Ghana. Kumasi represented the forest area of Ghana because it has the highest population (2,035,064) and is the most urbanised town in the forest area of Ghana (Ghana Statistical Services, 2010).

RESULTS

Farmer knowledge and awareness of proper uses of common soil amendments

As shown in Table 1, a higher percentage of urban more farmers (83%) in Kumasi were aware of the use of composted crop residues than urban farmers (50%) in Tamale χ^2 = (1, N = 60) = 7.500, p = 0.006. However, almost all urban farmers in Tamale and Kumasi were equally aware of the use of poultry as soil amendment. In contrast a higher percentage (Table 1) of urban farmers in Tamale (86%) was aware of the proper use of cow manure than urban farmers in Kumasi (53%). Table 1 also shows that, more farmers in Kumasi were aware of proper use of refuse dump soil, topsoil and sawdust for landscaping and for container production of ornamental plants (66, 100 and 100% respectively) than farmers in Tamale (3, 36 and 26% respectively).

Adoption of common soil amendments by urban farmers

A fewer number of farmers in both Tamale (17%) and Kumasi (7%) actually adopted composting (back yard crop residues, household waste composted with animal manure). In Tamale of 60% farmers adopted cow manure only 3% adopted same in Kumasi (3%), χ^2 = (1, N = 60) = 22.259, p = .001 (Table 2). In Kumasi 93% of farmers adopted poultry manure and only 63% farmers adopted same in Tamale, χ^2 = (1, N = 60) = 7.954, p = 0.005 (Table 2). This poultry manure was found to be poultry litter which is a combination of poultry droppings, sawdust or rice hull and poultry feed. As shown in Tables 3 and 4, the number of people experimenting with a particular soil amendments is significantly correlated (P < 0.05) with number of people actually adopting that amendment. This indicates that the more farmers experiment with the amendments, the more they are likely to be convinced about its usefulness. Farmer decision to experiment sometimes follows observation of fellow farmers, but in most cases it comes after outreach programmes supported by the Ministry of Food and Agriculture, Public

Table 2. Adoption of organic manure by urban farmers.

Organic material	Awareness	District response (%)		Chi-square value	p-value
		Tamale	Kumasi		
Cow manure	Yes	60	3.3	22.259	0.001
	No	40	96.7		
Poultry manure	Yes	63.3	93.3	7.954	0.005
	No	36.7	6.7		

Table 3. Correlations between farmers experimenting with compost and farmers adopting compost.

			Trying out compost	Adopted composting
Spearman's rho	Trying out compost	Correlation coefficient	1.000	0.799**
		Sig. (2-tailed)	-	0.000
		N	60	60
	Adopted composting	Correlation coefficient	0.799**	1.000
		Sig. (2-tailed)	0.000	-
		N	60	60

**Correlation is significant at the 0.01 level (2-tailed).

Table 4. Correlations between farmers experimenting with poultry manure and farmers adopting poultry manure.

			Trying out poultry manure	Adopted poultry manure
Spearman's rho	Trying out poultry manure	Correlation coefficient	1.000	0.515**
		Sig. (2-tailed)	.	0.000
		N	60	60
	Adoption poultry manure	Correlation coefficient	0.515**	1.000
		Sig. (2-tailed)	0.000	.
		N	60	60

**Correlation is significant at the 0.01 level (2-tailed).

Universities and Non-Governmental Organisations. As shown in Tables 5 and 6, both the district ($P < 0.05$) and the level of education ($P < 0.05$) determine a farmer awareness of composting. Relation between other factors such as farmer's age, knowledge sources, type of farm and the general land use could not be established.

Reasons for using particular amendments by urban farmers

Fifty six percent of famers who are using poultry manure believe poultry manure has better quality and lasting effect on soil compare to inorganic fertilizers. Judging the strength of soil amendments, 63% of farmers noticed better growth in plants and 21% noticed good soil properties. Twenty eight percent observed that poor or variable quality of soil amendments is a major weakness. It was observed that sawdust based poultry manure, composted crop residues and cow manure were the dominants amendments not just because they have good properties for crop growth, but more importantly, there are the most widely available materials.

Challenges of preparing, obtaining and applying soil amendments

As there are no well-maintained centralised composting plants in Ghana, sixty percent of farmers organise or prepare amendment themselves, 31% of them were supplied by decentralised soil amendment producers. Fifty eight percent of farmers either in Tamale or in Kumasi, obtained soil amendment within 1 to 15 km

Table 5. Cross tabulation relationship between education, district and level of awareness of compost.

Variable	B	SE	Wald	Df	Sig	Exp (B)	CI
District	1.625	0.644	6.366	1	0.012	5.079	1.437-17.947
Education	1.913	0.844	5.132	1	0.023	6.773	1.294-35.44
Constant	-3.078	0.900	11.698	1	0.001	0.046	

Table 6. Determinants of farmer awareness of composting by Logistic regression.

Aware of compost			District		Total (%)
			Tamale (%)	Kumasi (%)	
Yes	Education	Nine years or less	53.3	60.0	57.5
		More than nine	46.7	40.0	42.5
	Total		100.0	100.0	100.0
No	Education	Nine years or less	93.3	80.0	90.0
		More than nine	6.7	20.0	10.0
	Total		100.0	100.0	100.0

radius of their farm and 35% of other farmers in Tamale and Kumasi obtained soil amendment within 16 and 30 km radius of their farms. Most farmers applied between ½ and 1 bag (12.5-25 kg) per bed (72 m^2). This is equivalent to 1.7 to 3.4 ton ha^{-1}. About 90 of farmers use bicycles or “motor-king” (motor tricycle with trailers) to transport amendment to the farm.

DISCUSSION

Farmer knowledge and awareness of soil amendments

Generally the results indicate higher awareness of organic amendments especially compost, refuse dump soils (for landscaping), sawdust and rice hull in Kumasi than in Tamale. These differences may be the results of differences in age, access to labour, education, outreach programmes, cropping system, incentives and local market demand for horticultural produce and services (Supaporn et al., 2013). Kumasi is in the middle of the forest area and Tamale in the middle of the Savannah and educational levels are much higher in the forest areas (48.4%) compared to the savannah areas (19.3%) (Ghana Statistical Services, 2008). Also because of very high poverty levels in the savannah areas there are more outreach programmes on organic amendments. Consumer awareness and market demand for safer foods has served as incentives for increasing awareness about the need to use organic amendments. Farmers are aware of production and economic gains that can accrue from the use of organic amendments. They are also aware that variable quality of amendments can affect production and profit. It is therefore most likely that standardisation of amendment can lead to more adoption by farmers.

Farmer awareness and adoption of amendments depends on spatial and temporal availability of organic materials at the local levels. Studies on resources availability in Tamale, suggested organic materials for composting is not a limitation (Denis and Amelie, 2014, unpublished). Issaka et al. (2012) reported that 3.2 million Mt of manure comprising poultry, cattle sheep, goat and pig manure is produced annually in Ghana. This constitute 48, 695.7 Mt, 43,883.5 Mt, and 20,919.7 Mt equivalent of N, P and K respectively. According to the report, 366,000 Mt of rice straw and 63,000 Mt of rice husk were produced in the same year. The N, P and K equivalent (of the rice straw and husk) were 2,528 Mt, 990 Mt and 5450 Mt respectively. In 2008, $4,159 \times 10^3$ Mt of crop residues and 360×10^3 of logging residues (comprising 16 to 25% of sawdust) were produced (Duku et al., 2011).

Adoption of common soil amendments by urban farmers

Bellwood-Howard (2013) has reviewed two bodies of literature that sought to explain factors limiting adoption of soil fertility management (SFM) by small holder farmers. The first is the livelihood framework that describes how individual physical, financial, social and capital endowments affect the uptake of SFM technologies. The second body of literature; the innovative model draws on participatory, communication and structural models to explains how each model affect

a farmer adoption or non-adoption. Bellwood-Howards synthesized this literature and provided additional framework of how biophysical and socio-economic context determine which issues affect farmers decision to compost. Bellwood concluded that farmers decision to compost was influenced by three factors namely, the need to compost, the ability to compost and knowledge of composting. The relevance of these factors were seen to vary across agro-ecology, demographic, social and technological context. Encouraging composting and wide scale adoption of soil amendments will require innovation communication and policy changes especially on subsidies and incentives for decentralized composting.

Collection of waste materials for composting is a major investment and sometimes they require technologies beyond the reach of small scale farmers. Some waste materials such as market waste and urban solid waste are not ideal for small scale composting. The cost involved in collecting municipal solid waste and the quality issues associated with solid waste composting serve as a serious disincentive for decentralised composting schemes. Farmers therefore find it cost effective to use materials within their vicinity where collection cost is less and where they are also assured of the quality of the waste material and the resulting compost.

Challenges in soil amendment use

The main challenges limiting the use of soil amendments were therefore found to be associated with, transport and labour for application of amendment. A bicycle could only carry one bag of amendment at a time to the farm. Motor King could carry 10 to 15 bags at a time. Most farmers have bicycles in Tamale. Only a few farmers can afford to buy a Motor king, but “Motor King” services are available to all farmers at extra cost to the farmer. These findings are consistent with reports of compost use in West Africa (Lawal et al., 2007). The challenges with transporting compost may partly explain why farmers use less (1.7 to 3.4 ton ha^{-1}) than recommended rate (10-20 ton ha^{-1}) of amendment in soils. Although the technology for composting is available, current paradigm for composting development appears to be linked to waste recycling and solid waste management in urban areas (Olufunke et al., 2006). This approach often leads to the compost developers paying less attention to the quality of compost especially for different uses in urban horticulture. Farmers identified variable quality of amendments as a major weakness, this suggest standardisation may increase adoption rates. Potential waste materials that have been collected for large scale composting in Ghana have included: Solid waste, horticultural and agricultural waste, agro-industrial waste, sludge and bio-solid. Solid waste, sludge and bio-solid which include domestic and market wastes, food waste including vegetable and fruit peelings, charcoal ash have been the dominant materials for large scale composting plants such as the Teshie-Nungua plant in Accra. Horticultural and agricultural waste which include garden refuse, leaf litter, cut grass, tree clippings, weeds, animal dung, crop residues, waste from public parks and manure (poultry, pig, cow) have been largely used in small communal or home composting plants. Agro-industrial waste; waste generated by abattoirs, breweries and agro-based industries have not been explored for their potential in composting.

Conclusion

Various soil amendments are used by urban farmers in Ghana, but dominants ones are poultry litter, cow manure and composted crops residues and agro-industrial waste. Although, farmers are aware of other amendments materials such as landfill soil, collection and quality issues associated with these materials limit their use by farmers. Majority of farmers prepare or collect amendments by themselves. Barriers in use of amendments therefore appear to the technology to collect, funds to purchase and labour employment. Reasons for choice of amendments are therefore largely dependent on the easiness of collection and use. Farmers adopt varying application rates based on their experience. The major strength of soil amendments from farmer’s point of view is the improvement in crop growth and soil properties. The major weakness in using amendments appears to be labour involved and the varying quality of amendments. The agro-ecology and the farmers’ level of education largely determine the use of particular amendments by farmers. In developing soil amendment for Ghana, the availability of feedstock would be the most critical pre-condition. Rice husk, sawdust and poultry manure are available in quantities that would allow for commercial production of soil amendments. As farmers are already familiar with sawdust based poultry litter, the co-composting of sawdust would be the best option that can be developed and standardised for application in urban horticulture.

Conflict of Interest

The authors have not declared any conflict of interest.

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