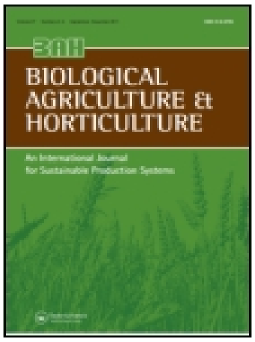

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Farmers' background and diversity of uses of palm oil wastes for sustainable agriculture in Southern Benin Republic

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Palm oil mill wastes (POMW) are well known to be rich in phosphorus, nitrogen, calcium, magnesium, sodium and potassium. This study was carried out in 2012 to assess farmers' practices on utilization of POMW in agriculture in the south of Benin. A total of 335 palm oil mills from the Communal Union of Palm Oil Producers were randomly selected and surveyed using a questionnaire. The use of POMW as fertilizers depends highly ($p < 0.001$) on the nature of fertilizers used by the farmer. The use of empty fruit bunches (EFB) and fibre as fertilizers depends on the knowledge of the farmer about their application directly in palm plantations or indirectly through composting. These wastes were applied by local application (76.5%) or mulching (33.3%). The use of EFB and fibre produced depends on their use in plantations ($p < 0.001$). POMW were composted by heaping, by breeding pigs on POMW and in pits. Breeding pigs on POMW involved placing POMW in a pig pen with added vegetables. The pit method consisted of making a hole. The POMW are put in the pit. After the short rain season, the compost obtained can be used. Composting is a process unknown by 67.5% of mill owners. The difference between those who know about and use composting, and those who know it but do not use it is based on their knowledge of composting advantages. The use of POMW in composting is mostly developed in Ifangni District (Plateau Department).

Keywords: composting; knowledge; palm oil mill waste

Introduction

Oil palm (*Elaeis guineensis* Jacq.) is a monocotyledon of the Arecaceae family (Jacquemard 2012). It provides 39% of world vegetable oil production with 7% of oleaginous plantation areas compared with soyabean (61%), colza (18%) and sunflower (14%) (Rival 2013). Palm oil is one of the two most important vegetable oils in the world oil and fats market (Hartley 1988). The extraction and purification processes generates different kinds of waste generally known as fibre, empty fruit bunches (EFB) and palm oil mill effluent (POME). The sustainable management of palm oil mill wastes (POMW) has received much attention in palm oil producing countries. The mismanagement of these wastes cause land and aquatic ecosystem contamination, loss of land and resources, negative impacts on soil micro flora and fauna and loss of biodiversity (Sridhar & AdeOluwa 2009). The sustainable management of these wastes is necessary for

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sustainable development (Ohimain et al. 2013). These wastes are useful for boiler fuel, soap production, fertilizer, pig feed and mushroom production (Fournier et al. 2002; Yacob et al. 2005; Beule 2006; Law et al. 2007). However, some of these practices are prohibited in Malaysia owing to their contribution to carbon emission (Sudirman et al. 2011). For example, incineration of these wastes in boilers emits gases with particulates such as tar and soot droplets of 20–100 μm and a dust load of about 3000–4000 mg nm^{-1} (Igwe & Onyegbado 2007). According to some research, POMW are rich in phosphorus, nitrogen, calcium, magnesium, sodium and potassium (Schuchardt et al. 2008; Iwara et al. 2011) and can be used in sustainable agriculture. This idea was confirmed by Sabiiti et al. (2005) who concluded that agricultural wastes such as POMW are widely available, renewable and virtually free, and can be a valuable resource for improving food security.

In the south of Benin Republic, palm oil covers 40% of national vegetable oil needs (MAEP 2011). It plays an important socio-cultural and economic role in the south of the country (Adegbola et al. 2009). In this area, soils are degraded and this is a great problem for farmers. To address this situation, farmers have to restore soil nutrients using inorganic, and sometimes organic, fertilizers to improve crop productivity. According to Odu and Mba (1991), inorganic fertilizers supply nutrients alone while organic fertilizers not only supply nutrient elements through microbial interactions but also improve soil physical properties. Although the use of organic manures for crop production is a traditional agricultural practice among subsistence farmers in the West Africa sub-region (Lombin et al. 1991), their use is not automatic nowadays. According to Iwara et al. (2011), in Nigeria, the use of POMW can help farmers, mostly in rural areas, to improve food production. However, this depends on farmers' understanding of the importance of POMW. In Malaysia, POMW are used as fertilizers by mulching in plantations, or after composting or vermicomposting (Sabrina et al. 2009; Rupani et al. 2010). In the south of Benin Republic, POMW are sometimes thrown away and no previous studies have been made of farmers' practices regarding their use as fertilizers. The present study investigated farmers' knowledge on the use of POMW in agriculture, their practices and the sustainability of these practices.

Materials and methods

Study area

This study was carried out in the south of Benin Republic and covered Atlantic, Mono, Couffo, Oueme and Plateau Departments (Figure 1). The south of Benin Republic extends from the coast (6° 25′ N) to 7° 30′ N and is part of the Guinea-Congolian zone with four seasons. The climate is sub-equatorial with two rainy seasons (March–June and September–mid-November) and two dry seasons (July–September and November–March). The annual rainfall varies between 1100 and 1400 mm. The average daily temperature ranges from 25 to 29°C and the average daily humidity from 69% to 97%. The Guinean zone is an area of deep lateritic soils of low fertility (700,000 ha) and more fertile alluvial soils and heavy clay soils (360,000 ha) located in the Mono, Couffo and Oueme river valleys, and in the Lama depression (Adjanohoun et al. 1989).

Methodology

A survey was conducted from November 2011 to February 2012 in palm oil mills that worked with palm oil producers of the Communal Union of Palm Oil Producers (CUPOP)

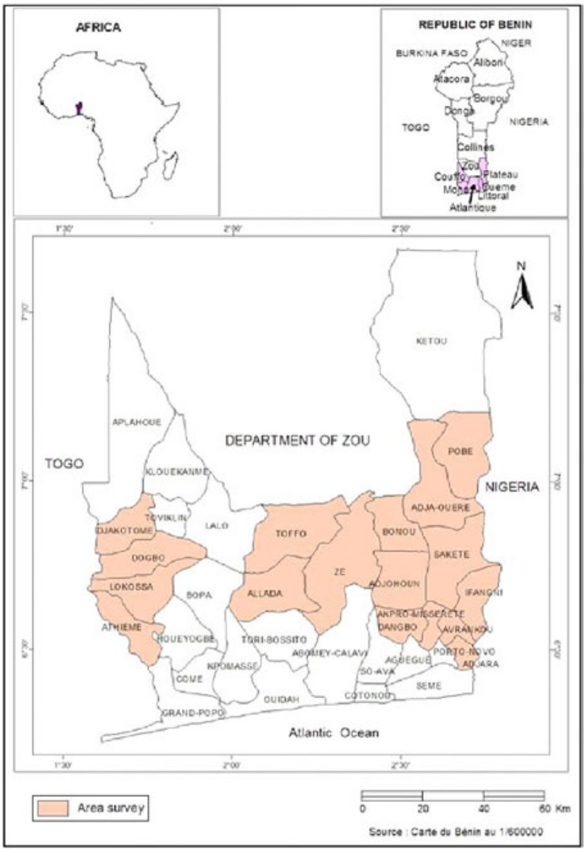

Figure 1. Location of experiment site.

and those that buy nuts from CUPOP members. Only mills that produced oil palm for commercial income were considered. Three hundred and thirty-five palm oil mills were selected in consultation with CUPOP chiefs. The mills were located in Atlantic (80), Couffo (56), Mono (63), Oueme (90) and Plateau (46) Departments. For each mill owner, a semi-structured questionnaire was administered and the mill was visited for personal observation. The questionnaire covered the sex, age, main activity undertaken by the informant, the oil palm plantation process, the type of soil fertility input used by the owner, and the knowledge and use of POMW in agriculture.

To quantify POMW, mills were classified into four categories according to the type of machine used for palm oil production in a partial or total process: traditional palm oil process (no machine use), small mechanized or improved palm oil process (integration of digester engine in the process), motorized or modern palm oil process (integration of digester and press engines as DECAM press in the process) and mini industry palm oil process (integration of large cookers, presses, digesters, sterilizers, clarifiers and other facilities in the process). Twenty-four mills: mini industrialized (9), traditional (7), modern (4) and improved (4) were randomly chosen and monitored three times. At each producing step, waste weight was assessed.

Statistical analysis

Descriptive analyses, average, percentage, pie chart and histograms were made using the Excel software. The fidelity level (FL) (Cheikh et al. 2011) was adapted to assess the importance of each waste according to the equation:

$$\mathrm{FL}(\%) = \mathrm{Np}/N \times 100,$$

where Np is the number of informants who called the waste for its use and *N* the number of uses.

The relationship between the following factors was assessed by Chi-squared analysis of farmers' background and fertilizers used, farmers' background and use of POMW as fertilizers, use of EFB in plantations and use of all POMW generated, use of POMW in plantation and plantation possession. Double principal component analysis (PCA) was carried out with the R software to explain the relationship between background knowledge of farmers of compost and compost uses.

Results and discussion

Socio-demographic characterization of palm oil mill owners

Seventy-five per cent of mill owners were male and 25% female. Thirty-seven per cent were over 50 years old and 63% were between 23 and 50 years. Although almost all (91.9%) mill owners were farmers, 15% of them were involved in the business and industry sectors. Seventy-one per cent of them had palm plantations and produced palm oil.

POMW quantities

The producers collected all the full fruits bunches (FFB) that they had from palm oil plantations of different age. Each palm oil mill produced an average of 712.1 kg of fruits, 254.7 kg of EFB, 399.8 kg of palm kernel cake, 114.9 kg of fibre, 240.4 l of POME and 152.3 l of crude palm oil from 1 t of FFB.

POMW management and place of agriculture

POMW play an important role for the population. Mills that use EFB, fibre and POME, respectively, represented 82%, 96% and 78% of mills surveyed (Table 1). POMW were

Table 1. POMW management.

	N_{cited}	Percentage of mills that use the wastes	FL	Uses	Quantity produced	Quantity used	Percentage use
EFB	275	82	95.83	Soap, cooking fuel, agriculture,	8684 t	5910 t	68.1
Fibre	323	96	63.00	Cooking fuel, fire starting cake, agriculture	3917 t	3062 t	78.2
POME	261	78	47.17	Fire starting cake, agriculture	8196 l	3313 l	40.4

used in agriculture or to produce energy (boiler fuel and fire starting cake) or soap. Also mill owners considered EFB (FL = 95.8) to be more valuable than fibre (FL = 63). While EFB and fibre were used as cooking fuel, fibre and POME were used to made fire starting cake, and EFB were used to prepare soap. POMW are used in agriculture for pig feed, mushroom production and soil fertilization. Although POMW are used for many purposes, some farmers threw away EFB (38%), POME (27.8%) and fibre (6.8%). In considering the percentage of quantity produced, POME was the least used (only 40% was used) whereas 68.1% of EFB and 78.2% of fibre were used (Table 1).

Farmers' practices and POMW use in agriculture patterns

Among palm oil mill owners surveyed, 92% of them are farmers, and in this group, 68% breed cattle, poultry, sheep and goats. Farmers produced maize, manihot, soya, cowpeas and groundnuts. Only 24% of them produced tomatoes and/or peppers. Thirty-six per cent of producers recognized that the land is infertile. Among farmers, 43% used no fertilizers, 49% used only inorganic fertilizers (NPK, urea and KCl), 1% only organic fertilizers (compost and chicken manure) and 7% both inorganic and organic. The use of POMW in agriculture was not known by 61% of mills owners (Figure 2). Mill owners who use POMW in agriculture had heard once on this practice. EFB were used as fertilizers by 25.7% of mill owners and for mushroom production by 1.8% of them. Mill owners who used fibre as fertilizers and those who used POME as fertilizers were, respectively, 1.8% and 2.4% of those surveyed. The use of POME for pig breeding was practised by 2.7% of mill owners surveyed. It is important to note that 5% of mill owners used POMW in their plantations despite reporting that they knew nothing about their use in agriculture. The main POMW utilization in agriculture was for soil fertilization (Figure 2). The Chi-squared test revealed that the use of POMW as fertilizers depended significantly on the farmers' knowledge ($p < 0.001$) and the nature of fertilizers used ($p < 0.001$). All farmers who used organic fertilizer systematically used POMW as fertilizers. EFB and sometimes fibre were used directly by applying them in palm plantation or indirectly

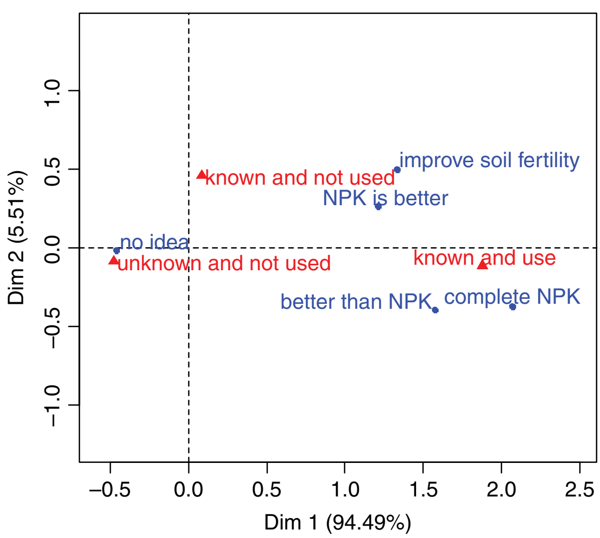

Figure 2. Projection of the farmers' background on compost system in the system axes 1 and 2.

through composting. Four per cent of farmers used POME for maize cropping, usually behind houses. According to them, POME is useful for this purpose.

Use of compost and farmers' background

Farmers gave five answers when asked what they know about compost: (1) compost is sustainable fertilizer and complete chemical fertilizer, in particular NPK; (2) compost is cheaper than NPK. It protects plants from attack and makes the seeds resistant to illness. So compost is better than NPK, (3) compost is sustainable and improves soil fertility, (4) compost is sustainable but slow to work, so NPK is better; (5) no idea, so no knowledge on it.

The double PCA shows that two axes explain 100% of information collected from mill owners who knew about composting. Table 2 shows the coefficients of correlation between the farmers' background knowledge on compost, its use and the first two PCA axes. This table shows the following parameters: 'compost is a sustainable and complete fertilizer', 'compost is sustainable but slow to work, so NPK is the best', 'no ideas', 'compost is better than NPK because it is cheap and protects plants', 'compost improves soil fertility, is efficient and sustainable', 'compost known and used' and 'compost unknown and not used' are more correlated with axis 1 than axis 2. These parameters may be explained with axis 1. Only 'compost unknown and not used' and 'no ideas' parameters are negatively correlated with axis 1. The parameter 'compost known and not used' was more correlated with axis 2 than axis 1. Figure 2 shows the projection of the farmers' background knowledge on compost system in the system axes 1 and 2. In considering axis 1, farmers who do not know about compost are opposite to those who know about compost and those who do not have any ideas are opposite to those who have some knowledge on compost. With axis 2, farmers who use compost are opposite to those who do not use it. Also, farmers who said that 'compost improves soil fertility, is efficient and sustainable' or 'compost is sustainable but slow to work, so NPK is the best' are opposite to those who said that 'compost is better than NPK because it is cheap and protects plants' or 'compost is a sustainable and complete fertilizer', so farmers who knew compost and used it thought that (i) compost is a sustainable and complete fertilizer, and (ii) compost was better than

Table 2. Correlation between the characteristics parameters (compost concept perception and use of compost) and the first two PCA axes (in brackets is the proportion of variation explained by each axis, expressed in percentage).

Parameters	Axis 1 (94.49%)	Axis 2 (5.51%)
Compost is a sustainable and complete fertilizer	2.071	−0.374
Compost is sustainable but slow to work, so NPK is the best	1.208	0.267
No ideas	−0.458	−0.015
Compost better than NPK because it is cheap and protects plants	1.576	−0.391
Compost improves soil fertility, is efficient and sustainable	1.329	0.502
Compost known and used	1.876	−0.113
Compost known and not used	0.089	0.461
Compost unknown and not used	−0.476	−0.086

NPK because it is cheap and protects plants. According to those who knew about compost but did not use it, compost is sustainable but slow to work, so NPK is the best.

Use of EFB and fibre in palm plantation: farmers' practices

Diversity of EFB and fibre application in palm plantation

Among farmers who use POMW in their plantation (33.1% of informants), 14.8% of them applied the wastes whenever they want and the rest applied them each year after the production season which varies from 3 to 12 months. The wastes were applied using two methods: local application (76.5%) and mulching (33.3%). The first method consists of putting a small quantity of the wastes around the tree. The second method consists of making a heap and leaving it for decomposition before using as mulch. The use of all EFB quantity produced depend on its use in plantations ($\chi^2 = 19.7$, $p = 8.9e^{-6}$). In the same manner, the use of all Fiber quantity produced depend on its use in plantations ($\chi^2 = 14.11$, $p = 1.7 \times 10^{-4}$). However the use of these wastes in plantation did not depend on plantation possession ($\chi^2 = 1.3$, $p = 0.26$).

Diversity of POMW composting practices

Composting is a process unknown by 67.5% of mills owners. Among those who knew about composting generally (32.5% of mills), only 41.8% did not know that POMW can be composted. For those who knew that POMW can be composted, 52% compost these wastes themselves. They represented 13.6% of palm oil mill owners. According to 62% of farmers who knew about compost, it performs better than NPK. POMW were composted using three methods. The first was making a heap of POMW and manure and/or other wastes and leaving for 3–6 months. This method was used by 87.5% of mill owners surveyed. The most adopted period for this was in the short rain season. The second practice for POMW utilization was in pig breeding. This involved placing POMW in a pig pen with added vegetables. This practice took at least 6 months. In the third method, used by 4.2% of producers, a pit was made into which all EFB, fibre and sometimes POME from their mill were placed and left for at least 3 months during the short rain season before use. The compost obtained was used to fertilize palm oil plantations or used in market gardens. However, this compost contained nylon bags and other wastes and probably also heavy metals. The composting of EFB and fibre was more developed in Ifangni District in Plateau Department than the others districts surveyed.

Discussion

As reported by Hodonou (2010), the present study shows that palm oil trees play an important socio-economic role in Benin because they are cultivated by many farmers and palm oil is retailed to secure a good income. The quantities of wastes generated by 1 t of FFB are similar to those observed in Malaysia (Maheswaran & Singam 1977) and in Indonesia (Hayashi 2007). Agriculture is the best way to utilize these wastes, which are important polluters, and thus plays an important role in POMW sustainable management. The present study revealed that these wastes were little used in agriculture. This was due to the fact that the majority of farmers are not aware of all the uses of all types of POMW in agriculture and their potential to cause pollution if not used sustainably. Those who were aware of the use of POMW in agriculture mainly used EFB and fibre as fertilizers in plantations. Lack of knowledge leads farmers to throw away large quantities of POMW, particularly POME. This is a problem because POME is the greatest polluter among POMW (Schuchardt et al. 2007; Singh et al. 2010; Kanu & Achi 2011). According to Nwoko et al. (2010), Embrandiri et al. (2012) and Kolade et al. (2012), these wastes are very rich in nutrients and improve soil fertility and crop growth and yield. For example, POME is rich in organic matter (Nwoko & Ogunyemi 2010) and organic nitrogen (Onyia et al. 2001) and can best be managed by use in agriculture (Cayuela et al. 2005) as animal feed or for soil improvement (Binder et al. 2002). The non-use of these wastes as fertilizers represents a waste for farmers of the south of Benin Republic where the majority of soils are degraded. The method of disposing of these wastes without treatment is a source of soil pollution as described by Ojonoma and Nnennaya (2007) and Singh et al. (2010). EFB and fibre are more valuable to mill owners than POME. The use of these two wastes as fertilizers is conditioned by the use of organic fertilizer and farmers' knowledge on this kind of use. It is easier for mill owners to manage small quantities of POMW by applying them locally. According to Schuchardt et al. (2007), the mulching of fresh EFB reduced erosion, decreased nitrogen losses, controlled weed growth and improved soils nutrients. The application of large POMW quantities demands more time and many employees. This is why some mill owners prefer to make a heap with these wastes and leave them to decompose. However, this practice should be avoided because of the danger of *Ganoderma boninense* and *Oryctes rhinoceros* (rhinoceros beetle), important pathogen and pest, respectively, of oil palm (Schuchardt et al. 2007). Composting of POMW, considered as a sustainable method of POMW use (Thambirajah et al. 1995; Yusri et al. 1995), was less practised in the south of Benin Republic. Mill owners mixed all wastes for composting. According to Hock et al. (2009), POMW co-composting is the best sustainable management. However, this practice was not known by many mill owners and the use of compost depends on their knowledge of the advantages of compost. Mill owners who compost POMW mix all wastes without turning and watering. However, heap turning is a very important step of composting (Misra et al. 2003).

Conclusion

Although the sustainable management of EFB, fibre and POME by their use in agriculture is an opportunity for farmers of the south of Benin Republic, these wastes are little used. This is due to the farmers' lack of knowledge of their use in agriculture. Farmers who knew about compost recognized that it is better than NPK. POMW composting has the potential to restore soil fertility in this part of Benin Republic but this will only be possible if farmers are informed on the use of POMW in agriculture, particularly crop production. Further studies must be made on POMW composting in Benin and on their effect on vegetable growth.

Disclosure statement

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