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Animal dung availability and their fertilizer values in a context of low soil fertility conditions for forage seed and crops production in Benin (West Africa).

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ABSTRACT

Livestock manure, feed biomass fed to animals that pass through digestive tract undigested and urine excreted from subsequent tissue metabolism, is conventionally termed as wastes. To optimize the use of animal manure for the purpose of agronomic processing or valorization, it is essential to know its availability and plant nutrients composition. The use of reference values is a quick method of estimation. However, books on farm fertilizers generally offer only an average value that is not representative of the diversity of situations. The aim of this study was to (1) estimate the quantity of manures from cattle, sheep, goats, pigs and poultry, (2) determine the physico-chemical characteristics and plant nutrient contents of these droppings and (3) identify the inter-relationships between the physical characteristics (pH, EC and dry matter(DM)) and the most essential macronutrients (N, P and K). A total of 30 animal groups (herds or flocks) were survived per species and a total of 30 samples were collected over twelve months (January 1st to December 31, 2016) for DM, pH, electrical conductibility, nitrogen, phosphorous, potassium, calcium, magnesium and sodium contents for each sample. According to animal population of the country, the results of the study showed that, an amount of 1.630600 tons DM of cattle manure, 227800 tons DM of sheep dung, 136,900 tons DM of goat dung,

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122,400 tons DM of pig dropping and 36,500 tons of poultry excreta are annually available in Benin. Physico-chemical and analyzes of droppings showed significant differences ($P<0.01$) between mineral compositions of these dropping. Poultry manure are richer in macronutrients than other types of animal manure (N = 11.7 ± 3.9, P = 4.6 ± 2.3, K = 7.6 ± 1.3, Ca = 41.2 ± 16.7 g/kg), followed by goat and sheep manure (N = 6.0 ± 3.7, P = 4.9 ± 3.9, K = 7.3 ± 3.3, Ca = 7.7 ± 3.8 g / kg and N = 6.7 ± 2.3, P = 4.4 ± 1.5, K = 7.3 ± 3.6, Ca = 7.7 ± 2.6 g / kg, respectively). Mean macronutrient compositions of swine dropping were: (N = 4.5 ± 2.0, P = 1.4 ± 0.8, K = 2.9 ± 0.8, Ca = 1.8 ± 0.9 g / kg). The animal manure that showed the lowest levels of these three macronutrients were those of cattle (N = 3.0 ± 0.6, P = 0.6 ± 0.1, K = 4.1 ± y, Ca = 6.4 ± 3.1 g/kg). Correlations between physico-chemical properties (pH, EC, DM) and nutrient concentration showed that dry matter (DM) and electrical conductivity (EC) could be used to estimate nutrient (nitrogen, phosphorus and potassium) concentrations. The results vary widely depending on the source and type of dejection but they are a good basis for choosing rational and optimal soil fertilization for crop and forage productions.

Keywords: animal manure, nitrogen, phosphorus, potassium, calcium, sodium, physico-chemical properties, Benin.

INTRODUCTION

Urbanization through which forested areas were deforested for the construction of social amenities such as schools, health centers, factories and the deforestation of forested areas had led to the use of inorganic fertilizers in the production of most food and forage crops. In recent years the increase in fossil fuel prices led to the increase in mineral fertilizer cost. In addition, the economic and environmental costs of excessive N fertilization have risen as one of the most important issues. These synthetic fertilizers have adverse effect on mankind from the consumption of crops or vegetables produced with inorganic fertilizers causing chronic diseases such as cancer, stroke, and hypertension and the pollution of the environment (FAO, 2000; Udoh et al., 2005; Ademiluyi et al., 2008). Several kinds of inorganic fertilizers contain toxic heavy metals that enter the soil and are absorbed by plants (Morton 1981; McLaughlin et al. 1996). Also, trace mineral fertilizers and liming materials derived from industrial waste can contain a number of heavy metals like Cd, Pb, Cu, Zn (Batelle Memorial Institute 1999). These heavy metals build up in the soil when these fertilizers are used continuously. This eventually threatens soil health and the environment (Smith et al. 1990; Harrison and Webb 2001). There is also a great interest in identifying suitable alternative forms of fertilizers such as manures (liquid manure, farmyard manures, composts and green manures) which can be used as sources of plant nutrients and at the same time increase nutrients use efficiency and crop-forage yield (Eghball 2002; Fageria and Baligar 2005).

On the other hand, organic manure is known to modify favorably the physical conditions of the soil by improving water holding capacity, aeration, drainage and friability (Schjønning et al. 1994; Maheswarappa et al. 1999; De Silva and Cook 2003). Most importantly, it helps in protecting crops from a temporary gross excess of mineral salts and toxic substances by decreasing their bioavailability (Chamon et al. 2005; Indoria and Poonia 2006; Kungolos et al. 2006; Neubauer et al. 2006). In this context, Materechera and Salagae (2002) used partially decomposed cattle and chicken manure amended with wood ash and reported that higher plant yield of fodder maize was obtained by the use of chicken manure. The use of organic fertilizers in crop production can supply nutrients required by crops and replenish nutrients removed from soil by crop harvest (Graves et al., 2001; Ademiluyi et al., 2008; Ghanbari et al., 2012). Other animal manures, such as that of poultry, may contain nitrogen in even higher proportions than cattle manure, and it is certainly worth considering their use where appropriate.

Otherwise, relationships between easily-determined parameters, such as pH, electrical conductivity (EC) or DM, and plants available nutrient content (nitrogen, phosphorus and potassium) can help to estimate manure fertilizer value and subsequently promote agricultural wastes use without negative environmental side-effects (Scotford et al., 1998b). Nowadays it is possible to do an accurate measure of pH (portable pHmeter), EC and DM (Tunney, 1978; Bellotti, 1997; Van Kessel et al., 1999; Provolo and Martinez-Suller, 2007) directly on farm. Thus, the control of the relationships between these easily determinable physico-chemical characteristics and the fertilizing values of animal waste would make their uses more practical in the context of an integrated farm-livestock system. This is particularly important in regions where soils were depleted.

The cattle, sheep, goat, swine and poultry and poultry population of Benin was reported to be 2.339; 0.915; 1.836; 0.466 and 20 million in 2016 (Houndjo et al. in press). An enormous quantity of manure is annually excreted and it can contribute to improve organic matter of soils and their physical, chemical and biological properties (Das et al., 2004, Herencia et al., 2007, Saïdou, 2006). This study aims to: i) estimate the quantity of animal manures per year in Benin; ii) to determine the physical-chemical properties and fertilizer values for manures of different animal species (pig, poultry, goat sheep and cattle) and iii) to evaluate the potential of some easily-determined physical-chemical properties (as pH, DM and EC) to provide estimates of fertilizer value content (NPK).

MATERIAL AND METHODS

Herd selection for survey and manure estimation

A multi-stage sampling technique was employed to select the herds or flocks for the survey. The first stage was the selection of five (5) departments (Zou, Collines, Ouémé, Plateau and Couffo) from the twelve in the country. The second stage involves the selection of three (3) communes (a lower territorial division of department) per department. The third stage involves the random selection of two (2) herds per each of the 5 animal species survived (cattle, sheep, goat, swine and poultry) making a total of thirty (30) animal groups (herd or flock) for the survey. Animal kippers were selected and an agreement was made with them for the survey. Four animals (heifers, steers, bulls, cows, male goat, she-goat, ram and ewe) were randomly chosen per herd or flock. Animal manure was collected from January 01 2015 to December 2015 in each herd or flock on 10th and 25th of each month.

Potentially dry manure of each category of animals per year (PM) was estimated on number of animals in 2016 reported by Houndjo et al. in press, estimated Tropical livestock unit (TLU) for each species (Adjolohoun 1992; Lesse 2015) and the potentially recorded manure collected during the survey.

PM = Number of animals (NA) × Tropical livestock unit (TLU) × excreted manure per animal (EMD) × 365.

where number of animals were 2339000 for cattle, 915000 for sheep, 1836000 for goat and 466000 for swine and 20000000 for poultry.

Tropical Livestock unit corresponding (TLU) was 0.57 TLU for cattle; 0.12 TLU for sheep; 0.10 TLU for goat; 0.20 TLU for swine and 0.0016TLU for poultry manure.

Sample collection and laboratory analysis

Data were collected two times per month. The pits were in static conditions. Samples of the animal manure were directly obtained from pits. A sample of about 1 kg manure of each animal species (cattle, goat ad sheep and swine) was taken and stored in a closed bottle kept as cool as possible upon arrival at the laboratory and stored at low temperature (3-5ºC).

Each sample was placed in a plastic beaker (4 L) and homogenized for 5 min under an extractor hood. EC, pH (standardized at 25 °C) and DM were determined on the full sample according to standard methods (APHA, 1998). Sub-samples were then taken for measurement of nutrient concentrations. For DM determination, 100 g of fresh sample was dried in an oven at 105 °C for 24 h. Following sulphuric acid digestion of the fresh sample (Byrne, 1979), total N was determined using Kjeldahl method and P concentrations were determined calorimetrically on a continuous-flow analyzer (Basson et al., 1968), and K, Ca, Mg and Na were measured by atomic absorption spectroscopy at the Laboratory of the University of Gembloux in Belgium.

Statistical analysis

A simple statistical descriptive analysis was carried out to find average value of each quantity of manure, fertilizer element (N, P, K, Ca, Mg and Na) and physical-chemical properties (pH, EC and DM) studied. The equality of average values in independent groups was tested with *proc glm*. The correlation among variables was identified using a Pearson correlation coefficient. Afterwards, single and multiple regressions between fertilizer value (NPK) and physical-chemical properties have been studied according to kind of agricultural waste and source. All statistical analyses were conducted using SAS software (vers 9.2) and $p < 0.05$ was considered statistically significant.

RESULTS

Manure production

Data of manure produced by different species per day and total dry matter of manure produced per year are presented in table 2. Species were of different size and they excreted very different quantity of manure [column of mean manure per animal per day (kg DM)]. Cattle produced from five to six times manure produced by sheep or goat. Swine produced one third manure of that of cattle. Poultry dropping were 382 times lower than that of cattle. The amount of manure produced annually in Benin is around 2154200 tons dry matter. The contribution of cattle, sheep, goat, swine and poultry is 76%, 6%, 11%, 3% and 2%, respectively.

Physico-chemical composition and variability in nutrient fertilizer value

According to the laboratory analysis results, composition of different kind of samples varied significantly. The pH dropping of goat (8.3) and sheep (8.4) had the highest values and the lowest value was recorded with poultry (6.9). Electrical Conductivity (EC) also varies from one animal species to another. Sheep and goat droppings have the highest EC values (0.61 ds/m and 0.63 ds/m respectively) and poultry the lowest value (0.44 ds/m). The Dry Matter (DM) content of poultry droppings is higher (42.8%) than those of others species. The lowest N content was found with cow dung (6.6‰). The highest values were recorded with poultry (15.3‰ and 12.6‰, respectively). The droppings of cattle, sheep and goat have similar potassium contents (1–1.2‰). The phosphorus content was highest in poultry droppings (5.2‰).

Relationship between DM, pH and EC and NPK concentration

The interrelationships among the physico-chemical and nutrient variables are shown in Tables (Tables 3). Dry matter and EC were highly correlated (P<0.0001) with all the nutriments. The correlation matrix of the analysis data of the samples of pigs manure (Table 3) shows a good correlation between EC and the variables N (r = 0.79, P<0.0001) and K (r = 0.64, P<0.0001). On the other hand, dry matter values are better correlated with P (r = 0.73, P<0.0001). A strong correlation is also observed between DM and Ca (r = 0.74, P<0.0001). The correlation matrix (Table 3) shows strong correlations between dry matter and the variables N, P, K (r = 0, 95, 0.93, 0.94 respectively) with highly significant probabilities (P<0.0001) after analyze of the samples poultry manure collected.

The data matrix of cattle slurries samples showed strong correlations between EC and nitrogen, phosphorus and potassium (r = 0.88, 0.86 and 0.82 respectively) with highly significant probabilities (P<0.0001). A strong correlation (0.90) and a high significance (P<0.0001) are observed between DM and Ca (Table 3).

Table 3 shows strong dependencies (P<0.0001) between the variable DM and the variables N, P, K and Ca (r = 0.97; 0.97; 0.98 and 0.74 respectively) in the goats droppings samples. Interdependent relationships are well known in sheep's droppings (table 3) between the variable DM and the macronutrients N, P, K, Ca (r = 0.97, 0.96, 0.98 and 0, 74 respectively). Strong correlations are also observed in these same drops between EC and these different chemical variables used in this study.

Selected simple and multiple regression equations for nutrient estimation

Simple regression equations

The single regression equations obtained after treatment of the laboratory test results of poultry manure show that the dry matter content makes it possible to better predict N, P, K levels in this type of dejection (r^2: 0.91 ; 0.86 and 0.89 respectively). On the other hand, the analysis of the results obtained with the pig manure data reveals that the EC is the most suitable for the estimation of N (r^2 =0.63) and K (r^2 = 0.41) nutrients. The DM allows a better prediction of the P content with a coefficient of determination of 0.53. The results obtained in the analysis of goat and sheep droppings show strong coefficients of determination for the dependent variables N (r^2: 0.94 for each one of the two types of droppings), P (r^2: 0.94 and 0.93), K (r^2: 0.96 and 0.96) as a function of the independent variable DM. However, EC can also be used to predict the levels of these different nutrients. From the analysis of the results of the cow dung samples, the EC is the best predictor of N, P, and K (r^2: 0.78, 0.74 and 0.67 respectively).

Multiple regression equations

For poultry droppings, the use of EC and DM as independent variables do not alter trends in the coefficients of determination observed in simple regression equations. The combination of EC and DM improves the r^2 of P (0.58) and K (0.48) for pig manure. EC and DM improve the coefficients of determination with goat droppings (r^2 = 0.58) and cattle dung (r^2 = 0.71).

DISCUSSION

Production and most constraints for manure utilization for crop or forage production

Houndjo *et al.* (in press) reported that the number of cattle, sheep, goat, swine and poultry in Benin during 2016 is estimated to about 2,399,000; 915,000; 1,836,000; 466,000 and 20,000,000, respectively. Considering these different numbers of animals (Table 2) the annual dejection calculated to be 1,630,600; 136,900, 227,800; 122,400 and 36,500 tons (15% of dry matter), respectively. A total annual of livestock manure managed in different systems is amounted to be 2,154,200 tons in Benin.

This quantity of animal manure is an important source of soil amendments which can improves both crop or forage productivity and the physical and chemical conditions of soils through supplying different nutrients and organic matter (Harendra et al., 2009; Alam et al., 2010; Koura et al., 2015).

Several constraints are linked to the use of animal waste. Lack of manure treatment, capacity, information and awareness, credit problem for the purchase of the necessary equipment, illiteracy, lack of bank loan facilities can be cited as major technical and socio-economic along with institutional constrains of improved manure management.

Physico-chemicals characteristics of animal manure

Dry matter content, organic matter and Electrical conductibility

Mean dry matter content of different animal waste varied between 11.0 and 42.8% which means that water content average were close to 57 to 89%. The low nutrient to volume ratio implies that large volumes of animal dung need to be transported, this being the limiting factor for economically and efficiently used of manure as fertilizer. On some farms, animal dungs are used around cattle pen (50 to 200 m).

Electrical conductivity (EC) is the ability of a waste to transmit (conduct) an electrical current. In this study, mean value (EC) varied over a range from 30 to 63 dS/m and is in the range reported by Suresh et al. (2009) and who reported 12.5 to 55.9 dS/m. (CE) values found in this trial is somewhat higher than that of the data obtained by Moral et al. (2005) and Martínez-Suller et al. (2008) where it ranged from 12.8 to 25.2 dS/m and 3.6 to 38.1 dS/m respectively. Also, it is lower than data from Sánchez and González (2005) and Suresh et al. (2009) where it ranged from 2.0 to 75.2 dS/m, probably linked to the dietary intake of salts. The indiscriminated use of manure may increase nitrogen levels and lead to soil salinization and increase in electric conductivity, which cause plant nutritional imbalance and result in hampering crop yield (Silva *et al*., 2000).

➢ pH

Sheep and goat manure analysed had a neutral-basic pH up to a value of 8.0 indicating that they can greatly contributed to pH reduction of acid soils. Soil pH affects all the physical, biological and chemical soil properties (Brady and Weil, 2002) and the growth of specific organisms, soil microbial biomass, and microbial activity. Through the range of pH recorded for manure, these wastes can greatly contributed to increase soil pH which directly affects the solubility of many of the nutrients in the soil needed for proper plant growth and development. These chemical reactions are complex. As soil pH decreases, nutrients, such as phosphorus, usually decrease in plant availability because of precipitate reactions with iron and aluminum. However, plants can affect their micro-environment and are often found to grow well over a range of soil pH and therefore most plants do well over a range of soil pH values. According to Phillips *et al*. (2000), Balsari et al. (2006) and Yagüe et al. (2012), pH values more than 7.3 observed for studied manure (except for poultry) favour nitrogen losses as gaseous ammonia from storage manure

➢ Carbone and organic matter

Statistical analysis showed a significant difference between species regarding organic carbon content of their manures which ranging in the following order: goat > cattle > sheep > swine = poultry. The use of organic manures has been recommended for long term cropping in the tropics as slow mineralization of these manures is known to promote crop yield for a long period of time. The speed of mineralization depends on C/N ratio. In this trial, cattle, goat, sheep, swine and poultry C/N ratio ranged in the following order: cattle (59) > goat (32) = swine (31) > sheep (25) > poultry (14). On the basis of C/N ratio, cattle manure would be more desirable of these natural fertilizers because of it ratio (59) revealing its ability to decompose very slowly and therefore, increases soil organic matter which has a powerful effect on its development, fertility, and available moisture (Simonson, 1999).

Macro-nutrients composition of manures and their variation

In this study, N content of poultry manure was 11.7‰ and is similar to those obtained by Bayram (2009), Ayeni et al. (2008) and Akanni et al. (2007) who reported 10.0, 11.1, and 11.9‰, respectively. This result is higher than those found by Bheki et al., (2011) and Nasim et al. (2012) who found 2.39‰ and 1.51‰, respectively. In contrast, the result is lower than those published by Farhad et al. (2009) and Adekiya et al. (2009) who recorded 20.4‰ and 22.3‰, respectively. In fact, nutrient contents of excreta are greatly variable according to animal feds, supplements and farm management (Van Kessel and Reeves 2000; Alkali et al. 2017). Phosphorous content of pig manure found in this trial was 1.4‰ and is in accordance with the range of 0.82-1.52‰ reported by Kowalski et al., (2013). It is very lower than that recorded by Sager (2007) (20.0‰). Potassium content (7.3‰) recorded for goat manure in this experiment is slightly higher than the range 4.21-6.17‰ reported by Uwah et al. (2014). Sodium content of cattle manure found is 1.2‰. It is higher than that reported by Mushambanyi (2002) (0.88‰) but lower than that recorded by Sager (2007) (3.59‰). Laboratory analysis showed that, manure composition is highly variable. As reported in the literature, the composition of animal manure vary to a great extent due to factors such as farm management, animal diet (Van Kessel and Reeves, 2000; Bokossa et al. 2014; Saïdou et al. 2016), water (Pederson (1994), supplements, medications, water management (Chastain et al. 2017) and storage duration (Ndegwa et al., 2002; Ndegwa & Zhu 2003; Balsari et al., 2006; Yagüe et al., 2011). The average ratio of major nutrients N:P:K recorded in this trial was (1:0.3:0.0.9) and is in accordance with the founding of Yagüe et al. (2011) who reported a range of (1:0.3:0.0.8)

1. Practical implication for relationship between physico-chemical characteristics (DM, pH and EC) of manures and their major plants nutrients composition (NPK)

Due to great variability of animal manure nutrient contents, it difficult for farmers to quantify the amount of plant nutrient fertilizers which can be applied on their crop or forage lands without using expensive manure tests (Hackett, 2007). In order to ensure that animal manures are a sought for arable farmers, farmers must ensure that animal wastes are as consistent as possible for both nutrient concentrations and DM content.

According to lab results, pH hasn't been correlated with any fertilizer element analyzed. This conclusion has been reported by Stevens et al. (1995); Bellotti, (1997) and Scotford et al. (1998ab).

For most of the samples analyzed the best single regression of macronutrients (NPK) was observed with DM amount as variable of poultry, goat and sheep manures, although the equations calculated using electrical conductivity showed a high coefficient of determination and a low standard error with pig and cattle manures. Stevens et al. (1995) have also observed high correlations between EC and both N and K concentrations of pig and cattle slurries, something confirmed later by Bellotti (1997). In this study phosphorus regressions have showed high determination coefficients except the samples of pig manure (single regression: r^2=0.41; sem = 0.41 and multiple regression: r^2 = 0.48; sem = 0.39).

The multiple regression equations obtained with two explanatory variables (EC and DM) did not significantly improve the coefficients of determination. The proportion of variation explained was not significantly increased by multiple regressions, compared with the best single variable predictor for poultry droppings, sheep and goat droppings. On the other hand, the coefficients of determinations and the standard deviations were improved in the equations of two variables of prediction of K in the samples of manure from pigs and cattle. This is due to the low correlation values that were initially observed between the different variables (EC and N, P, K or DM and N, P, K) involved in these equations.

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REFERENCES

Adekiya A. O. and Agbede T. M., 2009. Growth and yield of tomato (Lycopersicon esculentum Mill) as influenced by poultry manure and NPK fertilizer. *Emir. J. Food Agric*. 21 (1): 10-20 http://cfa.uaeu.ac.ae/ejfa.shtml

Ademiluyi BO, Omotoso S.O., 2008. Comparative evaluation of *Tithonia diversifolia* and NPK fertilizer for soil improvement in maize (*Zea mays*) production in Ado- Ekiti, South Western Nigeria. *Research Journal of Agronomy*, 2(1), 8: 11.

Adjolohoun S. 1992. Contribution à l'Etude des Systèmes d'Elevage et Gestion Agro-Pastorale du Terroir : Cas de Village de Tchankuehoun dans la Sous-Préfecture de Matéri (BENIN). Mémoire d'Ingénieur Agronome. Faculté des Sciences Agronomiques, Université d'Abomey-Calavi. 169p.

Akanni, D.I. and Ojeniyi S.O., 2007. Effect of different levels of poultry manure on soil physical properties, nutrient status, growth and yield of tomato (*Lycopersicon esculentum*). *Research Journal of Agronomy*, **1**:1-4.

Alam, M.N., Abedin, M.J., & Azad, M.A.K. 2010. Effect of micronutrients on growth and yield of onion under calcareous soil environment. *International Research Journal of Plant Sciences.* 1(3), 56-61.

Alkali H.A., Muhammad B.F., Njidda A.A., Abubakar M. and Ghude M.I., 2017. Relative forage preference by camel (*Camelus dromedarius*) as influenced by season, sex and age in the Sahel zone of north western Nigeria. *AJAR* 12(1), 1-5.

APHA. 1998. "Standard Methods for the Examination of Water and Wastewater". (eds. S.C. Lenore, A.E. Greenberg and A.D. Eaton), 20th Edition, American Public Health Association, Washington, DC, USA.

Ayeni, L.S., Adetunji, M.T., Ojeniyi, S. O., Ewulo, B.S. and Adeyemo, A.J., 2008. Comparative and Cumulative Effect of Cocoa Pod Husk Ash and Poultry Manure on Soil and Maize Nutrient Contents and Yield. *American-Eurasian Journal of Sustainable Agriculture*, **2**(1): 92-97.

Balsari, P., Dinuccio, E., & Gioelli, F., 2006. A low cost solution for ammonia emissions from covered slurry compared with uncover during storage. *Agriculture Ecosystems and Environment.* 112, 129-134.

Basson, W.D., Stanton, D.A. and Bohmer, R.G., 1968. Automated procedure for the simultaneous determination of phosphorus and nitrogen in plant tissue. *Analyst* **93:** 166–172.

Batelle Memorial Institute. 1999. Annual Reports 1999, Battelle Memorial Institute, USA.

Bayram G., Turk M., Carpici E.B., and Celik N., 2009. The effect of aeration and application of manure and fertilizer on the hay yield, its quality and botanical composition of the abandoned range. *African Journal of Agricultural Research* 4(5): 498-504.

Bellotti, G., 1997. Electrical Conductivity Meter: a device to estimate nutrient content of animal manure. Ricerca condotta presso l'Istituto di Ingegneria Agraria: 1-11.

Bheki G.M., Alpheus M. Z. and Stefan J.S. (2011) Poultry manure enhances grass establishment at aquarry rehabilitation site in subtropical South Africa. African Journal of Agricultural Research, 6(1), 46-50, http://www.academicjournals.org/AJAR

Bokossa, H.K.J., Saïdou, A., Sossoukpe, E., Fiogbé, D.E. and Kossou, D. (2014) Decomposition and Mineralization Effect of Various Sources of Pig Manure on Water Quality and Nutrients Availability for Agro-Fish System in Benin. *Agricultural Sciences*, **5**, 1194-1206. http://dx.doi.org/10.4236/as.2014.512129

Brady, N.C., Weil, R.R., (2002), The Nature and Properties of Soil, 13th ed. Springer Netherlands, p.249.

Byrne, E. 1979. "Analysis of Agricultural Materials". An Foras Taluntais (now Teagasc), Dublin, Ireland, 197 pages.

Chamon AS, Gerzabek MH, Mondol SM, Ullah M, Rahman WEH. 2005. Influence of soil amendments on heavy metal accumulation in crops on polluted soils of Bangladesh. Communic *Soil Sci Plant Anal* 36:907 – 924.

Chastain J.P., Camberato, J.J., & Albrecht, J.E. Nutrient content of livestock and poultry manure Clemson University. 2001. Accessed 28 October 2017. Available:

http://www.clemson.edu/extension/camm/manuals/poultry/pch3b_00.pdf

Das, A., Prasad, M., Shivay, Y.S. and Subha, K.M. 2004. Productivity and sustainability of cotton (Gossypium hirsutum L.)-Wheat (Triticum aestivum L.) cropping systeme as influenced by Prilled Urea, farmyard manure and azotobacter. J. Agronomy and crop science 190, 298-304.

De Silva ASH, Cook HF. 2003. Soil physical conditions and physiological performance of cowpea following organic matter amelioration of sandy substrates. Communic *Soil Sci Plant Anal* 34:1039 – 1058.

Eghball B (2002) Soil properties as influenced by phosphorusand nitrogen-based manure and compost applications. Agron J 94:128–135

Fageria NK, Baligar VC (2005) Enhancing nitrogen use efficiency in crop plants. *Advan Agron* 88:97–185

FAO. Fertilizers and their uses. 2000; 26- 29.

Farhad W., Saleem M. F., Cheema M. A .and Hammad H. M., 2009. Effect of poultry manure levels on the productivity of spring maize (*Zea mays* L.). *The Journal of Animal & Plant Sciences* 19(3), 122-125.

Ghanbari A., Babaeian M., Esmaeilian Y., Tavassoli A., and Asgharzade A., 2012. The effect of cattle manure and chemical fertilizer on yield and yield component of barley (*Hordeum vulgare*). *African Journal of Agricultural Research* 7(3), 504-508.

Graves A., Matthews R., Waldie K., Bhurtel R., Quashie-Sam J., 2001. Review of technologies being evaluated for the Forest/Agriculture Interface. Institute of Water and Environment Cranfield University Silsoe, Bedfordshire MK45 4DT UNITED KINGDOM.pp 229.

Hackett, R., 2007. Exploiting pig manure as a nutrient source for cereals in Ireland. In: National Tillage Conference. Teagasc, Crop Reserach Centre, Oak Park, Carlow, Ireland.

Harendra, S., Kumar, S.M., & Singh, K.V. (2009). Effect of Sulphur and FYM on Yield and Nutrients Uptake by Garlic (*Allium sativum* L.) in an Alluvial Soil. *Annals of Horticulture*, 2(1), 86-88.

Harrison R, Webb J. 2001. A review of the effect of N fertilizer type on gaseous emissions. Adv Agron, 73, 67 – 103.

Herencia, J.F., Ruiz-Porras, J.C., Melero, S., Garcia-Galavis, P.A., Morillo, E. and Maqueda C. 2007. Composition between organic and mineral fertilization for soil fertility levels, crop macronutrient concentrations and yield. Agron. J. 99, 973-983.

Indoria AK, Poonia SR. 2006. Phytoextractability of lead from soil by some oilseed crops as affected by sewage sludge and farmyard manure. Arch Agron Soil Sci 52, 667 – 677.

Koura B. I. (2015). Improvement of Animal Productivity by Using Crop Residues in Integrated Crop-livestock System in Benin. PhD Thesis, 216 p. University of Abomey-Calavi, Benin.

Kowalski Z., Makara A., and Fijorek K., 2013. Changes in the properties of pig manure slurry 2 Vol. 60, No 4/2013 845–850 on-line at: www.actabp.pl

Kungolos A, Samaras P, Tsiridis V, Petala P, Sakellaropoulos G. 2006. Bioavailability and toxicity of heavy metals in the presence of natural organic matter. *J Environ Sci Health* 41, 1509 – 1517.

Lesse D.P.A.A. (2016). Gestion et modélisation de la dynamique des parcours de transhumance dans un contexte de variabilités climatiques au nord-est du Bénin. Thèse de doctorat, Université d'Abomey-Calavi, Bénin, 299 p

Maheswarappa HP, Nanjappa HV, Hegde MR, Prabhu SR. 1999. Influence of planting material, plant population and organic manures on yield and East Indian galangal (Kaempferia galanga), soil physico-chemical and biological properties. *Ind J Agron* 44, 651-657.

Martínez-Suller, L., Azzelino A., & Provolo, G. (2008). Analysis of livestock slurries from farms across Northern Italy: relationship between indicators and nutrient content. *Biosystems Engineering*, 94(4), 540-552.

Materechera SA, Salagae AM (2002). Use of partially decomposed cattle and chicken manures amended with wood-ask in two South African arable soils with contrasting texture effect on nutrient uptake, early growth and dry matter yield of maize. Commun. *Soil Sci. Plant Anal*., 33(1/2), 179-200.

McLaughlin MJ, Tiller KG, Naidu R, Stevens DP. 1996. The behaviour and environmental impact of contaminants in fertilizers. Aust J Soil Res 34:1 – 54.

Moral, R., Perez-Murcia, M.D., Perez-Espinosa, A., Moreno-Caselles, J., Paredes, C., 2005. Estimation of nutrient values of pig slurries in southeast Spain using easily determined properties. *Waste Manage*. 25 (7), 719–725.

Morton JF. 1981. Atlas of medicinal plants of Middle America. Bahamas to Yucatan. Springfield, IL: C.C. Thomas.

Mushambanyi T.M.B., 2002. Contribution à la promotion de la culture du blé (Triticum aestivum L.) au Sud Kivu, République Démocratique du Congo: Evaluation du potentiel de rendement de deux génotypes d'origine burundaise, dans différentes zones agro-écologiques locales. *TROPICULTURA*, **20**(4): 210-216.

Nasim W., Ahmad A., Khaliq T., Wajid A., Munis M.F.H., Chaudhry H. J., Maqbool M. M., Ahmad S.and Hammad M.H., 2012. Effect of organic and inorganic fertilizer on maize hybrids under agro-environmental conditions of Faisalabad-Pakistan. *African Journal of Agricultural Research* **7**(17): 2713-2719.

Ndegwa, P.M., & Zhu, J. (2003). Sampling procedures for piggery in deep pits for estimation of nutrient content. Biosystems Engineering, 85(2), 239-248.

Ndegwa, P.M., Zhu, J., & Luo, A. (2002). Stratification of solids, nitrogen and phosphorus in swine manure in deep pits under slatted floors. Bioresource Technology, 83(3), 203-211.

Neubauer H, Furrer G, Kayser A, Schulin R. 2006. Siderophores, NTA, and citrate: Potential soil amendments to enhance heavy metal mobility in phytoremediation. Int J Phytoremediation 2:353 – 368.

O'Connell-Motherway, S., Lynch, P.B., Carton, O.T., O'Toole, P., 1997. Effect of water: feed

Pederson, B.K., 1994. Water intake and pig performances. In: Teagasc Pig Conference 1994, pp. 5..

Provolo, G., Martinez-Suller, L., 2007. In situ determination of slurry nutrient content by electrical conductivity. *Bioresource Technology* 98: 3235-3242.

Sager M., 2007. Trace and nutriment elements in manure, dung and compost samples in Austria. *Soil Biology & Biochemistry* **39:** 1383-1390.

SAÏDOU A. (2006) *Converting strategies by Farmers and Scientits to improve Soil Fertility and Enhance Crop-Production in Benin*. Ph.D. Thesis: Wageningen University, The Netherlands.

Saïdou, A , Kouessivi, H.J.B., Fiogbé, E.D. and Kossou D. (2016) Kinetic of pigs' manures decomposition and nutrient release pattern in ferralitic soil of Benin (West Africa). Journal of Soil Science and Environmental Management, 7(6), 73-80. http://www.academicjournals.org/JSSEM

Sánchez M, González JL (2005) The fertilizer value of pig slurry. I. Values depending on the type of operations. *Bioresour Technol* 96: 1117–1123.

SAS, 1991. SAS/STAT, User's guide, 4th Edn, Vers. 9.2. Cary, NC, USA, SASInstitute.

Schjønning P, Christensen BT, Carstensen B. 1994. Physical and chemical properties of a sandy loam receiving animal manure, mineral fertilizer or no fertilizer for 90 years. Eur *J Soil Sci* 45:257 – 268.

Scotford, I.,M., Cumby, T.,R., Han, L., Richards, P.,A., 1998a. Development of a prototype nutrient sensing system for livestock slurries. *Journal of Agricultural Engineering Research* 69: 217-228.

Scotford, I.,M., Cumby, T.,R., White, R.,P., Carton, O.,T., Lorenz, F., Hatterman, U., Provolo, G., 1998b. Estimation of the nutrient value of agricultural slurries by measurement of physical and chemical properties. *Journal of Agricultural Engineering Research* 71: 291-305.

Smith SJ, Scheepers JS, Porter LK. 1990. Assessing and managing agricultural nitrogen losses to the environment. *Adv Soil Sci* 14:1 – 32.

Smith, K.A., Charles, D.R., Moorhouse, D., 2000. Nitrogen excretion by farm livestock with respect to land spreading requirements and controlling nitrogen losses to ground and surface waters. Part 2: pigs and poultry. *Bioresource. Technologyl* 71, 183-194.

Stevens, R.J., O'Bric, C.J., Carton, O.T., 1995. Estimating nutrient content of animal slurries using electrical conductivity. *J. Agric. Sci*. 125, 233–238.

Suresh, A., Choi, H.L., Lee, J.H., Zhu, K., Yao, H.Q., Choi, H.J., Moon, O.K., Park, C.K., Kim, J.J., 2009. Swine slurry characterization and prediction equations for nutrients on South Korean farms. *Trans. ASABE* 52 (1), 267–273.

Suresh, A., Choi, H.L., Oh, D.I., Moon, O.K. (2009) Prediction of the nutrients value and biochemical characteristics of swine slurry by measurement of EC – Electrical conductivity. Bioresource Technology, 100, 4683–4689. www.elsevier.com/locate/biortech

Tunney, H., 1978. Dry matter, specific gravity and nutrient relationships of cattle and pig slurry. In Engineering Problems with Effluents from Livestock (Hawkins J.C. Ed.) Commission of the European Communities, EUR 6249, 430-444.

Udoh DJ, Ndoh BA, Asuquo PE, Ndaeyo NU. Crop Production Techniques for the tropics.Concept Publication.Lagos Nigeria. 2005; P. 446.

Uwah D.F., Undie U.L., and John N.M., 2014. Comparative Evaluation of Animal Manures on Soil Properties, Growth and Yield of Sweet Maize (Zea mays L. saccharata Strut.). *Journal of Agriculture and Environmental Sciences*. **3**(2) 315-331.

Van Kessel, J.S. and Reeves III, J.B. 2000. On-farm quick test for estimating nitrogen in dairy manure. *Journal of Dairy Science* **83:** 1837–1844.

Van Kessel, J.S., Thompson, R.B., Reeves III J.B., 1999. Rapid on-farm analysis of manure nutrients using quick tests. *Journal of Production Agriculture* 12(2): 215-224.

Yagüe M.R., Guillén, M., & Quílez, D. (2011). Effect of covers on swine slurry nitrogen conservation during storage in Mediterranean conditions. Nutrient Cycling in Agroecosystems, 90(1), 121-132.

Yagüe, M.R., Bosch-Serra, A.D., Boixadera, J. 2012. Measurement and estimation of the fertiliser value of pig slurry by physicochemical models: Usefulness and contraints. *Biosystems Engineering, 111 (2): 206-216*

Table 1. Estimates of animal manure quantities produced by different species during 2016 in Benin

Species	Total number of animals (2016)*	Estimated Tropical Livestock Unit (TLU)**	Mean manure per animal per day (kg DM)	Manure/year (tons DM)
Cattle	2339000	0.57	1.91	1630600
Sheep	915000	0.12	0.41	136900
Goat	1836000	0.1	0.34	227800
Swine	466000	0.21	0.72	122400
Poultry	20000000	0.0016	0.005	36500

* The number of animals per species was given by Houndjo et al. (in press); ** estimations based on reports of Adjolohoun (1992 and Lesse (2015)

Table 2. Physico-chemical characteristics and plant nutrient contents in Cattle, sheep, goat, swine and poultry manure during 2016 in Benin

Parameters	Species									
	Cattle		Sheep		Goat		Swine		Poultry	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Dry matter (%)	11.0c	8-19	26.8b	14-43	26.9b	14-47	23.7b	17-48	42.8a	33-60
pH	7.2b	6.7-7.9	8.2a	7.9-8.6	8.3a	7.8-8.3	7.6b	7.4-8.0	6.8c	5.5-7.3
EC (dS/m)	30d	25-40	61a	50-70	63a	50-70	52b	40-60	44c	30-50
Org Carb (g/kg)	178b	100-200	166c	99-243	189a	170-220	138d	88-150	141d	101-166
N (g/kg)	3.0d	1 – 5.4	6.7b	4.1-10.8	6.0b	3.0-10.5	4.5c	1.8 -9.7	11.7a	8.9-16.5
P (g/kg)	0.6c	0.2-1.1	4.4a	7.1– 2.7	4.9a	2.3 -8.7	1.4b	0.2-2.8	4.6a	2.7-12.4
K (g/kg)	4.1b	0.9-7.5	7.7a	4.6-12.3	7.3a	3.7-12.8	2.9c	1.8-4.9	7.6a	5.7-12.1
Ca (g/kg)	6.4b	3.8-11.7	7.8b	4.8-14.5	7.7b	5.2-13.1	1.8c	0.7-3.9	41.2a	26-82
Mg (g/kg)	2.2b	1.0-3.0	1.1c	0.4-2.3	1.2c	0.6-2	2.3b	1.0-3.0	3.2a	2-5
Na (g/kg)	1.2b	0.5-2	0.5c	0.1-1.5	0.5c	0.1-1.2	2.4a	1-3	1.1b	0.5-2

* For the same line, means followed by the same letters are not significantly different at $p < 0.05$

Table 3. Correlations among physical (pH, EC, DM) and chemical (N, P, K) properties of animal manures (n=360)

Variable tested	pH	EC	DM	N	P	K	Ca
				Cattle			
pH	1.00	0.38***	0.31***	0.33***	0.33***	0.32***	0.29***
EC		1.00	0.811***	0.88***	0.86***	0.82***	0.74***
DM			1.00	0.84***	0.72***	0.76***	0.90***
N				1.00	0.71***	0.77***	0.79***
P					1.00	0.71***	0.66***
K						1.00	0.70***
Ca							1.00
				Sheep			
pH	1.00	0.20**	0.22***	0.20***	0.21***	0.21***	0.16***
EC		1.00	0.95***	0.96***	0.95***	0.94***	0.72***
DM			1.00	0.97***	0.96***	0.98***	0.74***
N				1.00	0.94***	0.96***	0.73***
P					1.00	0.92***	0.71***
K						1.00	0.71***
Ca							1.00
				Goat			
pH	1.00	-0.02 NS	-0.03 NS	-0.05 NS	-0.05 NS	-0.03 NS	-0.02 NS
EC		1.00	0.93***	0.90***	0.09***	0.95***	0.70***
DM			1.00	0.97***	0.97***	0.98***	0.74***
N				1.00	0.97***	0.97***	0.73***
P					1.00	0.95***	0.72***
K						1.00	0.72***
Ca							1.00
				Swine			
pH	1.00	-0.16***	-0.11**	-0.13***	0.01NS	-0.08*	-0.08***
EC		1.00	0.57***	0.79***	0.23***	0.64***	0.47***
DM			1.00	0.49***	0.73***	0.57***	0.74***
N				1.00	0.07*	0.84***	0.34***
P					1.00	0.25***	0.46***
K						1.00	0.32***
Ca							1.00
				Poultry			
pH	1.00	-0.01 NS	0.04 NS	0.03 NS	0.03 NS	0.04 NS	-0.06 NS
EC		1.00	0.49***	0.51***	0.47***	0.47***	0.13*
DM			1.00	0.95***	0.93***	0.94***	0.20***
N				1.00	0.89***	0.90***	0.19
P					1.00	0.89***	0.17**
K						1.00	0.14**
Ca							1.00

NS: not significant; *0.01≤ p <0.05; ** 0.0001 ≤ p <0.01; ***p<0.0001

Table 4. Simple and multiple regression equations for predicting nutrient concentration (g/kg) of the different manures from the electrical conductivity [EC (dS/m)] and dry matter concentration [DM (%)]

	Property	Poultry manure			Pig manure			Goat dropping			Sheep dropping			Cattle slurries		
		Equation	r^2	sem	Equation	r^2	sem	Equation	r^2	sem	Equation	r^2	sem	Equation	r^2	sem
Simple regression	N	7,65 + 3,57 EC	0.26	1.60	-0,26 + 3,38 EC	0.63	0.99	1,80 + 1,88 EC	0.81	0.36	2,75 EC+2,18	0.93	0.20	0,06 + 2,03 EC	0.78	0.27
		0.062 + 0.27 DM	0.91	0.53	0,53 + 0,17 DM	0.24	1.42	0,0433 + 0,221DM	0.94	0.19	0,177 + 0,244DM	0.94	0.18	0.15 + 0.26 DM	0.72	0.31
	P	9,09 + 4,02 EC	0.21	2.04	1,05 + 0,20 EC	0.05	0.32	1,57 + 1,50 EC	0.76	0.33	1,34 + 1,87 EC	0.91	0.15	0,09 + 0,33 EC	0.74	0.04
		-0.32 + 0.32 DM	0.86	0.83	0,16 + 0,05 DM	0.53	0.22	0,0333 + 0,181DM	0.94	0.16	- 0,0426 + 0,166DM	0.93	0.13	0.17 + 0.03 DM	0.52	0.06
	K	5,06 + 2,25 EC	0.22	1.11	0,591 + 0,91 EC	0.41	0.41	1,99 + 2,36 EC	0.91	0.29	2,63 + 3,04 EC	0.88	0.28	0,17 + 2,75 EC	0.67	0.47
		- 0.17 + 0.18DM	0.89	0.41	0,34 + 0,06 DM	0.33	0.44	0,131 + 0,265 DM	0.96	0.17	0,168 + 0,279 DM	0.96	0.16	0.41 + 0.34 DM	0.58	0.55
Multiple regression	N	-0,06 + 0,26 DM + 0,45 EC	0.92	0.52	-0,52 + 0,02 DM + 3,23 EC	0.63	0.99	0,0129 + 0,227 DM - 0,0607 EC	0.94	0.19	0,911 + 1,21 EC + 0,142 DM	0.95	0.15	-0.19 +0.12 DM + 1.32 EC	0.72	0.31
	P	-0,38 + 0,32 DM + 0,20 EC	0.86	0.83	0,23 + 0,06 DM - 0,23 EC	0.58	0.21	- 0,155 + 0,219 DM - 0,375 EC	0.95	0.15	0,378 + 0,691 EC + 0,108 DM	0.94	0.11	0.08 + 0.01 DM + 0.31 EC	0.74	0.04
	K	-0,21 + 0,18 DM + 0,12 EC	0.89	0.41	0,13 + 0,03 DM + 0,66 EC	0.48	0.39	0,504 + 0,189 DM + 0,746 EC	0.98	0.13	0,275 + 0,176 EC + 0,264 DM	0.96	0.16	- 0.11 + 0.13 DM + 1.99 EC	0.71	0.45

sem: standard error of the mean.