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EFFECT OF COMPOST FROM DIFFERENT ANIMAL MANURES ON MAIZE (*Zea mays*) GROWTH

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ABSTRACT

Maize is one of the most important cereal used for people and animal alimentation in Côte d'Ivoire, but its productivity is low. Compost, which is an organic amendment, is known for its efficacy on agricultural productivity increase, but little is known about its influence on maize productivity in Côte d'Ivoire. The present study aimed to evaluate the benefits of compost from pig and chicken wastes on maize productivity. The field experiment was carried out under a randomized complete block design with three replicates on a ferralitic soil during three season-cycles. The agronomic parameters such as the number of leaves under the ear, the insertion height of ears, the plant height and yield attributes were investigated. Results of the study showed that the tallest plant (169.56 cm) was obtained with pig compost. The highest number of grains per row (30.87), the longest ear (17.59 cm), and the heaviest ear (181.33 g) were obtained with pig compost. The highest numbers of row of grains per ear were obtained with pig compost (13.50) and chicken compost (12.83). The highest weights of 100 grains were 13.51 g and 12.70 g respectively with pig compost and chicken compost. The results of the study suggest that pig and chicken manures could be used as fertilizer through composting to improve maize productivity in Côte d'Ivoire.

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1 Introduction

Maize or corn (*Zea mays* L.) is a crop originated from Mexico, from where it has been spread all over the world. It is the most important cereal crop in Sub-Saharan Africa and is an important staple food for more than 1.2 billion people (Nuss & Tanumihardjo, 2010). In industrialized countries, maize is largely used as livestock feed and as a raw material for various industrial products such as starch, sweeteners, oil, beverages, glue, industrial alcohol, fuel ethanol, paper manufacture, etc. (Orhun, 2013).

Maize worldwide production is about 1,134 million tons and the United States is the largest producer with 42% (ATLAS, 2017). Africa produced 6.5% of the total production of maize and the largest African producer is Nigeria with nearly 8 million tons, followed by South Africa (ATLAS, 2017). Africa imports 28% of the required maize from countries outside the continent (ATLAS, 2017). The average worldwide yield is approximately 5.5 tons/hectare/year while the production in Africa is around 2 tons/hectare/year and that has led to an increase of the kg of maize grains (US $ 26.37/kg) (ATLAS, 2017).

In Côte d'Ivoire, maize productivity varied from 0.8 to 2 tons per hectare and the annual production is about 967,000 tons for 278, 679 hectares when the annual human consumption is 1,026,000 tons per year (ATLAS, 2017). Consequently, Côte d'Ivoire still imports about 42,000 tons of maize per year to meet the needs of the populations (ATLAS, 2017).

Soil fertility has been described as one of the major causes of low agricultural productivity (Zake et al., 2015; Panagos et al., 2018). This is most likely due to unsustainable production systems associated with continuous nutrient mining without sufficient external inputs for soil fertility improving. Low soil carbon stock is an indicator of adverse soil quality and fertility (Lal, 2005; Feller et al., 2012). However, higher soil organic matter is a major constraint to increased food production in Sub-Saharan Africa, and to reduce poverty and food insecurity (Lal, 2005; Lal, 2008). Therefore, it is imperative to proceed with soil amendment to increase agricultural productivity. Chemical fertilizers are known for their negative effects on soil properties and their high cost. Thus, organic amendments remain one of the cost-effective options to sustain long-term agricultural productivity enhancement (Hartmann et al., 2014; Kumar et al., 2014). According to Djiakariya (2004), large quantities of pig waste (five thousand four hundred and fifty-four tons) and chicken waste (one hundred tons) are produced per year in Côte d'Ivoire. These wastes are not agriculturally used and most of the farmers throw them away or use them to fill ravines. However, these two wastes can be valorized in agriculture to improve soil fertility in developing countries (FAO, 1980). In fact, animal wastes can constitute a valuable source for improving soil structure, increasing microorganism's activity and maintaining soil humus (Albaladejo et al., 2000; Ipinmoroti et al., 2008). They also contain macronutrients and micronutrients essential for plant growth and for the improvement of physicochemical and biological properties of the soil (N'Dayegamiye & Côté, 1996; Albaladejo et al., 2000; Bresson et al., 2002) and cause reduction in the apparent density of soils (Giusquiani et al., 1995). The application of manure has contributed to increase the yield of various plants and was found superior to the yield obtained with mineral fertilization (Bockman et al., 1990; Soltner, 2003; Awodun, 2007). For example, in Burkina Faso, Zougmore et al. (2003) have reported that the application of animal manure on sorghum has increased the yield 20 to 39 times higher than that obtained without amendment. Similarly, N'Dayegamiye & Côté (1996) reported that animal manure intake, at a low dose for long term, achieved same levels of maize productivity as full mineral fertilization. In Côte d'Ivoire, Soro et al. (2015) reported significant improvement in maize productivity with chicken manure.

Despite the undeniable agronomic value of manure, its use in agriculture has some disadvantages and limitations. Indeed, the application of manure can cause serious environmental problems such as the emission of odors, the contamination of groundwater by metals, bacteria and nitrates (Elwell et al., 2001; Gay et al., 2003; Kunz et al., 2009; Venglovsky et al., 2009). In addition, while decomposing in the soil, manure is likely to release organic compounds such as skatole, indole and other phenols which, absorbed by plants, can give an abnormal flavor to the production (Maheshbabu et al., 2008). Although manure is an effective organic amendment, the unnatural flavor of the production and the estimation of ecological risks associated with its use make its treatment necessary before application. Among organic wastes treatment methods, composting is the most common one which is used by small scale farmers because its cost of achievement is affordable, and the majority of Sahelian countries farmers have adopted it (Danso et al., 2006; Folefack, 2008) as a source of organic matter production to increase organic matter content of poor soils. Composting is a biological aerobic transformation of an organic by-product into a different hygienic organic product that can be added to the soil without detrimental effects on crop growth (Baca et al., 1992). Natsheh & Mousa (2014) found that compost application is the best management for increasing soil fertility, cucumber yield and decrease the cost of N mineral fertilizers. According to Ehab & Ahmed (2015), compost improves *L. siceraria* yield. It contains organic matter and nutriments that enhance plant growth and biological substances inhibiting diseases pathogens action (Liu et al., 2013; Cattelo et al., 2014). Compost has numerous advantages in agricultural productivity increase, but little is known about its efficacy in Côte d'Ivoire. The objective of the present study was to evaluate the effect of the compost from pig and chicken wastes on the growth and yield of maize (*Zea maize*) in Côte d'Ivoire.

2 Material and methods

2.1 *Study site*

The study was carried out at the experimental station of the University Nangui-Abrogoua (Abidjan, Côte d'Ivoire) located in Abidjan (latitudes 5°17 N - 5°31 N and longitudes 3°45W - 4°22W). The climate of the city of Abidjan corresponds to that of southern Côte d'Ivoire. It has a tropical humid climate (Durand & Skubich, 1982) with four seasons including two rainy seasons and two dry seasons. The big rainy season extends from April to July (4 months) and the short rainy season lasts two months (October and November). As for the big dry season, it covers 4 months (December to March), while the short dry season lasts two months (August and September) (Durand & Skubich, 1982). The average monthly temperature varies from 24.54°C in August to 28.45°C in March. The mean maximum precipitation is observed in the month of June (330.25 mm) and the minimum value in January (15.47 mm). The relative humidity is higher in September (91.94%) and lower in April (85.41%). The soil of the experimental station of the University Nangui Abrogoua is ferralitic (ferralsol) (Yao-Kouamé & Allou, 2008). The pH is more acidic at the surface than at depth, and the organic matter content varies from 2 to 3% (Yao-Kouamé & Allou, 2008).

2.2 *Biological materials*

Large quantities of pig and chicken wastes are produced per year in Côte d'Ivoire. These wastes were collected from different farms of Abidjan. The excreta were constituted of a mixture of faeces and urine without any bedding material. In order to facilitate their manipulation and reduce the smell, the wastes were air dried before use. The pH of pig and chicken wastes was respectively 5.28 and 8.52. The total carbon and the nitrogen of the collected material were estimated, and it was reported 50.45% and 0.35% for pig waste and 38.50% and 0.73% for chicken waste. Also, the total phosphorus and potassium were reported respectively 0.50% and 0.76% for pig waste and 0.81% and 1.75% for chicken waste. The maize seed used in this experiment was a local variety called "Boundiali".

2.3 *Preparation of compost*

For compost preparation, 2 pits (1 m × 1 m × 1 m) were dug and their bottoms were cemented to avoid nutriments loss. One pit was filled with 50 kilos of pig dried manure while the second one received 50 kg of chicken manure. The content of the different pits was returned thrice according to the "Indienne Indore method" (FAO, 1980). The moisture content of the pits was also regularly adjusted to 50-60%. The pits were covered with some coconut palm leaves to maintain humidity for three months.

2.4 *Experimental design*

The experimental design consisted of three randomized complete blocks. Each block (15.8 m x 6.4 m) was corresponded to a type of treatment and control and contained three plots separated each another by an aisle of 1 m. The treatments were represented by pig and chicken manure compost and the control. Seedlings of maize were made three crop cycles. The sowing was carried out on the same day for all treatments with 3 seeds per hole at a depth of 2 to 3 cm at each cropping cycle. The lifting occurred 2 weeks after the sowing and seedlings were thinned to keep only the two strongest at each sowing point. Sixty plants were retained per plot. A total of 1 kg compost was spread at each sowing point and buried at 15 cm depth in the soil with a hoe to avoid leaching and facilitate nutrients absorption by plant roots.

Vegetative, yield and biomass parameters were evaluated in this study. The vegetative parameters were the number of leaves under the ear, the insertion height of ears and plant height. Yield attributes investigated were the diameter of ear, the number of grains per row, the length of ear, the weight of ear, the number of row of grains per ear and the weight of 100 grains. The fresh and dried biomass of the aerial part of the plant and the roots were also evaluated in this study.

Data were analyzed by factorial analysis of variance (ANOVA) using the statistical software R. Least Significant Difference (LSD) multiple range-tests procedure were used to separate the means of the different treatments. Means were given as mean followed by standard deviation (M ± SD). Significant differences were determined at $P \leq 0.05$.

3 Results and discussion

3.1 *Effect of composts on vegetative parameters of maize*

The vegetative parameters of maize with respect to the type of fertilizer are presented in **Table 1**. The number of branches per tassel varied from 16.2 to 29.83. However, the number of branches per tassel differed significantly (P< 0.05) between the used two types of fertilizers. The highest numbers of branches per tassel were obtained with pig compost (17.0) and chicken compost (16.2) and the lowest with the control (9.83).

The number of leaves under the ear was reported 6.43 for pig compost, 7.25 for chicken compost and 6.23 for the control. According to ANOVA test, the number of leaves under the ear was similar despite the type of fertilizer.

Concerning the insertion height of ears, it varied significantly (P< 0.05) from one type of fertilizer to another. The highest insertion height was obtained with chicken compost (66.97 cm) and it was followed respectively by those obtained with pig compost (64.03) and the control (29.12 cm).

Statistically, plant height differed significantly at 45, 60 and 75 days respectively in function of the type of fertilizer. At 45 days, the tallest plant (70.19 cm) was measured with the compost from pig waste, followed by the chicken compost (51.4 cm) and the shortest was noted with the control (22.45 cm). Similar trends were reported at day 60 and day 75 from sowing. Among the tested manure, pig compost show superiority over the chicken compost and the control (**Table 1**). All the vegetative parameters were more developed with the compost than with the control. This can be linked to the efficacy of the different composts. Organic amendments particularly composts significantly enhanced soil organic carbon and thus had a considerable effect on soil microbes and nutrient availability and uptake for plant (Baca et al., 1992). It has been demonstrated that pig and chicken composts are rich in micro and macronutrients that can increase plant growth (Warren et al., 2006; Coulibaly et al., 2016). The efficiency of the compost could be explained by its capacity to improve the organic matter content, soil structure, nutrient retention, aeration, soil moisture holding capacity and water infiltration for plants. Similarly, Ali et al. (2003) had reported that the use of poultry manure increased the height of maize because of the presence of macro and micronutrients. Ridine et al. (2014) observed more developed maize plant parameters when applying bat's manure and NPK as fertilizer. However, the plant height obtained in our study with the composts was close to the 1.7 m reported by Ridine et al. (2014) with the variety "IB" and lower than the 2 m with another variety namely "TZEE-W". These differences could be linked to the maize variety and the initial composition of the different wastes.

3.2 *Effect of composts on yield attributes of maize*

The effect of the two composts on maize yield attributes are presented in **Table 2**. The diameter of ears varied from 8.07 mm to 13.44 mm. Ear diameters significantly varied from one type of compost to another. Further, among the tested two composts, the largest diameter of ears was obtained with pig compost (13.44 mm) and this was followed by the chicken compost (12.92 mm) and the control (8.07 mm). However, the diameters of ears obtained with pig and chicken composts were statistically equal and were significantly different from the control.

Table 1 Effect of the type of fertilizer on maize growth parameters

Vegetative parameters	Type of fertilizer			*P*
	Pig compost	Chicken compost	Control	
Number of branches per tassel	17.00±3.08[a]	16.20±0.98[a]	9.83±1.41[b]	0.011
Number of leaves under the ear	6.43±0.51[a]	7.25±1.49[a]	6.23±0.80[a]	0.25
Insertion height of ears (cm)	64.03±26.19[a]	66.97±5.4[a]	29.12±9.37[b]	0.021
Plant height at 45 days (cm)	70.19±16.22[a]	51.40±5.16[b]	22.45±1.70[c]	0.003
Plant height at 60 days (cm)	147.51±65.08[a]	154.30±10.64a	42.28±5.48[b]	< 0.001
Plant height at 75 days (cm)	169.56±24.25[a]	124.47±13.65[b]	76.99±12.35[c]	< 0.001

NB. Mean values denoted with the same letter in every row were not significantly different (P > 0.05).

Table 2 Effect of the type of fertilizer on yield growth parameters

Yield parameters	Type of fertilizer			Statistical test
	Pig compost	Chicken compost	Control	*P*
DE(mm)	13.44±0.32[a]	12.92±0.17[a]	8.07±2.37[b]	0.04
NG/R	30.87±2.83a	18.40±1.69b	9.57±5.44c	0.04
LE(cm)	17.59±0.47a	13.10±0.39b	8.85±3.39c	0.044
WE(g)	181.33±16.15a	82.84±9.22b	44.08±10.37c	0.044
NRG/E	13.50±0.36[a]	12.83±0.29[a]	7.25±3.46[b]	0.042
W_{100}(g)	13.51±0.72[a]	12.70±0.90[a]	5.12±2.14[b]	0.096

DE: Diameter of ears. NG/R: Number of grains per row. LE: Length of ear. WE: Weight of ear. NRG/E: Number of row of grain per ear. W100: Weight of 100 grains.

NB. Mean values denoted with the same letter in every row were not significantly different (P > 0.05).

Concerning the number of grains per row, it ranged from 9.57 with the control to 30.87 with the pig compost. Similarly, Abd El-Gawad & Morsy (2017) recorded 33.97 and 34.29 grains per row respectively after an application of compost from sheep manure and sheep manure mixed with urea. Laekemariam & Gidago (2012) recorded 34 grains per row while combining compost and urea. In the case of ear length, a significant difference (P<0.05) was reported between the type of fertilizers used. The highest length was measured with pig compost (17.59 cm) which was followed by the chicken compost (13.1 cm) and the control (8.85 cm). The maximum length of ear in our study was higher than the 16.85 cm reported by Laekemariam & Gidago (2012) after compost application. Higher values of ear length (19.42 cm and 18.83 cm) were recorded by Yigermal et al. (2019). The weight of the ear varied from 44.08g to 181.33g. The decreasing order of ears weight was 181.33g for pig compost, 82.84g for chicken compost and 44.08 g for the control.

The number of grains' row per ear and the weight of 100 grains respectively varied significantly in function of the type of fertilizer. The highest number of row of grains per ear (13.50) and the maximum weight of 100 grains (13.51 g) were obtained with the compost from pig manure. In case of chicken compost, the number of row of grains per ear and the weight of 100 grains were reported 12.83 and 12.7g respectively, and were significantly higher than those obtained with the control (7.25 and 5.12 g respectively). Laekemariam & Gidago (2012) counted 15 rows of grains per ear after compost application. Similarly, Ayoola & Makinde (2006) found an increase in maize yield attributes after application of animal manures composts. According to Satyanarayana et al. (2002) and Ayoola & Makinde (2006), the efficiency of organic amendment on plant yield is due to more availability plant nutrients, enzyme, vitamins and better soil characters which helped the plant to uptake more soil nutrients along with water. Our results are supported by those of Shah et al. (2009), Achieng et al. (2010), who reported that number of grains per cob, 1000-grain weight, and grain yield gave higher values, when using organic amendments as sources of nutrients. Similar results were revealed by Elamin & Elagib (2001), who reported significant differences between non-treated and treated maize plants with organic fertilizers.

Despite that yield attributes were higher with the composts than those obtained with the control, there was a significant difference between those observed with the different composts. That could be explained by the initial characteristics of the manures. The different nutrients in the pig compost might be more mobile than those in the poultry manure and consequently more available.

3.3 *Effect of compost on plant biomass*

The different parameters relative to maize biomass and its moisture content are registered in **Table 3**. Statistically, fresh and dried biomass of the aerial part varied significantly with respect to the used organic fertilizers. It appeared that the highest plant aerial biomasses (307.41g for fresh) and (89.36g for dried) were obtained from the pig compost while the lowest biomasses (108.84g for fresh and 11.79g for dried) were reported from control plots. In contrast, the highest moisture content (89%) was obtained with the control which was followed in decreasing order by that got with pig compost (71%) and chicken compost (69%).

Fresh roots biomass varied from 11.79g to 20.81g while in the case of dried roots biomass it ranged from 2.67g to 6.57g. The highest fresh roots biomass (20.81g) was obtained with pig compost and the lowest fresh biomass (11.79g) was measured with the control. The highest dried roots biomass (6.57) was got with the chicken compost and the lowest (2.67±0.01) was observed with the control. Concerning roots moisture content, the decreasing order was reported for the control (77%), pig (73%) and chicken compost (54%). The highest biomass obtained with the composts could be explained by their nutritional qualities. These results could also be explained by a higher increase of the photosynthesis accompanied with an increase in plant transpiration. In contrast, with the control, the photosynthesis was weak and that also lower the transpiration. Consequently, the

Table 3 Effect of the type of fertilizer on maize parts biomass after harvest.

Biomass	Type of fertilizer			Statistical test
	Pig compost	Chicken compost	Control	P
FBAP(g)	307.41±107.12^{a}	142.75±15.19^{b}	108.84±2.121^{c}	0.044
DBAP(g)	89.36±28.2^{a}	51.41±7.53^{b}	11.79±2.12^{c}	0.004
MCAP	71.00±20^{c}	69.00±8.00^{b}	89.00±1.00^{a}	0.012
FRB(g)	20.81±3.34^{a}	14.67±3.98^{b}	11.79±2.12^{c}	0.01
DRB(g)	5.56±0.18^{a}	6.57±0.87^{a}	2.67±0.010^{b}	0.043
MCR (%)	73.00±4.00^{b}	54.00±1.00^{c}	77.00±4.00^{a}	0.006

FBAP: Fresh biomass of aerial part, DBAP: Dried biomass of aerial part, MCAP: Moisture content of aerial part, FRB: Fresh roots biomass, DRB: Dried roots biomass, MCR: Moisture content of roots.
NB. Mean values denoted with the same letter in every row were not significantly different (P > 0.05).

moisture content obtained with the control was higher than those obtained with the composts. Organic manures, especially compost from pig and chicken manure supply balanced nutrients to plant roots and stimulate growth, increase organic matter content of the soil including the humic substances that affect nutrient accumulation and promote plant aerial part (Canellas et al., 2000).

Conclusion

Application of compost from chicken and pig manure had a positive influence on maize growth, yield and yield components. Among animal manures, compost from pig manure showed the highest increase in maize growth compared to chicken manure. However, the valorization of these two manures can be recommended through composting to increase maize productivity.

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Conflict of interest

The authors declare that there is no conflict of interest for the present work.

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