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Research Article

Effect of the application timing of compost and vermicompost on mays (*Zea mays*) productivity parameters

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Abstract: Compost and vermicompost are organic fertilizers known for improving soil properties and agricultural productivity but little is known about their application timing for optimum efficacy on plant productivity particularly on maize growth. A field experiment was conducted to evaluate the effect of compost and vermicompost from poultry waste and their application timing on maize growth and yield attributes under randomized complete block design with three replicates during three season-cycles. Results showed that the seeds germination was not influenced by the organic fertilizers. The highest number of leaves under the ear, the highest insertion height of ears was respectively 5.65 and 66.2 cm with the vermicompost spread before sowing, and 5.45 and 84.25 cm with the compost before sowing. The tallest plant was obtained with the compost (178.95 cm) applied before sowing. The longest leaves (74.98 cm) were measured when the vermicompost was spread before sowing. The longest ear (15.55±4.15 cm) was got with the compost applied before sowing. The highest number of rows of grains per ear (15), the maximum number of grains per row (18) and the highest weigh of 100 grains (15.11 g) were obtained with the compost and the vermicompost applied before sowing. Thus, compost and vermicompost from poultry waste can be used to increase maize productivity when they are spread before sowing.

Keywords: maize, compost, vermicompost, application timing, Côte d'Ivoire.

INTRODUCTION

Increasing food resources sustainably remains today one of the fundamental options to ensure populations prosperity in developing countries. However, despite the efforts made by the population, the production of certain crops is still low. This is the case of corn productivity in Côte d'Ivoire, with an average global production of 654,738 tons for a total area of 327 800 ha (ATLAS, 2017). In fact, maize is the most important cereal in the world after wheat and rice (Zamir *et al*., 2013). It is a tropical crop, originated from South America and has been adapted magnificently to temperate environment with much higher productivity. Maize is also called "Queen of Cereals" because of its higher production potential and adaptability to a wide range of environments compared to other cereals (Kumar, 2013). In Côte d'Ivoire, maize plays an important role in the economy and is a potential source of food for human being and quality feed for animals (N'da *et al*., 2014). Moreover, maize is a basic raw material to industries for starch production, oil, protein, alcoholic beverages, and food sweeteners etc. (Orhun, 2013).

The productivity of corn varied from 1 to 2 tons per hectare each crop year in Côte d'Ivoire (Boone *et al*., 2008) which is very low compared to the 5.5 tons/hectare/year defined as the average worldwide productivity (FAO, 2008). The main maize producers in Africa include Kenya, Tanzania, Zambia, Zimbabwe, and Ethiopia where the productivity is higher than 3.6 tons/ha (CSA, 2011; Mitiku and Asnakech, 2016). In 2017, the national consumption of corn was 1,026,000 tons when the annual production was 967,000 tons in Côte d'Ivoire (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).

Various reasons among which the loss of soil fertility explain the low yield. Indeed, soil fertility is an important component for higher agricultural productivity, it is its state of nutrient availability, and ability to provide nutrients from its own reserves for the production of crops that define its level of fertility (Zake *et al.*, 2015; Panagos *et al.*, 2018). Application of fertilizers is necessary if soil fertility is low and unsuitable for maintaining a desired level of plant production. 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). The application of organic amendments to soil results in increasing soils organic matter, biological activity and therefore crop productivity and quality (Kumar *et al.*, 2014).

In recent years, the application of animal wastes for increasing soil fertility has gained importance due to the high cost and adverse impact of inorganic fertilizers. Incorporation of animal manures has given a hope to reduce the cost of cultivation and improve agricultural productivity (Albaladejo *et al.*, 2000; Ipinmoroti *et al.*, 2008). In fact, animal wastes are known to contain macronutrients and micronutrients essential for plant growth and for the improvement of physicochemical and biological properties of the soil (Albaladejo *et al.*, 2000; Bresson *et al.*, 2002). The application of animal wastes has contributed to increase the yield of a lot of plants (Bockman *et al.*, 1990, Soltner, 2003, Awodun, 2007; Soro *et al.*, 2015). However, despite the undeniable agronomic value of manure, its use in agriculture has 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 (Gay *et al.*, 2003, Kunz *et al.*, 2009; Carter and Kim, 2013). 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). If the manure is an effective organic amendment, the unnatural flavor of the production and the ecological risks associated with its use make its treatment necessary before application. This may be feasible if stakeholders have the opportunity to bear the costs. Among organic wastes treatment methods, composting and vermicomposting are known for their affordable cost of achievement (Danso *et al.*, 2006; Folefack, 2008) and their organic matter production to increase organic matter content of poor soils. Compost and vermicompost resulting respectively from composting and vermicomposting can be added to the soil without detrimental effects on crop growth (Baca *et al.* 1992). The efficacy of compost and vermicompost in improving agricultural productivity is well recognized (Liu *et al.*, 2013; Cattelo *et al.*, 2014; Ehab and Ahmed, 2015; Olle, 2016; Zaremanesh *et al.*, 2017; Adiloğlu *et al.*, 2018) but little is known about their efficacy on maize growth in Côte d'Ivoire. Moreover, the literature relative to the application timing of these organic fertilizers for optimum agricultural productivity is still limited. The objective of the present study was to evaluate the effect of compost and vermicompost and maize growth and to determine their application schedule for optimum productivity of maize.

MATERIALS AND METHODS

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's a humid tropical climate (Durand and 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 to September) (Durand and 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 was ferralitic (ferralsol) (Yao-Kouamé and Allou, 2008). The pH was more acidic at the surface than at depth, and the organic matter content varied from 2 at 3% (Yao-Kouamé and Allou, 2008).

Biological materials

Poultry waste was collected from different farms in Abidjan to be used. The excreta were constituted of a mixture of faeces and urine without any bedding material. In order to facilitate their manipulation and reduce smell, the wastes were air dried before their use. The pH of poultry waste was 8.52. The total carbon and the total nitrogen were respectively 38.50% and 0.73%. The total phosphorus and the total potassium were respectively 0.81% and 1.75%. The seeds of maize used in this experiment were a local variety called "Boundiali".

Compost and vermicompost preparation

For the compost and the vermicompost preparation, 4 pits (1 m × 1 m × 1 m) were dug and their bottom cemented to avoid nutriments loss. Each pit received 50 kilos of dried poultry waste. Two of the four pits were reserved to the compost and the other to the vermicompost. The content of the different pits designated for the compost was returned thrice according to the "Indienne Indore method" (FAO, 1980) and the moisture content regularly adjusted to 50-60%. Concerning the vermicompost, the content of the pits was turned over manually every day for 2 weeks to remove volatile gases, which may be potentially toxic to the earthworms. The moisture content of the pits was also regularly adjusted to 70-80%. After pre-composting, each of the two pits received 750 individuals of *E. eugeniae* for the substrate mineralization. Then, all the four pits were covered up with coconut palm leaves to avoid colonization of earthworms by pests and to maintain humidity for three months.

Experimental design

The experimental design consisted of three randomized complete blocks. Each block corresponded to a type of treatment and control and contained seven plots separated each another by an aisle of 1 m. Each plot had 8 m² (4 m x 2 m) and the plots were separated each another by a distance of 1 m. The treatments were represented in by the vermicompost and compost before sowing, at plant emergence, at plant flowering and the control. Seedlings of maize were made three crop cycles. The sowing was done on the same day for all the treatments with 3 seeds per hole at a depth of 2 to 3 cm at each cropping cycle. The lifting occurred 2 weeks after sowing and seedlings were thinned to keep only the strongest plant at each sowing point. Thirty plants were retained per plot. A total of 2.5 kg of vermicompost or compost was spread on each plant in the corresponding plot at the different stages of the plants development. After the fertilizer application, it was buried on the same day 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 the plant height. Yield attributes investigated were the diameter of ears, the length of ear, the weight of ear, the number of row of grains per ear, the number of grains per row, and the weight of 100 grains. The roots biomass and the aerial biomass of the plant 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 $P \leq 0.05$.

RESULTS AND DISCUSSION

Effect of organic fertilizers application timing on vegetative parameters of maize

The application timing of the fertilizer on the number of leaves under the ear, the insertion height of the ear and the rate of germination are registered in **Table 1**.

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

Treatments	Agronomic parameters		
	RGer (%)	NLUE	IHE
VBS	73.3±20.82	5.65±1.3ª	66.2±14.34ᵇ
VEm	80±10	3.4±0.99ᵇ	32.6±7.64ᶜ
VFl	90±10	2.65±0.81ᵇ	28±14.59ᶜ
CBS	70±20	5.45±1ª	87.25±25ª
CEm	53.33±23.09	3.25±0.97ᵇ	38.15±16.97ᶜ
CFl	86.67±11.55	3.2±1.28ᵇ	31.6±14.38ᶜ
Control	60±10	5.1±2.75ª	29.13±21.36ᶜ
F	2.12	14.932	35.854
P	0.05	< 0.001	< 0.001

Mean values of parameters denoted with the same letter in each column were not significantly different.

RGer: Rate of germination, **IHE:** insertion height of ears, **NLUE:** number of leaves under the ear, **VBS:** Vermicompost before sowing, **VEm:** Vermicompost at emergence, **VFl:** Vermicompost at flowering, **CBS:** Compost before sowing, **CEm:** Compost at emergence, **CFl:** Compost at flowering,

The rate of seeds germination varied from 60% to 73%. However, there was no significant difference (P < 0.05) between the rates of germination. This could be explained by the fact that fertilizer may not influence the germination of seeds. Seeds might use their reserve energy to germinate when the soil conditions are favorable. According to Huang *et al*. (2004) and Yazdi *et al*. (2013), temperature, pH and sowing depth are the main factors influencing seeds germination in the soil.

The number of leaves under the ear varied from one treatment to another. The highest number of leaves (5.65±1.3) was obtained with the vermicompost spread before sowing and the lowest (2.65±0.81) with the vermicompost applied at the emergence. Relatively to the insertion height of the ear, it was lower (28±14.59 cm) with the vermicompost spread at the emergence and higher (87.25±25 cm) with the compost before sowing. The highest number of leaves and insertion height of ears obtained with the fertilizers applied before sowing compared to the other ones could be explained by an availability of the nutrients for plant growth at the right time. In fact, when bringing the fertilizer before sowing, roots could absorb nutrients easily as they are already in contact with the fertilizers. In contrast, after emergence, fertilizer might take time to release nutrients to plant and that can affect negatively plant growth. Moreover, when burring the fertilizer into depth after its application with the hoe, that can stress the plants and therefore influence negatively its growth parameters. Similarly, Ogbonna *et al*. (2012) observed higher vegetative growth parameters with maize after the application of compost and vermicompost from poultry dropping in port Harcourt, Nigeria.

Plant height varied significantly from one treatment to another in function of the fertilizer application timing (**Figure 1**).

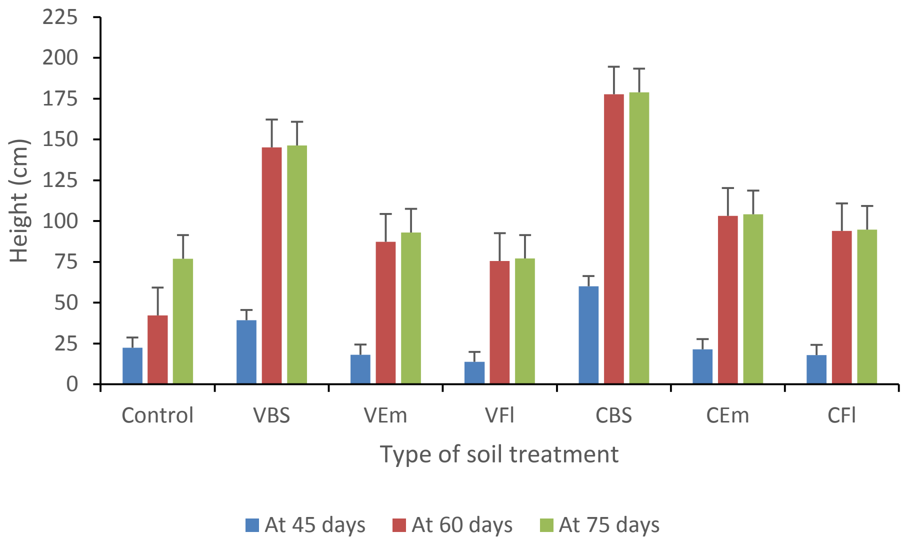

Figure 1. Effect of the spreading timing of organic fertilizers on maize height

VBS: Vermicompost before sowing, **VEm:** Vermicompost at emergence, **VFl:** Vermicompost at flowering, **CBS:** Compost before sowing, **CEm:** Compost at emergence, **CFl:** Compost at flowering,

At 45 days, the tallest plant (60.05±20.46 cm) was obtained with the compost spread before sowing and the shortest (13.7±5.31 cm) was measured with vermicompost applied at flowering. The height of the plant obtained with the control, the vermicompost spread before sowing, the vermicompost at emergence, the compost at emergence and the compost at flowering were respectively 22.45±9.05 cm, 39.25±11.06 cm, 18.05±5.75 cm, 21.4±7.73 cm, and 17.95±7.49 cm.

At 60 and 75 days respectively, the tallest plants (177.65±30.17 cm and 178.95±30.09 cm) were obtained with the compost applied before sowing and followed respectively by those got with the vermicompost applied before sowing (145.2±19.78 cm and 146.3±19.42 cm), the compost applied at emergence (103.25±23.33 cm and 104.2±23.54 cm), the compost at flowering (93.9±27.4 cm and 94.8±27.42 cm), the vermicompost at emergence (87.35±24.88 cm and 93.05±23.55 cm), the vermicompost at flowering (75.6±25.39 cm and 77.05±25.3 cm) and the control (42.28±30.49 cm and 76.99±37.18 cm). Yigermal *et al*. (2019) also observed higher maize height after compost and vermicompost application. However, the maximum plant height (237.25 cm) obtained by the authors was higher than the 178.95 cm got in our study as maximum maize height. Ravi *et al*. (2012) and Zerihum *et al*. (2013) reported respectively higher maize plant height of 187.8 cm and 222 cm after the application of some fertilizer from crops residues. These differences could be linked to the initial characteristics of the soil and the material used as fertilizer.

The leaves length varied from one soil treatment to another (**Figure 2**).

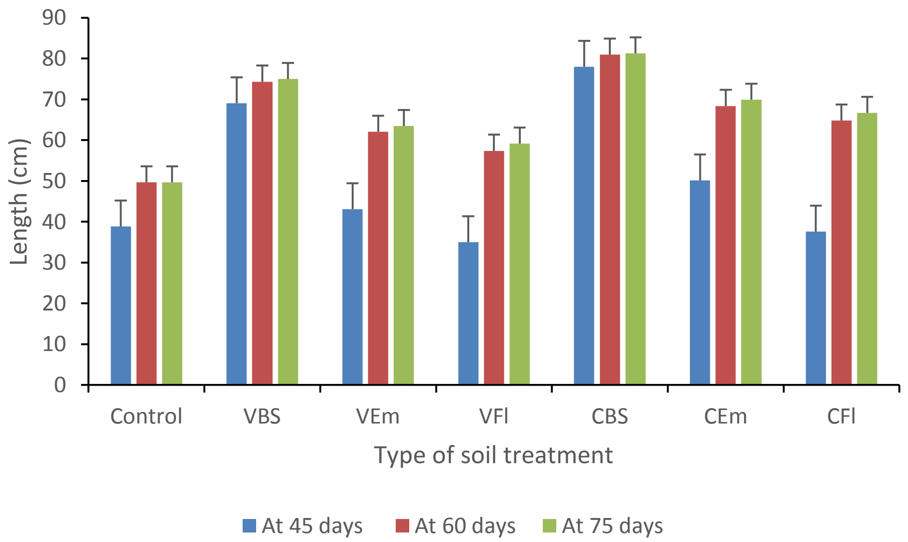

Figure 2. Effect of the spreading timing of organic fertilizers on leaves length

VBS: Vermicompost before sowing, **VEm:** Vermicompost at emergence, **VFl:** Vermicompost at flowering, **CBS:** Compost before sowing, **CEm:** Compost at emergence, **CFl:** Compost at flowering,

At 45 days, the longest leaves (77.94±16.01 cm) were obtained with the compost spread before sowing and was followed in decreasing order by those got with the vermicompost before sowing (69.06±15.25 cm), the compost at emergence (50.16±14.36 cm), the vermicompost at emergence (43.09±13.63 cm), the control (38.83±27.16 cm), the compost at flowering (37.59±13.41 cm), and the vermicompost at emergence (34.99±12.91 cm). At 60 and 75 days respectively, the leaves lengths were 74.31±17.84 cm and 74.98±17 cm with the vermicompost spread before sowing, 62.05±17.19 cm and 63.48±16.5 cm for the vermicompost at emergence, 57.39±16.38 cm and 59.14±16.71 cm for the vermicompost at flowering. At the same dates, leaves measured 80.94±17.35 cm and 81.24±17.49 cm with the compost before sowing, 68.35±14.71cm and 69.9±13.84 cm with the compost at emergence and 64.8±16.27 cm and 66.7±16.11 cm with the compost applied at flowering. Leaves length was 49.66±22.48 cm and 49.66±22.48 cm with the control at 60 days and 75 days respectively.

In general, it appeared that the highest plant and the longest leaves were obtained with the compost and the vermicompost spread before sowing. There was a reduction in these parameters when the fertilizer application was away from the sowing. This explains that the application timing of fertilizers has an effect on plant growth.

Effect of organic fertilizers application timing on yield attributes of maize

Table 2. Influence of soil treatment on maize yield attributes

Type of soil treatment	Yield attributes					
	LE (cm)	NGr/R	DiE (cm)	NRGr/E	WE (g)	W_{100gr} (g)
VBS	13.65±4.49[a]	16.8±7.8 [a]	12.15±3.18 [ab]	13±3.37 [ab]	97.5±41.96 [ab]	15.11±5.22 [a]
VEm	8.75±1.74[b]	6.58±3.36[b]	9.7±1.08 [abc]	8.05±3.39[bc]	28.17±9.44[d]	8.05±4.24[b]
VFl	4.45±4.33[c]	3.33±4.32[b]	5.15±4.55[d]	4.9±5.13[c]	15.12±21.35[d]	5.75±5.62[b]
CBS	15.55±4.15 [a]	17.62±8.05 [a]	12.6±3.62 [a]	14.8±3.79 [a]	114.21±52.95 [a]	14.77±4.97 [a]
CEm	13.65±2.21 [a]	16.56±6.48 [a]	11.25±1.45 [ab]	11.05±2.11 [ab]	73.75±32.05[bc]	8.22±3.81[b]
CFl	9.9±4.54[b]	8.16±5.36[b]	9.3±3.53[bc]	9.9±4.63 [abc]	44.55±26.43[cd]	6.99±4.54[b]
Control	8.85±5 .62[b]	9.58±11.15[b]	8.08±3.67[cd]	9.58±11.15 [abc]	48.29±55.62[cd]	5.11±4.48[b]
F	17.635	13.024	12.869	6.866	18.653	15.149
P	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*

Mean values of parameters denoted with the same letter in each column were not significantly different.

LE: Length of ear**, NRGr/E:** Number of row of grains per ear, **DiE:** Diameter of ear, **NGr/R:** Number of grains per row, **WE:** Weight of ear, **$W_{100\ gr}$:** Weight of 100 grains, **VBS:** Vermicompost before sowing, **VEm:** Vermicompost at emergence, **VFl:** Vermicompost at flowering, **CBS:** Compost before sowing, **CEm:** Compost at emergence, **CFl:** Compost at flowering,

Table 2 encapsulates yield attributes in function of the application period of the compost and vermicompost. Yield attributes as the length of ear, the diameter of ear, the weight of ear, the number of grains row per ear, the number of grains per row, the weight of 100 grains are important yield contributing parameters of maize. They varied significantly from one treatment to another. The longest ear was got with the compost applied before sowing (15.55±4.15 cm) followed in decreasing order by that measured with the vermicompost applied before sowing (13.65±4.49 cm), the compost applied at emergence (13.65±2.21 cm). However, there was no significant difference (*P* > 0.05) between these lengths. The shortest ear (4.45±4.33 cm) was obtained with the vermicompost spread at flowering stage. The maximum length of ear in our study was 15.55 cm which was close to the 16.85 cm got by Laekemariam and Gidago (2012) after compost application. Abd El-Gawad and Morsy (2017) reported that ear length was significantly affected by the type of fertilizer and the growing season. Highest values of 19.42 and 18.83 cm ear length were recorded by Yigermal *et al* (2019).

The number of rows of grains per ear varied from 4 to 14.8. The maximum was obtained with the compost applied before sowing and the minimum with the vermicompost at flowering stage. This explains that organic amendment could negatively affect the production when it is spread late. Laekemariam and Gidago (2012) counted 15 rows of grains after compost application before sowing.

The number of grains per row, the diameter of ear and the weight of the ear also varied in the same direction with that of the length of ear. The maximum numbers of grains per row in our study were 17.62 and 16.8 respectively with the compost and vermicompost spread before sowing. Laekemariam and Gidago (2012) recorded 34 grains per row while combining compost and urea. Similarly, Abd El-Gawad and Morsy (2017) recorded 33.97 and 34.29 grains per row respectively after an application of compost and sheep mixed with urea. These higher numbers could be linked to the type of soil and the additional urea. The increase in the number of grains per row may be due to more photosynthetic activities and other nutrients from either organic source for plant development up to ear formation.

Concerning the weight of 100 grains, it varied from 5.75 g with the vermicompost applied at the flowering stage to 15.11 g with the vermicompost spread before sowing. The weight of 100 grains obtained with the compost applied before sowing was 14.77 g and was statistically similar to that of the vermicompost spread before sowing. Also, there was significant difference between the weight of 100 grains obtained with the vermicompost applied at the emergence (8.05 g), the vermicompost at flowering (5.75 g), the compost at emergence (8.22 g), the compost at flowering (6.99 g), and the control (5.11 g). These results testify that the application timing of the fertilizer influence agricultural productivity.

CONCLUSION

Maize production in Cote d'Ivoire has been confronted to serious problems due to the gradual decline of soil fertility. The results of this study showed that organic fertilizers such as compost and vermicompost from poultry waste can improve maize productivity. The application time of these fertilizers affect the productivity. The highest yield and yield attributes were obtained when the vermicompost and the vermicompost are spread before sowing.

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