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RESEARCH ARTICLE

ASSESSMENT OF THE AGRONOMIC VALUE OF COMPOST FROM SOURCE SEPARATED BIOWASTES THROUGH PHYTOTOXICITY AND AGRONOMIC TEST ON RICE (*Oryza. sp.*)

Dotanhan Yeo[1,2], Phaniwa Zié Zoumana Coulibaly[3], Kouassi Dongo[2,3]

[1]Unité de Formation et de Recherche Agriculture, Ressources Halieutiques et Agro-Industries (UFR AHAI), Université de San Pedro, Côte d'Ivoire, BP 1800 San Pedro, Côte d'Ivoire; [2]Centre Suisse de Recherches Scientifiques en Côte d'Ivoire (CSRS), 01 BP 1303 Abidjan 01, Côte d'Ivoire; [3]Unité de Formation et de Recherche des Sciences de la Terre et des Ressources Minières (UFR STRM), Université Félix Houphouët-Boigny, 22 BP 582 Abidjan 22, Côte d'Ivoire

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**Corresponding author:*
Dotanhan Yeo

ABSTRACT

Background: In Côte d'Ivoire, as elsewhere in sub-Saharan Africa, source-separated biowaste composts are generally considered to be of good quality. However, the agronomic value of these composts is still questionable due to a lack of scientific data. ***Objective:*** The aim of this study was to assess the agronomic efficiency of compost produced from source-separated organic waste on rice growth. ***Methods:*** The methodological approach involved physico-chemical analyses, a phytotoxicity test and an agronomic trial. ***Results:*** The results showed that the compost produced from source-separated organic waste had an alkaline pH (9.6) and was rich in organic matter (34%) and major elements: 14.5 g/kg, 4.56 g/kg and 33.1 g/kg of N, P and K respectively. The study also showed that the incorporation of this type of compost into the soil had no inhibitory effect on rice germination. Its application significantly increased the production of above-ground and root biomass and therefore the productivity of the rice. Furthermore, the dose of 15 t/ha can be recommended to farmers for an optimum yield. ***Conclusion:*** These results indicate that source segregated biowaste compost possess growth-promoting properties that can be advantageous for plant development.

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INTRODUCTION

Demographic growth coupled with changes in population consumption habits lead to an increase in municipal solid waste (MSW) production in SSA urban centers (Bodjona *et al*., 2022; Ndiaye *et al*., 2021; Zoma *et al*., 2023). This trend is set to continue in the coming years according to World Bank projections in its latest "What a waste 2.0" report (Kaza *et al*., 2018). This situation therefore calls for a paradigm shift in waste management systems by shifting the current linear management mode (collection - landfill) to a circular management (reuse of resources) more environmentally friendly. In sub-Saharan Africa, municipal solid waste streams are dominated by the organic fraction, which according to the literature represents between 50 and 70% of MSW streams (Sema *et al*., 2021; Ngnikam *et al*., 2017). The high moisture and organic matter content of this waste render composting one of the most suitable solution for the circular management of this waste (Drescher and Zurbrügg, 2006). Indeed, composting organic waste significantly reduces the negative environmental impact of uncontrolled degradation of this fraction, and produces an organic amendment called compost (Siles *et al*., 2020). Compost represents an alternative to the use of mineral fertilizers in agriculture (Pandyaswargo and Premakumara, 2014; Yeo *et al*., 2020). In contrast to mineral fertilizers, which are very expensive, cause soil acidification and the accumulation of harmful compounds in fruit and vegetables, composts offer several advantages (Trupiano *et al*., 2017; Adiloğlu *et al*., 2018). On the one hand, they improve the physical, chemical and biological properties of the soil (Trupiano *et al*., 2017), and on the other, they improve nutrient availability for plants, resulting in better crop growth and yield (Jjagwe *et al*., 2019). However, the first MSW composting initiatives in Côte d'Ivoire, as elsewhere in Sub-Saharan Africa, have failed (Charnay, 2005; Bromblet and Somaroo, 2015). Most of these failures were due to the poor quality of the composts produced. To overcome this issue, researchers and NGOs are now promoting source segregation as the solution for improving the quality of composts produced from MSW.To promote this new approach, the Swiss Center for Scientific Research in Côte d'Ivoire (CSRS) installed a decentralized composting pilot plant with source separation of organic waste in the town of Tiassalé in 2017.

Although the first results of this project have proven that the quality of the composts produced have been significantly improved (Yeo *et al*., 2021).However, the agronomic value of these composts is still unclear. The present work aimed at filling this gap by assessing the agronomic value of these composts on rice (*Oryza. sp.*) growth. The data gathered from this study could guide farmers to properly use these composts on the one hand and on the other hand provide scientific evidence for the promotion of these composts.

METHODS

Site description: This study was carried out at the national floristic center (CNF) of Felix Houphouët Boigny University in the city of Abidjan, the economic capital of Côte d'Ivoire. This center is located between 5°20'45" and 5°20'58" north latitude and between 3°59'6" and 3°58'53" west longitude, and covers an area of 9.3 ha. The vegetation of the CNF is dominated by dense tropical forest (N'Dri *et al*., 2020). This region's climate is sub-equatorial, characterized by alternating rainy and dry seasons. The city of Abidjan is one of the most rain-fed regions in Côte d'Ivoire, with an average interannual rainfall of over 1,800 mm. The average temperature is 27.8°C and the average relative humidity is 83% (Ahoussi *et al*., 2013).

Soil and compost sampling: The soil used in this experiment was taken from the fallow land within the CNF. Samples were taken from a depth of between 0 and 20 cm at various locations until a sufficient quantity was obtained for the experiment. The composite sample was then mixed three times to obtain a homogeneous substrate. Regarding the compost used, it came from the Tiassalé pilot composting unit located around 130 km from Abidjan. The compost was produced from source-segregated biowastes. The composting process took three months, including one month of fermentation and two months of maturation. At the end of the maturation phase, a 20 kg sample was taken and sent to the CNF in Abidjan for the experiments.

Plant Material: The plant material used was rice (*Oryza. sp.*), a cereal of the Poaceae family.The choice of rice was justified by the fact that this cereal is the most widely consumed food in Côte d'Ivoire.The seeds used were of the Nerica 2 variety from the Tiassalé rice-growing area.

Chemical analysis: Prior to the start of the experiment, a one-kilogram sample of each substrate (soil and compost) was taken and sent to the laboratory for physico-chemical analysis. These analyses focused on parameters such as pH, salinity, moisture, organic matter content, organic carbon content and the analysis of major elements. Moisture content was measured by drying 100 g of each substrate for 48 hours at 105 ± 2°C in an oven. Organic matter was measured by calcining the dry matter at 550°C for 4 hours. pH and conductivity were determined on aqueous suspensions (1:2.5 H_2O) of the substrates. Organic carbon content was determined by the Walkey and Black method, and total nitrogen by the Kjeldahl method. Total phosphorus, total potassium, CaO and MgO were determined by atomic absorption spectrometry (AAS).

Phytotoxicity test: This test consisted in evaluating the germination ability of rice seeds in the presence of compost. For this purpose, 20 rice seeds pre-germinated for three days were sown in plastic pots containing variable proportions of compost and sand. The different proportions of compost and sand were: 100%S, 75%S+25%C, 50%S+50%C, 25%S+75%C, 100%C (S: sand and C: compost), with three replicates for each treatment. Pots were watered once every three days to maintain the substrate humidity between 60 and 80% of field capacity. Before each watering, the number of germinating seeds was counted and the average plant size measured, until the number of germinating seeds remained constant. These data were subsequently used to determine two parameters: germination index (GI) and growth rate index (GR), whose expressions are given in equations 1 and 2 below (Luo *et al*., 2018).

$$GI = \frac{Number\ of\ germinated\ seeds\ (sample)}{Number\ of\ germinated\ seeds\ (control)} \times 100 \quad (1)$$

$$GR = \frac{Average\ plant\ height\ (sample)}{Average\ plant\ height\ (control)} \times 100 \quad (2)$$

Pot experiment: The agronomic trial was carried out from June 17 to July 31, 2023. The experiment was conducted in 4-liter pots. Each pot has received around 4 kg of soil. A total of 6 treatments were tested: 4 treatments with different doses of compost (T1= 7.5 t/ha, T2= 15 t/ha,T3= 30 t/ha, T4= 60 t/ha), which were compared to a treatment that received mineral fertilization (T5= 250 kg/ha at sowing + 100 kg/ha 30 days after sowing) and a control treatment (T0) which received no fertilizer. The pots were set up in a Fischer block design with three replicates. The proportions of compost corresponding to the different doses were applied to treatments T1 to T4, one week before sowing. Treatment T5 received NKP fertilizer (15-15-15) at a dose of 250 kg/ha at sowing, as recommended by the national agricultural research center (CNRA). During sowing, the rice seeds were sown in the center of the pots at a density of 5 seeds per pot. Two weeks after germination, some plants were pulled out, leaving just one plant per pot. This experiment lasted 45 days, during which the plants were regularly watered with 0.5 liters every three days, and weeding was carried out manually. At the end of the experiment, the agronomic parameters measured were the dry biomass yield of the above-ground and root parts. For that purpose, the plants were removed from the pots, cut at the collar and dried in an oven at 105°C for 24 hours.

Statistical analysis: The agronomic parameters measured for the two crops were subjected to a two-way analysis of variance (ANOVA) to assess the effect of treatments on the variables measured. The Fisher test was used to compare means when the ANOVA revealed significant differences between treatments, at the 5% probability threshold. These analyses were carried out using R software version 3.2.2.

RESULTS

Physico-chemical characteristics of soil and compost: The results of physico-chemical analyses showed that the soil used in this study had a very low organic matter content (1.74%) and an acidic pH (5.1). In addition, the primary elements content of the soil was very low: 0.75 g/kg, 0.05 g/kg and 0.01 g/kg for N, P and K respectively (Table 1). Regarding the compost, the results showed that in addition to its high organic matter content (34%), the compost produced was relatively nutrient-rich, especially in terms of primary elements, with nitrogen,

Table 1. Physico-chemical characteristics of soil and compost

Parameters	pH [-]	EC [µS/cm]	Water [%]	OM [%]	C [g/kg TS]	C/N [-]	N [g/kg TS]	P [g/kg TS]	K [g/kg TS]	Ca [g/kg]	Mg [g/kg]
Soil	5.10	76.90	6.70	1.74	15.10	13.46	0.75	0.05	0.01	1.08	0.16
Compost	9.60	8000.00	11.00	34.00	175.00	12.07	14.50	4.56	33.10	23.00	4.00

EC= Electrical conductivity; TS= Total solid; OM= Organic matter

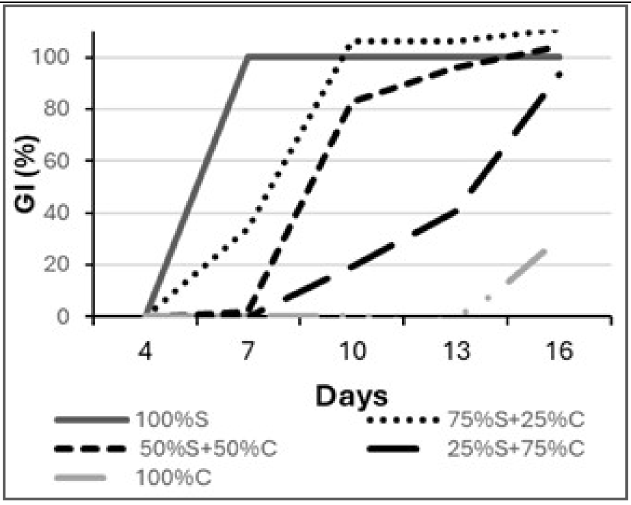

Figure 1. Evolution of germination index

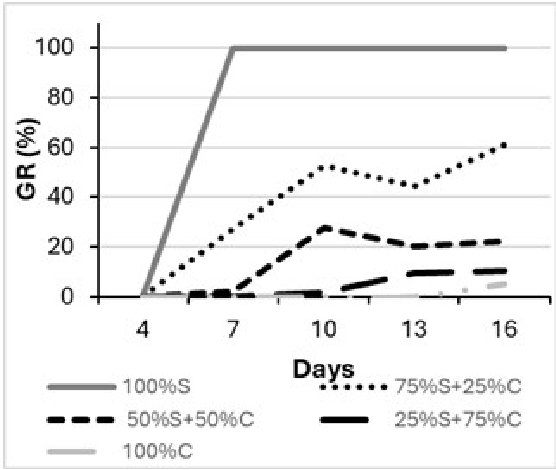

Figure 2. Evolution of the growth rate

Table 2. Above-ground dry biomass yield

Treatments	weights	Standard deviation	p-value
T0- (control without fertilizers)	7.20a	±0.53	< 0.001
T1- compost (7.5 t/ha)	9.66ab	±1.04	
T2- compost (15 t/ha)	12.46bc	±0.44	
T3- compost (30 t/ha)	18.93d	±0.75	
T4- compost (60 t/ha)	11.42bc	±1.11	
T5- fertilizer (250 t/ha NPK + 100 t/ha urea)	14.35c	±1.84	

Table 3. Root dry biomass yield

Treatments	Weights	Standard deviation	p-value
T0- (control without fertilizers)	3.85a	±0.22	< 0.001
T1- compost (7.5 t/ha)	6.01a	±1.27	
T2- compost (15 t/ha)	8.27b	±0.65	
T3- compost (30 t/ha)	13.04c	±0.61	
T4- compost (60 t/ha)	8.94b	±0.84	
T5- fertilizer (250 t/ha NPK + 100 t/ha urea)	12.58c	±0.76	

Values followed by the same letter in each column are not statistically different at the 5% probability level according to Fisher's test.

phosphorus and potassium contents of 14.5 g/kg, 4.56 g/kg and 33.1 g/kg respectively (Table 1).

Compost phytotoxicity: Phytotoxicity test results showed that except for the 100% compost treatment, all other treatments had a germination index above 90% (110%, 104% and 93% for the 75%S+25%C, 50%S+50%C and 25%S+75%C treatments respectively), as shown in Figure 1. The analysis of the results also showed that the increase in the proportion of compost had a delaying effect on both germination and seedling growth (Figures 1 and 2).

Effect of composts on rice growth: The study revealed that the above-ground dry biomass yield of rice plants increased with the dose of compost applied, except for treatment T4, whose yield was lower than those of treatments T2 and T3 (Table 2). Therefore, the lowest above-ground dry biomass yield was obtained with treatment T0, which received no fertilizer, while treatment T3 gave the highest yield for compost-based treatments. Treatment T5, which received mineral fertilization, had a higher above-ground dry biomass yield than the other treatments, except for treatment T3, whose yield was higher. From a statistical point of view, the differences observed between T5 and treatments T2 and T4 were not significant, while the difference observed between treatments T5 and T3 was significant at the 5% threshold (Table 2). Regarding root dry biomass yield, the results obtained are similar to those observed for above-ground dry biomass yield (Table 3). However, in contrast to the above-ground dry biomass yield, no significant difference was observed between the root dry biomass yield of treatments T5 and T4 at the 5% threshold.

DISCUSSION

Physico-chemical characteristics of soil and compost: The results of physico-chemical analysis showed that the soil used as a growing media in this study was slightly acidic and poor in nutrients. These characteristics clearly indicate that this soil in its current state cannot ensure optimal rice production. However, it is an excellent choice for evaluating the agronomic value of fertilizers. Concerning the compost used, the results showed that it was nutrient-rich. In addition, the major element content of the compost was higher than values observed in the literature in sub-Saharan Africa (Tchanate *et al*., 2017; Temgoua *et al*., 2014; Compaoré and Nanéma, 2010). This result confirms the quality of the sorting carried out by households. The results also showed that the pH of the compost used was alkaline. The use of this type of compost could therefore positively impact the soils of the region of Abidjan, which are generally acidic (Godefroy, 1975). The C/N ratio of the compost was 12.07, which indicates that the compost used was mature. Indeed, according to authors such as Pearson *et al*, (2004) and Confesor *et al*, (2008) a C/N ratio of between 10-15 is an indication of compost maturity. However, the electrical conductivity of the compost was well above the recommended limit value (4.10 µs/cm) for composts. This high salinity can adversely affect plant growth if the dose used is excessive. In fact, high salinity disrupts plant mineral nutrition, which has a negative impact on growth (Singh and Kalamdhad, 2014).

Compost phytotoxicity: The phytotoxicity test is an essential parameter for assessing the maturity of composts intended for agricultural use. The use of immature composts releases toxic substances that prevent seed germination and plant growth (Tang *et al*., 2006; Alburquerque *et al*., 2006). The results of the phytotoxicity test showed that, except for the 100% compost treatment, all other treatments had germination indices of over 90%. According to Tiquia *et al*, (1996), germination indices above 80% prove that the compost tested is not phytotoxic. The compost used in this study can therefore be considered as mature. The study also showed that increasing the proportion of compost had a delaying effect on germination and seedling growth. This confirms the findings of Berjon *et al*, (1997) that the depressive effect of composts is not only linked to their immaturity, but also depends on the dose of compost applied, and the type of crop.

Effect of composts on rice growth: The study revealed that the T0 treatment had the lowest above-ground and root dry biomass yields. This result could be explained by the poor nutrient content in the soil used. This result confirms the results of the chemical analyses, which showed that the soil used was poor in organic matter and major elements. The increase in biomass yield observed for the compost-based treatments could be explained by the fact that compost decomposition releases additional nutrients to the soil, resulting in a positive effect on crop development and growth (Pale *et al*., 2021). Also, above-ground and root biomass production of the plants increased with the doses of compost applied, except for treatment T4. This result proves that the efficiency of compost is proportional to the dose applied and confirms the observations of several previous studies (Sawadogo *et al*., 2008). The drop in yield observed for treatment T4 is probably linked to the saline stress induced by the application of 60 tonnes of compost per hectare. Indeed, according to Hichem *et al*. (2015), high soil salinity can lead to nutrient imbalances and reduced water infiltration, which limits plant growth. The application of such high doses of compost should therefore be avoided, given the high salinity content of compost. Furthermore, the study showed that the above-ground biomass yield obtained with treatment T2 was not significantly different from treatment T5, which received mineral fertilization. The dose of 15 t.ha-1 can therefore be recommended to rice farmers to achieve optimum yield while reducing their production costs.

CONCLUSION

The aim of this study was to evaluate the agronomic value of compost produced from source-separated municipal solid organic waste for rice growth. The investigation involved laboratory analysis to assess the soil and compost quality and an agronomic trial to evaluate the effect of the compost on rice growth. The results of the study revealed that compost produced from municipal solid organic waste was rich in organic matter and nutrients. Its incorporation into the soil had no repressive effect on rice germination. The study also showed that adding this type of compost to the soil significantly increased above-ground and root biomass production, and consequently rice productivity. The dose of 15 t.ha-1 can be recommended to farmers to achieve yields comparable to those of chemical fertilizers, while reducing production costs. These results indicate that source segregated biowaste compost possess growth-promoting properties that can be advantageous for plant development. Therefore, the establishment of sustainable composting systems is achievable in sub-Saharan Africa if these facilities are linked to selective biowaste collection systems.

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Conflict of Interest: The authors declare that they have no conflicts of interest.

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