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Impacts of household waste compost formed in public garbage dump on the organo-mineral status and productivity of a sandy soil

Ferdinand Gohi Bi ZRO, Arnauth Martinez GUEI, Yves Krogba NANGAH, Albert Yao-Kouamé.

Abstract— **The inefficient use of mineral fertilizers on sandy soils in general has led users of this type of soil in Daloa (Côte d'Ivoire), especially vegetable growers, to turn to other fertilizers more readily available such as household waste composted in open air. This study was conducted to evaluate the impact of the inputs of these residues on the fertility of the soils exploited by these producers. Thus, an experimental device was set up on lettuce according to farmers' conditions. This device consisted of four blocks; each block was 21 m long. One block consisted of four elementary plots where different treatments were randomly distributed: the control did not receive compost and three additions of different compost doses (20, 40 and 60 t/ha). Some indicators of soil fertility, namely, soil organo-mineral status and the agricultural yield of the cultivation of lettuce carried out were evaluated. The results showed that the compost used had a significant positive effect on soil properties, and then, on the lettuce production when it was brought to soil at 40 and 60 t/ha. We concluded that solid waste compost can be an attractive alternative to chemical fertilizers on sandy soils.**

Index Terms— **Compost, garbage, productivity, yield, sandy soil..**

I. INTRODUCTION

In Côte d'Ivoire, sandy soils cover large areas of alluvium, mainly in the coastal region (Lagoon area) [1]. In Daloa, these soils are generally located in valleys [2]. They are not very fertile due to their low contents in organic matter, phosphorus, nitrogen and potassium [2]. However, despite their poor qualities, these soils are regularly grown, especially for market gardening [3]. Thus, it appears very important to bring to these soils fertilizers. As mineral fertilizer inputs are not very efficient on sandy soils in general (these fertilizers are rapidly driven by rainwater or irrigation water), the use of household waste inputs composted naturally in public garbage dumps is increasingly being considered by producers. This research was initiated to assess, not only the fertilizing value of the compost of household waste formed in public garbage dumps, but also, the effect of this compost on soils fertility.

Ferdinand Gohi Bi ZRO, Département Sciences du sol et agrosystèmes, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire, Mobile : +225 48713491

Arnauth Martinez GUEI, Département Sciences du sol et agrosystèmes, Université Jean Lorougnon Guédé, Daloa, Côte d'Ivoire, Mobile : +225 48988857

Yves Krogba NANGAH, Département Géosciences, Université Péléforo Gon Coulibaly, Korogho, Côte d'Ivoire, +225 48320079

II. MATERIAL AND METHODS

A. Site description

The study was conducted in the city of Daloa (Fig. 1) located in the west-central part of Côte d'Ivoire (West Africa). This city is bounded by longitudes West 6.48° and 6.41° and latitudes North 6.91° and 6.84°.

The climatic regime of the Haut-Sassandra region, where Daloa is the capital, is that of the Guinean domain. This climatic regime is characterized by an equatorial and subequatorial regime with two rainfall maxima [4]. The relief is little contrasted, little varied and dominated by plateaus of 200 to 400 m [5]. The geological formations covering the Haut-Sassandra region are dominated by granites dating from Middle Precambrian.

The soils of the zone are generally ferralitic moderately leached on plateaus and sandy hydromorphic on river terraces [6]. These sandy soils sometimes have large areas and are more or less usable according to their texture, their chemical richness and their possibility of irrigation or drainage [6]. This study was carried out on one of these sandy soils used regularly for market gardening, precisely the soil located in the lowland of Tazibouo district (Figure 1). The rate of sands in this soil exceeds 80 % [2]. This predisposes it to massive leaching of plant nutrients.

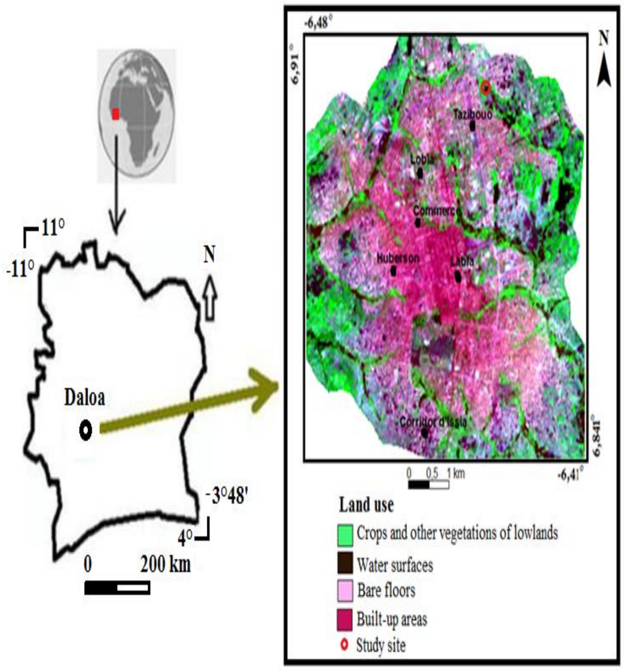

Fig. 1. Location map of the study area.

A. Sampling and analysis of the used compost

The fertilizing value of composts in general is their ability to provide nutrients (N, P, K, Ca, Mg, Na ...) to plants, especially nitrogen (N). Thus, the fertilizing value of the garbage compost used (Fig. 2) was determined based on the analysis data of four samples of this compost. Sampling was done according to the existing requirements [7]: it consisted of mixing several samples and randomly choosing the samples to be analyzed, packing them in plastic bags and keeping the whole cool. In the laboratory, the pH was determined by the electrometric method [8]; the total nitrogen, organic carbon, assimilable phosphorus and exchangeable bases were respectively determined by Kjeldahl, Walkley and Black, modified Olsen and atomic absorption spectrophotometry techniques. [9].

In addition, as composts generally contain high concentrations of soil-toxic heavy metals [10], some of these metals, including copper, lead, and zinc, have been assayed by spectrometry atomic absorption [11] after the compost samples were disaggregated by wet digestion with acids ($HNO3$, HCl and HF).

Fig. 2. Compost sample of solid household waste formed naturally in public garbage dumps in Daloa City.

B. Implementation and description of the experiment

The study ran from july 2015 to february 2016. The trial included four treatments: three treatments consisted of bringing 20, 40 and 60 t/ha of compost to the soil; these treatments were compared to a control (soil without amendment).

The four treatments were subjected to four repetitions in space and three repetitions in time on a lettuce crop. The time interval observed between two successive cycles of culture is approximately one month. The experimental plan put in place is established according to Fischer's scheme [12]. In fact, each block of 21 m consisted of a set of four elementary plots at a distance of one meter where the different treatments were randomly distributed. The basic parcel was 8 m² board (4m x 2m). On each single plot, 15 lettuce plants were transplanted on four lines with a spacing of 30 cm between the rows. Sixty poets were thus obtained per elementary parcel, or 720 poets per hectare. The transplanting of the seedlings on the elementary plots was done after a nursery setting of 15 days. Throughout their development cycle, the plants were regularly watered in the same way.

At the end of the experiment, a soil sample was taken from the topsoil, at a depth of 0 to 20 cm, per category of basic parcel, ie four soil samples per block, or 16 soil samples in total. The soil variables were determined on these samples; the methods of analysis used are identical to the case of compost. Also, the agricultural yield was determined at the end of each crop cycle by reporting the average biomass produced per treatment to the total area covered by the treatment. These biomasses were determined using a DENVER INSTRUMENT electronic scale that has a precision of 0.0001 g.

C. Data analysis

Mean values of soil variables measured by treatments were subjected to one-way ANOVA analysis under Statistica 7.0 (Statsoft, Tulsa, USA). The Student-Newman-Keuls test was performed at 5% threshold to compare two by two the averages. Also, the coefficient of correlation between the agricultural yields obtained and the compost doses applied to soils was calculated.

III. RESULTS

A. Compost properties

The properties of the compost used are shown in Table I. Its contents of carbon and organic matter are 9.05 and 15.56 %. Its total nitrogen content and then its C/N ratio are respectively 0.88 % and 10.28. The levels of available phosphorus, calcium, magnesium, potassium and sodium are respectively 0.056 $g.kg^{-1}$, 8.77, 2.29, 0.90 and 0.16 $cmol.kg^{-1}$. Copper, lead and zinc are detected at the respective doses of 233, 113.2 and 140 mg.kg -1. The pH measured is 7.3.

B. Evolution of soil properties according to applied compost doses

Table II summarizes the results of the statistical treatments. It appears that the initial soil pH which is 5.15 has risen to 5.17 and 5.30 following compost intake at the respective doses of 20 and 40 t/ha. This increase is not significant. On the other hand, with the soil input of 60 t/ha of compost, the pH reached 5.52 and thus became very significantly higher ($p < 0.005$) than the initial pH of the soil. Also, the different inputs of compost on the ground have raised the contents of mineral elements in general in the soil. In fact, the calcium, sodium and copper contents increased very highly ($p < 0.001$), unlike phosphorus and potassium contents which have hardly changed. The increase in magnesium and zinc levels appeared very highly significant ($p < 0.001$); for lead, this increase was less ($p < 0.05$). In these two cases, the increases were only induced by the only doses of 40 and 60 t/ha of compost. Finally, it was necessary to add 60 t/ha of compost to the soil to observe an enhancement of the CEC which, moreover, appeared very highly significant ($p < 0.001$). With regard to organic matter, the levels were increased very significantly ($p < 0.001$) in general by each contribution of compost.

Tableau I. Compost properties

pH	Organic matters				Phosphorus	Adsorbent complex (cmol.kg^{-1})				Metallic trace elements (mg.kg^{-1})		
	C (%)	MO (%)	N (%)	C/N	P.ass (g.kg^{-1})	Ca	Mg	K	Na	Pb	Zn	Cu
7.3	9.05±0.9	15.56±1.1	0.88±0.04	10.28±0.99	0.056±0	8.77±0.3	2.29±0.02	0.90±0.07	0.16±0	113.2±2.2	140±4	233±6.1

P.ass: *assimilable phosphorus*

Tableau II. Soils properties according to the amount of compost received

Treatments	Acidity	Organic matters (%)			Phosphorus (g.kg^{-1})	Adsorbent complex (cmol.kg^{-1})					Metallic trace elements (mg.kg^{-1})		
	pH	C	MO	N	P.ass	CEC	Ca	Mg	K	Na	Pb	Zn	Cu
T0	5.15 ± 0^{a}	0.49 ± 0^{a}	0.85 ± 0^{a}	0.05 ± 0^{a}	0.019±0	4.9 ± 0.01^{a}	0.21 ± 0^{a}	0.17 ± 0^{a}	0.04±0	0.09 ± 0^{a}	9.0 ± 2^{a}	14 ± 2^{a}	199 ± 4^{a}
T20	5.17 ± 0^{a}	1.22 ± 0.01^{b}	2.09 ± 0^{b}	0.06 ± 0^{a}	0.024±0	5.2 ± 0.02^{a}	0.31 ± 0^{b}	0.17 ± 0^{a}	0.043±0	0.14 ± 0^{b}	$9.6\pm1{,}8^{a}$	16 ± 2^{a}	264 ± 4^{b}
T40	5.3 ± 0.05^{a}	1.38 ± 0^{c}	2.37 ± 0^{c}	0.1 ± 0^{b}	0.03±0	5.2 ± 0^{a}	0.32 ± 0^{b}	0.21 ± 0^{b}	0.044±0	0.15 ± 0^{c}	14.14 ± 2^{b}	32 ± 3^{b}	305 ± 6^{c}
T60	5.52 ± 0^{b}	1.77 ± 0^{d}	3.04 ± 0^{d}	0.14 ± 0^{c}	0.15±0.11	6.2 ± 0.15^{a}	0.33 ± 0^{b}	0.25 ± 0.01^{c}	0.044±0	0.17 ± 0^{d}	13.12 ± 2^{b}	48 ± 2^{c}	325 ± 5^{d}

T0: *control (soil without compost);* ***T20:*** *soil + 20 t/ha of compost;* ***T40****: soil + 40 t/ha of compost;* ***T60:*** *soil + 60 t/ha of compost.*
The letters ***a***, ***b***, ***c*** *and* ***d*** *indicate for each treatment the average values significantly different at the 5% threshold.*

C. Evolution of lettuce yield according to increasing doses of compost applied to soils

The photographs in Fig. 3 show the lettuce plants according to the treatments on the 13th day after transplanting. We notice that lettuce grown on soils that received compost grew three to six times more than the lettuce of the control. Among plants grown in the presence of compost, the rate of 60 t/ha grew plants about one and a half times faster than the rate of 40 t/ha, which, in turn, induced a similar growth compared to the rate of 20 t/ha.

In addition, the yield of cultivated lettuce evolved from 0.04 t/ha on the control soil to 0.15 t/ha on the soil amended with 60 t/ha of compost. The intermediate yields obtained with the inputs of 20 and 40 t/ha of compost are, respectively, 0.08 and 0.12 t/ha. These results highlight a positive relationship between the rate of compost added to soils and the agricultural yield. This relationship is illustrated in Fig. 4 which shows that the variability observed in the yields is explained to 99% (r^2 = 0.99) by the contributions of compost to the soil.

Fig. 3. Plants levels of growth at the 13th day after transplanting (**A:** T0 ; **B:** T20 ; **C:** T40 ; **D:** T60).

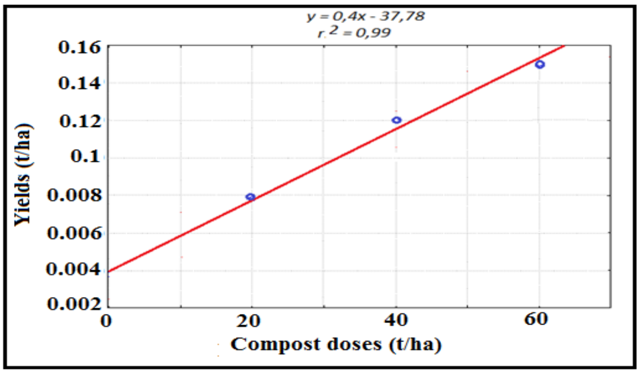

Fig. 4. Evolution of the yield of lettuce according to compost doses brought to the soil.

IV. DISCUSSION

A. Analysis of the fertilizing value and the quality of the compost used

According to agronomic parameters of French standards for urban composts [13], the organic matter content must always be greater than 20%. This rate which is equal to 15.56% in the compost used is thus low. For total nitrogen, the determined rate (0.88 %) is in accordance with French standards which recommend that this element be less than 2 % in composts in general. But, it will be necessary that the compost used reaches the stage of maturity.

The degree of maturity of composts is generally appreciated by their C/N ratio and their pH. Indeed, it has been established that for mature composts, these parameters vary, in this order, between 10 and 15 [14] and 7 and 9 ([15]. Thus, the compost used has reached the stage of maturity and it is well mineralized. This explains why its content in basic elements (Ca, Mg, K and Na) appeared relatively high in general. Also, by reference to these same French standards, the contents of compost in metallic trace elements (respectively 233, 3.2 and 140 mg.kg^{-1} for Cu, Pb and Zn) are low. Indeed, the limit values of these elements in compost garbage are respectively: 800, 800 and 1000 mg.kg^{-1}.

The compost used has therefore a good fertilizing value which would be more interesting if it had not been formed in the open air, exposed to heavy rains. Indeed, these rains are able to carry, by runoff or infiltration, a large part of its mineral content.

B. Effects of the compost on the organo-mineral status of the sandy soil used

The addition of 60 t/ha of compost to the soil has moved it from the acid soil stage to the low acid soil stage, which is more suitable in agriculture according to the work of Landon [16]. This improvement in pH is explained by the relatively high content of compost in basic cations, mainly Ca and Mg [17-18-19]. Also, the release of OH^- ions in the soil by organic matter can also explain this fact. On the other hand, almost all the compost doses brought to the soil caused a very highly significant increase in exchangeable base contents except for potassium. Some research has reached the same results and concluded that organic fertilization, by increasing the soil organic carbon content, also leads to an increase in the soil content of exchangeable cations [20]. But, the elevation of soil salinity may be due to the presence in the compost of food residues containing cooking salt, like the observations made by Kremer [21] during a similar experiment on a sandy soil. The slight increase in potassium levels, regardless of the amount of compost supplied to the soil, is essentially justified by the fact that this element will be washed out massively, given the sandy texture of the soil used. It is the same for phosphorus, that content has not been significantly increased by the different inputs of compost. However, in addition to bringing phosphorus to the soil, compost of garbage also removes this element from the soil solution through its content of metal compounds that have the ability to bind phosphates [22]. Thus, even though it has been observed that heavy metals are present in the compost used at low levels in general, it can't be ruled out that these heavy metals have had to prevent the raising of the phosphorus level in the soil studied.

In sum, the different inputs of compost on the ground have variously raised the contents of exchangeable bases which are generally used by plants. This led to slightly raising the soil CEC level with inputs of 20 and 40 t/ha and very significantly with the addition of 60 t/ha. This beneficial effect of compost on soil fertility was also reflected in the yield of the lettuce crop grown. A study [23] also devoted to the growth of lettuce in the presence of different concentrations of compost waste has resulted in two to three times more growth in the presence of compost during the first six weeks of the development cycle of the plants. According to these authors, the positive effect of compost on plant growth was mainly due to the improvement of certain soil properties, notably: the physico-chemical and biological quality of the soil, the rate of nutrient diffusion and the capacity of the soil to retain water. The compost used would have produced the same effects on the soil.

V. CONCLUSION

This study tackled the general problem of the agronomic valorization of garbage compost. The results of the experiment revealed that the addition of 60 t/ha of this compost to the soil increased significantly the soil content in exchangeable bases. The Soil CEC was therefore also significantly increased with this input as well as the yield of the lettuce crop grown. Thus, under the conditions of this test, the contribution of 60 t/ha of compost to the soil proves to be the optimum dose for lettuce. This dose can be reduced if the compost is made under optimal conditions: selective sorting of garbage before composting them sheltered from bad weather. In fact, in these conditions, the compost formed would not only be low in heavy metals, but also, it would be richer in nutrients, because these elements would not be washed away by rainwater.

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