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Effects of compost from urban solid household waste on the respiration of soil microbial flora and the yield of tomato (*Lycopersicon esculentum*) at the agronomic experimental station of Lome in Togo

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Abstract

The objective of the study is to evaluate the respiration of the microbial flora of soils amended with household waste compost under tomato cultivation. The experimental device adopted was that of complete random blocks with three repetitions. The compost was applied in doses of 10 $t.ha^{-1}$, 20 $t.ha^{-1}$, 30 $t.ha^{-1}$ and 40 $t.ha^{-1}$. To these treatments are added those of absolute control, mineral fertilization (0.2 $t.ha^{-1}$ of NPK 15-15-15 and 0.1 t.ha-1 of Urea 46% N) and organo fertilization -mineral (10 $t.ha^{-1}$ of compost combined with 0.1 $t.ha^{-1}$ of NPK 15-15-15 and 0.05 $t.ha^{-1}$ of Urea 46% N). Soil samples were taken from the plots at a depth of 0 - 20 cm and incubated in the laboratory for the evaluation of the respiration of the microbial flora. Soil CO_2 emission was measured daily for 28 days of incubation using NaOH and 0.1 N HCl as titrant after precipitating the carbonate with barium chloride ($BaCl_2$) solution by alkaline back titration in the presence of the colored indicator (phenolphthalein). The results showed that the application of compost from household waste induced an increase in CO_2 emission from the soil (60.67-215.4 mg.kg-1 of soil) and fruit yield of tomato (8.61-36.43 $t.ha^{-1}$). Thus the application of compost at the dose of 30 $t.ha^{-1}$ improves soil biological activity and tomato fruit yield.

Keywords: Compost; Soil Respiration; Soil Microbial Flora; Tomato; Yield

1. Introduction

The need to increase production to meet the growing needs of the population has resulted in the continuous exploitation of the land without fallowing or organic restitution [1]. Soils are increasingly subject to many variations in taxonomic diversity and functionality of microbial communities [2]. The ferralitic soils of southern Togo are no exception to this reality. They are often overexploited and lack time to recover. Improving soil fertility defined as a multifunctional game necessarily involves better recovery of organic matter [3].

Indeed, organic matter is the source of trophic energy for microorganisms and contributes to improving the biological and physico-chemical properties of the soil [4]. It is recognized that soil microorganisms play a determining role in the recycling of nutrients, in the facilitation of chemical processes, and especially in the improvement of crop yields [5]. The diversity of soil organisms and interspecific relationships improve soil resilience and productivity. The microbial population is the final link in the soil trophic chain through which the carbon and nutrients of organic matter transit, before becoming available again for plants [6].

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In Togo, tomato (*Lycopersicum esculentulum* Mill.) is one of the main market garden crops grown by farmers. It is part of the diet of the majority if not almost the entire population. But in recent years it is increasingly faced with many constraints including degradation and declining soil fertility. The negative impacts of these production constraints more specifically influence the growth and development of plants, metabolism and fruit formation and therefore the fruit yield of tomato.

The application of compost based on household waste seems like a resilient option to improve soil fertility and boost the yield of market garden crops.

With a view to improving the biological activity of the bar lands of South Togo and the fruit yield of the tomato, this study was conducted at the Agronomic Experiment Station of the University of Lomé during two growing seasons. To assess the effect of municipal solid waste compost on microbial flora respiration and fruit yield of tomato.

2. Materials and Method

2.1. Experimental framework

The agronomic trials which constitute the first part of the study were carried out at the Lomé Agronomic Experimentation Station (SEAL). The University of Lomé is located between 6°22' Latitude North and 1°13' Longitude East. The site benefits from a Guinean-type climate with alternating four seasons, including two rainy seasons and two dry seasons. The soil is of the ferralitic type developed on a continental deposit [7].

The second part of the study which constitutes the analyzes of soil respiration and carbon sequestration was carried out in the laboratory of the Higher School of Agronomy of the University of Lomé and in the laboratory of the Togolese Institute of Agronomic Research (ITRA).

2.2. Plant material

The test plant chosen for this study was the tomato (Lycopersicon esculentum, Mill). The Mongal F1 variety, a hybrid variety selected in France by INRA was used. It is a hybrid variety that can be grown during the hot season [8]. The fruits have a flattened round shape with 4 compartments with a bright red color when ripe; they weigh 100 to 120 g. This variety has an earliness of 65 days after transplanting. It is both tolerant to high heat and more or less resistant to diseases (in particular bacterial wilt, powdery mildew), and in particular to bacteria of the genus Pseudomonas, Solanacearum, Fusarium and Verticillium [9].

2.3. Fertilizers used

The organic fertilizer used is household waste compost obtained from the composting platform of the NGO Ecosystem Natural Clean (ENPRO), the characteristics of which are presented in Table 1. This compost is made from 70% household waste and enriched with 30% poultry manure. Apart from the organic fertilizer, two chemical fertilizers; NPK 15-15-15 and 46% N ordinary urea were used in the formulation of the treatments.

Table 1 Some physico-chemical characteristics of the compost used

%OM	% NTK	C/N %	P_2O_6 (meq.kg-1)	CEC	Ca^2 (g.kg^{-1})	Mg^{2+} (g.kg-1)
2.54±0.03	0.36±0.06	34.19±0.3	2.51±0.3	8.28.±0.3	2.6±0.3	2.46±0.7

NTK: Total Kjeldhal Nitrogen; MO: Organic Matter; CEC: Cation Exchange Capacity

2.4. Methods

2.4.1. Experimental device and treatments

The trial was conducted according to the experimental design in complete random blocks with three (3) repetitions. The treatments consisted of seven (7) doses: T0, the absolute control, T1, T2, T3 and T4 represent the compost applied at respective doses of 10 t.ha^{-1} 20 t.ha^{-1} 30 t.ha^{-1} and 40 t.ha^{-1}. T5 and T6 correspond respectively to organo-mineral fertilization (10 t.ha^{-1} of compost combined with 100 kg of NPK 15-15-15 and 50 kg of Urea 46%) and to mineral fertilization (200 kg of NPK 15-15-15 and 100 kg of Urea 46%).

The following parameters were observed: soil organic carbon stock

2.4.2. Collection and incubation of soil samples

Soil samples were taken from the topsoil in the 0-20 cm horizon with an auger at the end of each cropping season randomly on each plot unit. For the determination of the CO_2 emitted, the samples taken were dried, homogenized and screened at 2mm. These samples were incubated under optimal laboratory conditions. Measurements of the respiration of the soil microbial flora were carried out during 28 days of incubation.

2.5. Evaluation of the effect of amendments on the respiration of microbial flora

The experimental protocol used to assess the respiration of soil microbial flora by CO_2 emission was adapted from that of the French standard XPU44-163 [10]. Fifty grams of each soil sample were incubated at 28°C in hermetically sealed glass jars of 1000 ml volume. Soil water content was adjusted to 25%. The CO_2 released during the incubation is trapped in 15 ml of sodium hydroxide (NaOH, 1N) contained in plastic pillboxes placed together with the soil sample in the jar. Soil CO_2 emission measurements were performed daily during the 28-day incubation. Three replicates were done for each treatment. Soil sample moisture is checked and adjusted to field capacity moisture content on the sixth, twelfth, eighteenth, and twenty-fourth day. To evaluate the initial carbonation of the soda and that of the CO_2 of the ambient air, 3 pillboxes of soda were placed in 3 jars without a soil sample incubated as a control. The dosage of the CO_2 emitted is done on 10 ml of soda taken from the pillbox after homogenization. Part of the soda precipitates with the CO_2 in the presence of the barium chloride solution (2 ml). The remaining sodium hydroxide is titrated with hydrochloric acid until it turns from pink to white in the presence of a colored indicator (phenolphthalein). The quantities of CO_2 released daily were calculated using the following formula:

$$\text{Quantity of } CO_2 \text{ released (mg per kg of soil)} = ([(B - V.E.N.])/M$$

where

B is the volume of HCl used to titrate the control (mL),
V the volume of HCl used to titrate the sample (mL),
N the normality of HCl,
E (=22) the molar mass of CO_2 divided by 2 (2 moles of OH- are consumed by 1 mole of CO_2
M = the weight of the soil

2.6. Evaluation of the effect of amendments on some agronomic parameters of tomato

Agronomic parameters including average plant height, average number of fruits per plant and fruit yield were measured. As regards the average height of the plants and the average number of fruits per plant, four plants were sampled, at random, at the start of the trial on each of the elementary plots to take the height of the plants as well as at the counting the number of fruits per plant. As for the fruit yield, all the plants in the plot were considered. Fruits were harvested when they turned yellowish-red at three-day intervals on each plot. All harvested fruits (marketable and non-marketable) were considered in the assessment of fruit yield.

2.7. Statistical analysis

The data collected in the field and in the laboratory were entered and processed with the Excel 2013 spreadsheet and the statistical analyzes were carried out with the GENSTAT software version 2013. The comparisons of the means were made with the DUNCAN test at the 5% threshold when the F of the analysis of variance was significant at the same level of 5%.

3. Results

3.1. CO_2 emission

Figures 1 and 2 illustrate the daily quantities of CO_2 emitted by soil samples during 28 days of incubation respectively in the first and second growing seasons. The curves reflecting the daily quantities of CO_2 emitted have almost the same trend for all the treatments during the two cropping seasons. Two phases are revealed at each curve. A first ascending phase which constitutes a maximum of CO_2 emission observed on the first day of incubation. This first phase of peak respiration of the microbial flora is followed by a second phase of decrease over time. It is observed that the start of this phase of decline is sudden (figures 1 and 2). The daily CO_2 emission values varied from 4.1 to 9.5 $mg.kg^{-1}$ of soil in the first season and from 6.4 to 12.05 $mg.kg^{-1}$ of soil in the second season.

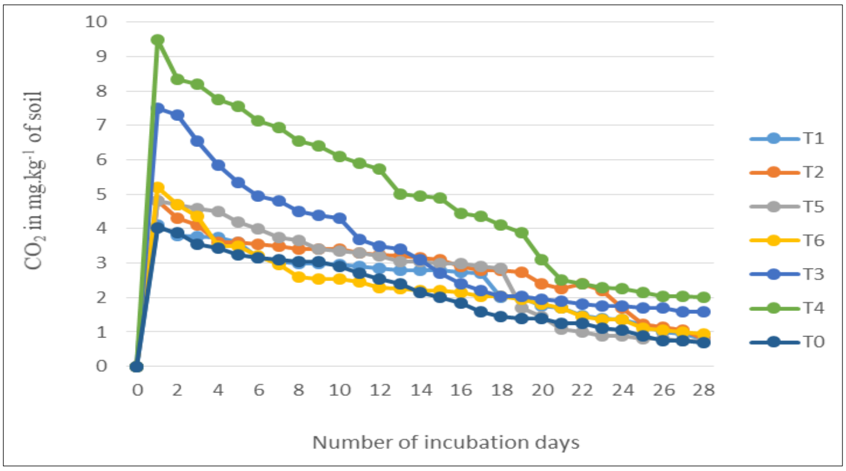

Figure 1 Kinetics of daily soil respiration after the first growing season

T0: Absolute control (without addition of compost); T1, T2, T3, T4 are compost treatments at respective doses of 10 t.ha^{-1}, 20 t.ha^{-1}, 30 t.ha^{-1} and 40 t.ha^{-1}, T5 (10 t.ha^{-1} of compost + 100 kg of NPK 15-15-15 + 50 kg of Urea 46%); T6 (200 kg of NPK 15-15-15 + 100 kg of Urea 46%).

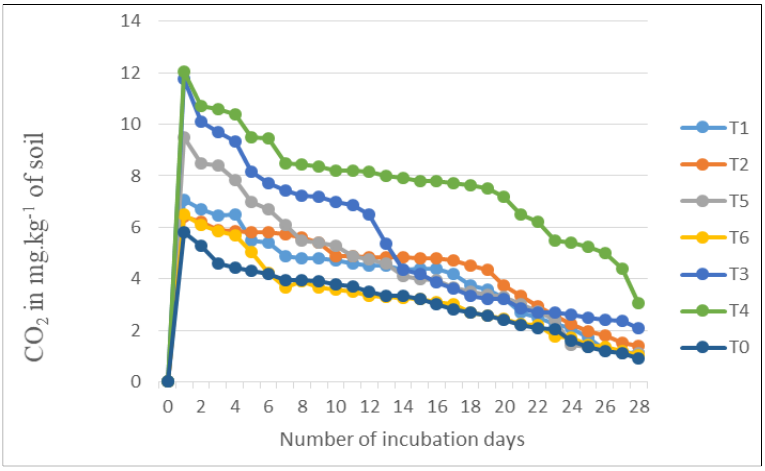

Figure 2 Kinetics of daily soil respiration after the second cropping season

T0: Absolute control (without addition of compost); T1, T2, T3, T4 are compost treatments at respective doses of 10 t.ha^{-1}, 20 t.ha^{-1}, 30 t.ha^{-1} and 40 t.ha^{-1}, T5 (10 t.ha^{-1} of compost + 100 kg of NPK 15-15-15 + 50 kg of Urea 46%); T6 (200 kg of NPK 15-15-15 + 100 kg of Urea 46%).

3.2. Total CO_2 emissions

The total respiration of the microbial flora during the study is expressed by the cumulative daily quantities of CO_2 for one month (28 days). The results of these measurements during the two seasons of the trial are shown in Table 2. At the 5% threshold, the analysis of variance reveals a highly significant difference. These results show that the doses of compost and mineral fertilizers had effects on soil microorganisms. In the first season, the cumulative highest quantity of CO_2 (138.60 mg.kg^{-1} of soil) is recorded on the plot which received 40 t.ha^{-1} of compost (T4) while the control registers the lowest amount of CO_2 (60.67 mg.kg^{-1} of soil). In the second season, the trend is maintained; the largest (215.4mg.kg^{-1} soil) amount of CO_2 is observed at T4 and the smallest (87.3 mg.kg^{-1}) at T0. The quantities of CO_2 accumulated in the second season are well above those recorded in the first season. During the two seasons, the accumulation of CO_2 on the treatments that received the compost is also greater than the quantity of CO_2 accumulated at the control level and at the level of the treatment with mineral fertilizers only (T6).

Table 2 Cumulative quantities of CO_2 (mg.kg^{-1} of soil) released per season

Treatments	Cumulative CO_2 (mg.kg^{-1} of soil) in Season 1	Cumulative CO_2 (mg.kg^{-1} of soil) in Season 2
T0	60.67g	87.3 d
T1	69.40 e	113.1 c
T2	80.08 c	121.7 c
$T3_2$	96.35 b	150.3 b
T4	138.60 a	215.4 a
T5	75,43 d	124.8 c
T6	66.43 f	91.6 d
F	896.63	53.09
P	< 0.001	< 0.001

T0: Absolute control (without addition of compost); T1, T2, T3, T4 are compost treatments at respective doses of 10 t.ha^{-1}, 20 t.ha^{-1}, 30 t.ha^{-1} and 40 t.ha^{-1} T5 (10 t.ha^{-1} of compost + 100 kg of NPK 15-15-15 + 50 kg of Urea 46%); T6 (200 kg of NPK 15-15-15 + 100 kg of Urea 46%). The values assigned the same letter index are statistically identical at the 5% threshold.

3.3. Effects of compost made from household waste on the agronomic parameters of tomato

Average plant height (size), average number of fruits per plant and average fruit yield were assessed at the end of the two seasons. The results of all these measurements in the first season and in the second season are recorded respectively in Tables 3 and 4. The nalysis of variance at the 5% threshold shows a significant difference for the three parameters evaluated during the two seasons of culture. These results show that the addition of amendments had effects on the average height of the plants, on the average number of fruits per plant, and on the fruit yield of the tomato compared to the control. The largest size (74.03 cm), the largest number of fruits (23.67) and the highest yield (36.43 t.ha^{-1}) were observed at the level of treatment T3 (30 t.ha^{-1} of compost) in the first season. The results show that the tomato plants performed better in the first season than in the second season. It is also observed that the plots which have received fertilizers have a better performance and that the results obtained are not proportional to the increasing doses of compost. It appears that the fertilizers brought in this case the compost of urban solid household waste at a dose of 30 t.ha^{-1} would have favored good nutritional conditions and would have greatly stimulated the growth in height of the plants throughout their vegetative cycle for give after a higher return.

Table 3 Effects of treatments on average height, average number of fruits per plant and fruit yield of tomato in the first season

Treatment	Yield t.ha^{-1}	Average plant height (cm)	Average number of fruits per plant
T0	15.17e	60.90e	15.0c
T1	23.07d	65.96d	20.0b
T2	26.27cd	57.70cd	20.33b
T3	36.43a	74.03a	23.67a
T4	31.93ad	71.10b	21.67ab
T5	28.63bc	69.80bc	19.33b
T6	26.55cd	67.80cd	19.33b
F	18.90	24.93	13.76
P	< 0.001	< 0.001	< 0.001

Treatments Yield (t.ha^{-1}) Average plant height (cm) Average number of fruits per plant T0 15.17 and 60.90 and 15.0 c Q1 23.07d 65.967d 20.0b T2 26.27cd 67.7cd 20.33b T3 36.43a 74.03a 23.67a T4 31.93ab 71.1b 21.67ab T5 28.63bc 69.8bc 19.33bc T6 26.55cd 67.8cd 19.33b F 18.9 24.93 13.76 P < 0.001 < 0.001 < 0.001

Table 4 Effects of treatments on average height, average number of fruits per plant and fruit yield of tomato in second season

Treatments	Yield t.ha^{-1}	Average plant height (cm)	Average number of fruits per plant
T0	8.61d	20.23c	9.67c
T1	12.90c	51.67bc	13.0b
T2	16.10b	56.70a	15.33a
T3	22.47a	56.43a	16.33a
T4	21.70a	54.87ab	16.33a
T5	17.40b	52.23bc	13.33b
T6	16.23b	50.73c	12.67b
F	25.91	5.33	36.75
P	< 0.001	< 0.007	< 0.001

T0: Absolute control (without addition of compost); T1, T2, T3, T4 are compost treatments at respective doses of 10 t.ha^{-1}, 20 t. ha^{-1}, 30 t.ha^{-1} and 40 t.ha^{-1}; T5 (10 t.ha^{-1} of compost + 100 kg of NPK 15-15-15 + 50 kg of Urea 46%); T6 (200 kg of NPK 15-15-15 + 100 kg of Urea 46%). For each parameter, the values assigned the same letter index are statistically identical at the 5% threshold.

4. Discussion

4.1. Respiration of soil microbial flora

The results revealed a strong CO_2 emission during the first days of incubation. This strong CO_2 emission observed during the first days of incubation could be explained by the high intensity of mineralization of organic matter during the first days of incubation. This phase of strong mineralization of organic matter corresponds according to Gnimassoun et al. [11] to the biodegradation of labile compounds such as sugars, protein compounds and dead microorganisms during the desiccation phase of composting. The drop in CO_2 emissions over time would be due to the depletion of organic matter in the soil.

The total quantity of CO_2 emitted in soils amended with compost is greater than the quantity of CO_2 in soils not amended with compost at the end of this study. This difference would be due to the contribution of organic matter from compost as a source of nutrients and energy, thus promoting the improvement of living conditions and the multiplication of soil microorganisms [12]. Application of municipal solid waste compost increased soil microbial populations. Our results corroborate those of Galic et al. [13] who carried out a long-term fertilization study on the growing season of wheat and maize and finally concluded that the highest CO_2 flux in the soil came from the treatment of organic fertilizers. Also Alate et al. [14] in a study carried out in Togo on CO_2 emissions from the soil in a tomato test field subjected to different water regimes and doses of compost recorded the highest CO_2 emissions on plots amended with compost.

The fact that the amount of CO_2 collected on the compost-amended plots in the first cropping season is below that of the second season can be explained by the cumulative residual effect of organic matter. Indeed, the presence of vegetation or cultivation affects CO_2 fluxes mainly by photosynthesizing and increasing the total respiration of the ecosystem [15]. Zombre et al. [16] in a study in Burkina Faso recorded strong correlations between the respiration of soil microbial flora and the presence of vegetation on the soil. The low CO_2 emission on the plots that received a dose of chemical fertilizer would be due to the repressive effects of mineral fertilizers on soil microorganisms.

In our study, the cumulative quantity of CO_2 is between 60.67 and 215.4 mg.kg-1 of soil. These results are close to those of [17]. Indeed, in a study carried out in Burkina in 2014, Dambara et al. [17] recorded soil microbial flora respiration values between 92 and 150 mg CO_2.kg-1 in the upper 20 cm of the soil following the application of compost in sorghum cultivation.

4.2. Agronomic performance of tomato

The results of fruit yield, average plant size and average number of fruits per plant obtained following the addition of fertilizers are statistically different from the control level.

First, the difference in average height of the plants obtained would be due to the presence of compost which provided nutrients to tomato plants throughout their vegetative cycle. Indeed the compost used is rich in nitrogen and phosphorus. This richness in nitrogen and phosphorus of the compost would have allowed the plants which received the compost to develop more quickly.

Then the degree of superiority in terms of the average number of fruits per plant shows the importance of the use of compost and also this superiority would be due to the incorporation of poultry droppings known to be rich in phosphorus in the compost used. Indeed, phosphorus is an important element for fruit production. Our results are in line with those of Useni et al. [18] on Chinese cabbage cultivation after application of hen manure compost. Also Peyvast et al. [19] showed in a trial that adding compost from municipal waste significantly improved the number of fruits per plant of green pepper. Our results are also similar to those of Abigail [20]. Indeed in a study Abigail [20] evaluated the effect of municipal waste compost on the number of fruits per plant and other tomato parameters. The two doses (25 and 50 $t.ha^{-1}$ of compost) formulated significantly improved the number of fruits per plant.

Finally, the difference in tomato fruit yield observed between the treatments during the two growing seasons also shows the importance of using compost from municipal solid household waste enriched with poultry droppings. Several studies have found results similar to ours. In 2016, in the Democratic Republic of Congo, Kitabala et al. [21] conducted trials using a mixed compost enriched with poultry manure at different doses under the tomato crop. Under a minimum dose of $30t.ha^{-1}$ and a maximum dose of $60t.ha^{-1}$ these authors recorded an average fruit yield of 15.01 $t.ha^{-1}$, lower than ours despite our doses being even lower. Compost made from municipal solid waste would be more efficient and richer in nutrients. Another study by N'Dayegamiye et al. [22] confirms these results. Indeed, N'Dayegamiye et al. [22] studied the effects of household waste compost inputs on crop yield and certain soil properties and concluded that compost inputs alone at 20, 40 and 60 $t.ha^{-1}$ increased crop yields proportionally to the applied rates compared to the absolute control in two consecutive years.

However, our results show that there is a limit to the use of compost because according to the study, the yield increased according to the doses of compost provided but decreased from 40 $t.ha^{-1}$. This situation could be explained by the fact that the quantity of fertilizing elements brought by the compost goes beyond the needs of the culture. This would therefore have led to a drop in yield linked to the antagonism between nutrients [21].

The increase in yields observed in this study is believed to be largely due to improved physical and chemical properties of the soil which created better optimal growing and nutrient conditions for the crops. Let us also mean that compost does not only act on the properties of the soil which results in an increase in yield but it also plays an important role in the health of the plants.

So, a good quality compost can be used successfully in the biological control of diseases among others in vegetable crops [23].

The results of this study also show that plants amended with compost alone at a dose of 20, 30 and 40 tons per hectare recorded better performance than the organo-mineral and mineral treatment, contrary to the results obtained by Gorobani et al. [24]. Indeed, in a study in South Togo, these authors recorded a better yield on the organo-mineral treatment compared to treatments that received only farm compost from small ruminant manure. This difference may be due to the type of compost used. Throughout the trial, treatments with compost alone revealed better biological activity of the soil compared to control and to organo-mineral and mineral treatment. This increase in biological activity would have given the tomato plants that received the compost resistance to certain diseases and pests. Thus in a study, Abassi et al. [25] have shown that the application of municipal solid waste compost can reduce the attack of tomato on certain diseases. The results obtained during this test show that the contribution of organic matter, in particular compost made from solid urban household waste, leads to an increase in yield. Thus, to maintain or increase soil productivity, this compost could be an alternative. The addition of mineral fertilizers alone cannot maintain long-term soil productivity due to leaching and degradation of soil properties [26],

5. Conclusion

The study on the effect of compost obtained from municipal solid household waste on the microbial activity of the ferralitic soils of the Agronomic Experimentation Station of Lome and the fruit yield of the tomato showed that the contribution of this compost under tomato cultivation has contributed to the increase in the microbial population in the soils of the cultivated plots and increased the emission of CO_2 in these soils. In the first season the amount of CO_2 on the plots tested was 60.67-138.60 mg.kg-1. In the second season on the same plots it was 87.3-215.4mg.kg-1. The results obtained from the trial showed that the best yields (36.43 $t.ha^{-1}$ and 31.93 $t.ha^{-1}$) are obtained from plots respectively treated with compost at a dose of 30 $t.ha^{-1}$ and 40 $t.ha^{-1}$. However, the highest tomato yield (36.43 $t.ha^{-1}$) is obtained from the plot treated with compost of 30 $t.ha^{-1}$. Thus the agronomic recovery of urban solid household waste by composting could be seen as an alternative that respects the environment. It will contribute on the one hand to the elimination of household waste landfills in cities and to the reduction of greenhouse gas emissions from these landfills into the atmosphere and on the other hand to increase crop yields.

Compliance with ethical standards

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Disclosure of conflict of interest

Authors have declared that no competing interests exist.

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