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RESEARCH ARTICLE

EFFECT OF COMPOSTS BASED ON SEWAGE SLUDGE AND MARKET GARDENING WASTE ON THE GROWTH AND YIELD OF TOMATO

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ABSTRACT

In urban and peri-urban areas, wastewater and sewage sludge are used without prior treatment to fertilise vegetable soils. To this end, sewage sludge treated with market garden waste was tested to evaluate the morphological performance and yield of tomatoes. Thus, the composts based on faecal sludge and market garden waste are T0, T1 and T2 (for respectively T0: composted faecal sludge alone, T1: compost with 2/3 faecal sludge and 1/3 market garden waste and T2: compost with ½ sewage sludge and ½ vegetable waste). For this purpose, a market garden bed set-up allowed a comparison of growth and yield parameters with a series of morphology measurements and fruit weighing at harvest. The results obtained over two tomato growing seasons revealed interesting morphological performances and appreciable yields found in the literature. In fact, in the first and second seasons, tomato plants that were fertilized with treatments T0, T1 and T2 showed greater height gain than the other treatments (non-composted sewage sludge (BVNC); chemical fertiliser (EN), no-input plot). Besides, between these compost treatments, T1 gives satisfactory results. With the yields obtained at harvest, the vegetable beds fertilized with T1 show the highest yields (27,718kg/ha) than the other treatments (no-input plot, T0 and T2 for 13076kg/ha; 22847kg/ha; and 24829kg/ha respectively).

INTRODUCTION

As in many developing countries, agriculture in Senegal has undergone significant changes over the past fifty years (ANSD, 2018). From an originally subsistence and family-based agriculture, it has been strongly oriented towards cash crops (groundnuts, cotton) that impoverish the soil. With the progress made, especially the development of irrigation, particularly in the sandy Niayes areas, market gardening is gaining ground in this agricultural sector and requires increasingly costly technologies and equipment. In response to the growing demand, unconventional techniques are being used, with harmful consequences. Indeed, in order to boost agricultural production and maintain a certain level of results, means are deployed such as the increasing use of chemical fertilisers (DAPSA, 2009) which impoverish the soil in the long term (Bado *et al*., 1997), the elimination of certain cultivation practices, fallowing, the use of crops that are too demanding in terms of mineral elements, etc.

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One of the limiting factors favouring such practices is the insufficiency or deficiency of soil fertilising elements (Bado *et al*., 1997, Petit and Jodin, 2005, Akanza *et al*., 2018). However, producers are resorting to alternatives that perform well and preserve soil characteristics. Among them, composts are increasingly used to replace chemical fertilisers, due to the high costs of the latter (Konaté *et al* 2018). On the other hand, developing countries have a nutrient-rich material that can be valued by the composting technique in combination with organic matter (Cofie *et al*., 2009), i.e.faecal sludge, which encounters problems in management. However, faecal sludge frequently contains several pathogens such as bacteria, viruses and parasites (Capizzi-Banas *et al*., 2004). This use is motivated by the fact that faecal sludge is rich in mineral and organic matter (Sonko, 2015; Lô, 2015, Lô *et al* 2019) which can be beneficial for plant development and soil structure. Agricultural reuse of sludge can be considered as the most suitable recycling method to rebalance biogeochemical cycles, and is of great economic interest. It aims to conserve natural resources and avoid any waste of organic matter due to incineration or landfill (Lachassagne, 2014). With the high temperature produced during the composting technique, the faecal sludge comes out more enriched and pathogen free. In this study, treated composts are tested to evaluate the morphological performance and yields of tomato compared to other inputs used (chemical fertilisers, non-composted faecal sludge (NCFS)).

MATERIALS AND METHODS

For this study, three (03) main types of material are used: the local crop (tomato or *Lycopersicon esculentum*-Mill), compost and technical material. Then the vegetable plots underwent two cropping seasons with tomato. The faecal sludge and vegetable waste composts were used as organic fertilizers on the experimental plots where other treatments such as chemical fertilizer (CF), non-composted faecal sludge (NCFS) and the no-input plot were tested in parallel for comparison with the faecal sludge and vegetable waste composts. The proportions of faecal sludge and vegetable waste are distributed by volume as follows

- **T0:** No-input plot, only faecal sludge (FS);
- **T1:** Mixture of 2 volumes of faecal sludge + 1 volume of market garden waste (MGW) and
- **T2:** Mixture of 1 volume of faecal sludge + 1 volume of market garden waste.

The following tables (1, 2 and 3) give the characteristics of the physico-chemical, parasitic and microbiological parameters of the composts. As regards the technical equipment used, it is composed of several tools, notably.

- A 0-20kg scale, for weighing the quantities of material of the amendment applied to the soil on the field
- A tape measure, for measuring the plots on the field
- A digital camera, for taking pictures
- A machete, for clearing the plot;
- A soil scientist's knife and plastic bags for harvesting tomato fruits and
- A digital scale for weighing the tomato fruits.

The study was carried out in Sangalkam Municipality in the Dakar Region/Senegal. The climatic data are listed in Table 4 and Figure 1 shows the tomato plot shown on this map with its geographical coordinates. Table 4 shows the climatic data with parameters on monthly rainfall, temperature for each month within the scope of the experiment and finally on monthly relative humidity. The highlighted months coincide with the cultivation periods of the tomato crops. These data are collected at the Sangalkam station.

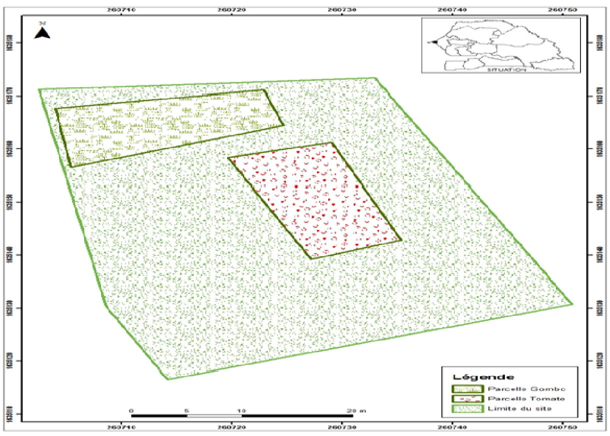

Figure 1. Map of tomato crops in the study

Setting up the experimental design: The experimental design was established with repetitions. In fact, the vegetable test beds are 10 m2 (10 m x 1 m) spaced 1 m apart to avoid proximity between treatments; in total, the vegetable crop (tomato) occupied a net area of 150 m2.

Conduct of the trial: setting up and maintenance of the nursery: The nursery is set up by broadcasting seedlings on beds 2 m wide and 4 m long. The beds are covered with mosquito netting for the first 3 days after sowing to maintain humidity at the level of the transplanted seedlings, then covered by a shade canopy mounted at a height of 80 cm to protect the seedlings from the sun and bad weather. This shade is gradually lightened by reducing the amount of leaves and then completely removed a week before transplanting the plants. The nursery is regularly watered (morning and evening) during this phase of the study.

Transplanting and fertilising the tomato: The nursery is thoroughly watered before the 20-30 day old plants are removed. Transplanting is carried out 20-30 days after the seedlings are placed in the nursery. Each elementary plot is fertilized by spreading compost at a rate of 12t/ha, one month before transplanting to allow its decomposition and one month after transplanting.

Measurements of tomato growth and production variables
On all nine (09) elementary plots, measurements were carried out on five (05) randomly selected plants three (03) times a week. These measurements concerned, by treatment on the height of the plants;

- The number of flowers;
- The number of bouquets;
- Number of fruits;
- Length of fruits and
- Fruit weight.

Observations began in the sixth week after transplanting with measurements of plant length, number of clusters and number of flowers. These measurements were repeated every week.

Statistical analysis of the data: The measured data were subjected to aone-way analysis of variance (ANOVA) using Statistix statistical software. Then, a classification of the averages is carried out using the Tukey HSD test. This test is used to complete the interpretation and to identify groups of homogeneous means. The results are considered significant when $P \leq 0.05$.

RESULTS

The morphological parameters are carried out at fairly regular periods for a fairly accurate transmission of data just one (01) month after transplanting the tomato plants. The height of the plants is an important parameter for monitoring the growth of the plant throughout the cultivation period. Figure 2 shows the height of the tomato plants in the 1st growing season for the different treatments T0, T1 and T3. From the figure, the treatments are classified into two distinct groups A and B. The tomato beds fertilized with treatments T0 and T2 show similar but much more significant heights than the tomato plants fertilized with T1, which is less important than the former. Figure 3 shows the variation in tomato plant height during the second season.

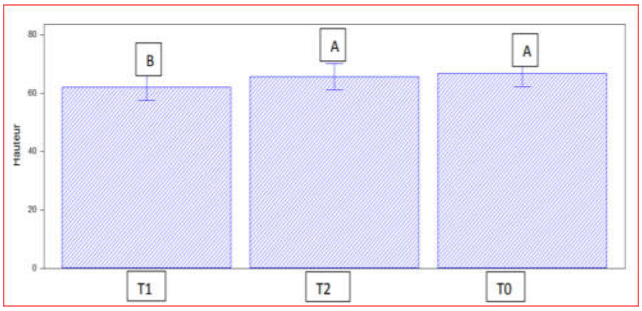

Figure 2. Height of tomato plants in the 1st season

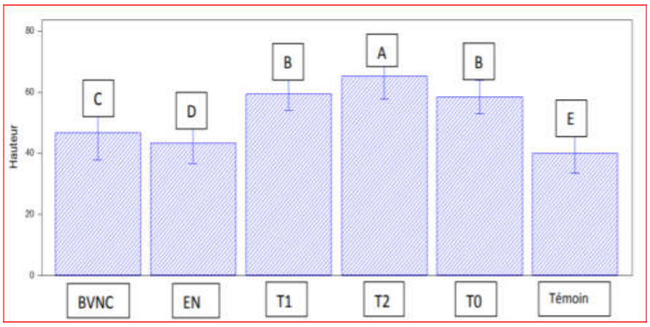

Figure 3. Height of tomato plants in the 2nd season

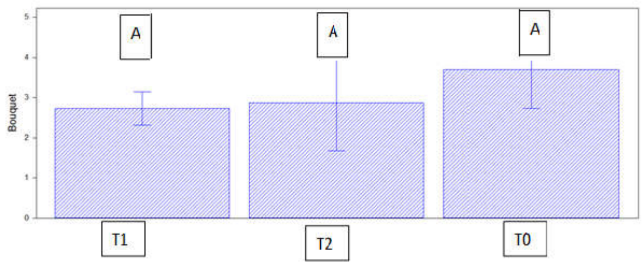

Figure 4. Number of bunches of tomato plants in the 1st season

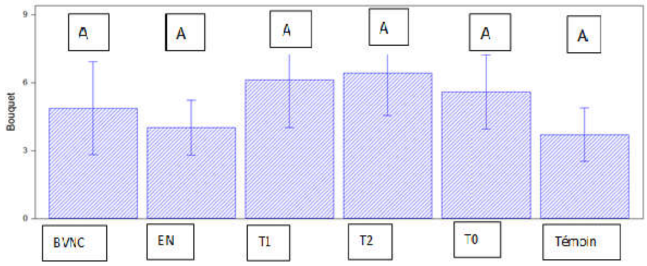

Figure 5. Number of bunches of tomato plants in the 2nd season

It shows the height of the tomato plants in the second growing season. According to the analysis of variance the treatments are in distinct groups (p=0.007). Figure 4 shows the number of bunches obtained during the first tomato growing season. The three (03) treatments T0, T1 and T2 show a similar number of bunches overall. The variance shows a p=0.1 greater than 0.05 which indicates a non-significant difference in the number of bunches of the different treatments and the groups are similar. There are no significant differences by pair between the averages. Figure 5 shows the number of bunches obtained from tomato plants in the second growing season. The treatments show non-significant differences in the number of bunches per tomato plant. The variance shows a coefficient of p= 0.7 that is significantly higher than 0.05 and indicates a homogeneous group for all treatments. Like the first season, the second season shows similarities in the number of bunch.

These results from the two campaigns show that the treatments do not have a great influence on the number of bunches of tomato plants. Figure 6 shows the number of flowers per tomato plant per treatment during the first cropping season. Treatment T0 has the best value in number of flowers followed by T2 and finally T1. But the analysis of variance indicates that the differences between the treatments are not significant because p=0.15 greater than 0.05 indicates a large coefficient compared to the established threshold. The treatments in this season do not influence the number of flowers on tomato plants. There are 2 groups (A and B) for which the averages are not significantly different from each other. Figure 7 shows the number of flowers on tomato plants during the second season. In this figure, the analysis of variance indicates a p coefficient below the threshold (P=0.00). This shows that the numbers of flowers per treatment are significantly different. There are 3 groups (A, B, etc.) for which the averages are not significantly different from each other. The beds with treatments T0, T1 and T2 have the highest values compared to CF, NCFS and the no-input plot.

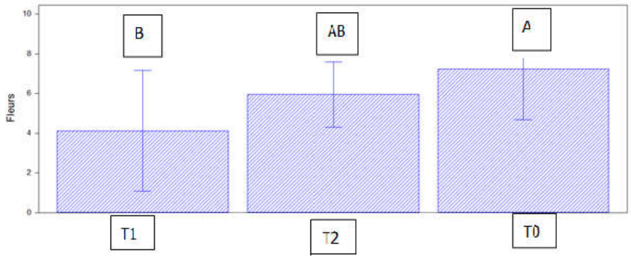

Figure 6. Number of flowers on tomato plants in the 1st season

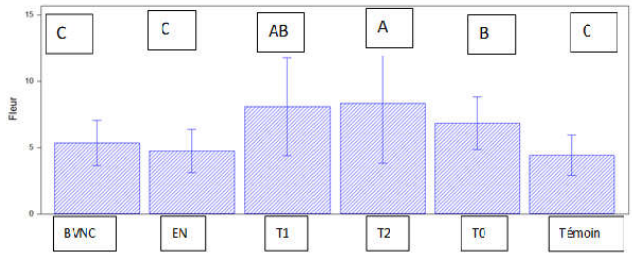

Figure 7. Number of flowers in tomato plants in the 2nd season

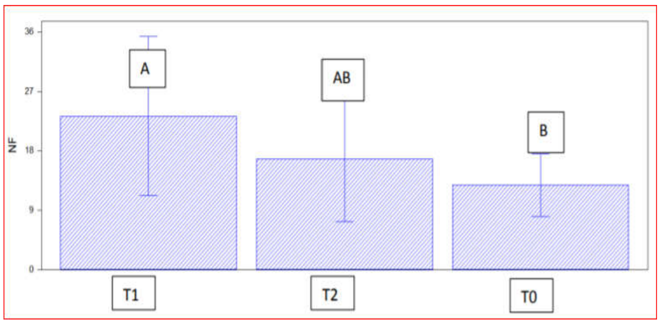

Figure 8. Number of tomato fruits in the 1st season

Yield parameters: Figure 8 shows the variation in the number of tomato fruits from treatments T0, T1 and T2. After analysis of variance, there are 2 groups (A and B) for which the averages are not significantly different from each other. The vegetable beds fertilized with T1 have a higher number of tomato fruits than treatments T0 and T2. Figure 9 shows the variation in the number of tomato fruits in the second season.

There are 4 groups (A, B, etc.) for which the averages are not significantly different from each other. The difference between the treatments is significant (with p less than the 0.0 threshold). Table 5 shows the yields recorded during the first tomato growing season. The vegetable beds fertilized with treatment T1 have the highest value (2.1 t/ha) compared to the other treatments T0 and T2 for 1.4t/ha and 1.54t/ha respectively. Table 6 shows the yield values recorded in the second tomato growing season. The vegetable beds fertilised with T1 have the highest yields (27.718 kg/ha) than the other treatments. The tomato plants that received the T2 treatment have interesting values (24.829 kg/ha). Figure 10 shows the total weight found during the harvest of the first season. This figure shows a similar result for the three treatments T0, T1 and T2. The analysis of variance with a coefficient above the threshold shows a homogeneous group for all treatments. Furthermore, there are no significant pairwise differences between the averages. Figure 11 shows the variation in total fruit weight of tomatoes harvested in the second season. This figure above, after analysis of variance, shows a significant difference between treatments with a dominance in total fruit weight of the plants that received the T0, T1 and T2 fertilizers. Here the pattern is similar with the results obtained with the number of fruits where we note a dominance in number of fruits of the vegetable beds that are fertilised with treatments T0, T1 and T2. Figure 12 shows the average fruit weight in the first season of tomato cultivation. It shows the average weight obtained for each treatment during the harvest period. According to the analysis of variance, there are 2 groups (A and B) for which the averages are not significantly different from each other.

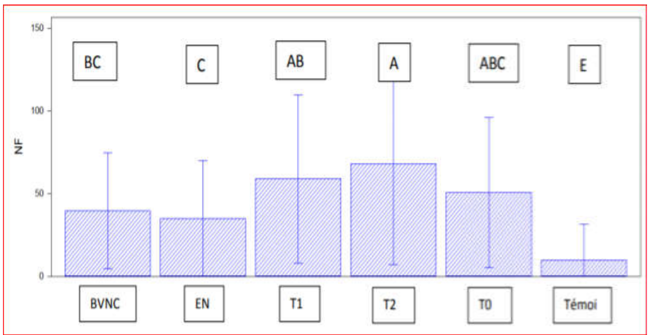

Figure 9. Number of fruits of tomato plants in the 2nd season

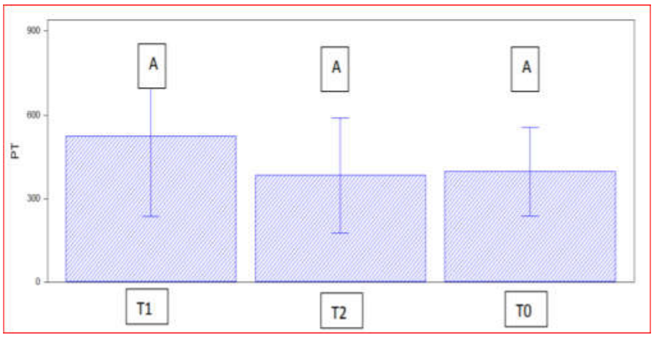

Figure 10. Total weight of tomato fruits of the 1st season

Figure 13 shows the average weight of tomato fruit in the second season. It shows the average weight of tomato fruits in the second season of cultivation. The analysis of variance reveals the presence of 4 groups (A, B, etc.) for which the averages are not significantly different from each other. The average fruit weight of the plants fertilised with T0, T1 and T2 had the highest values compared to the other treatments.

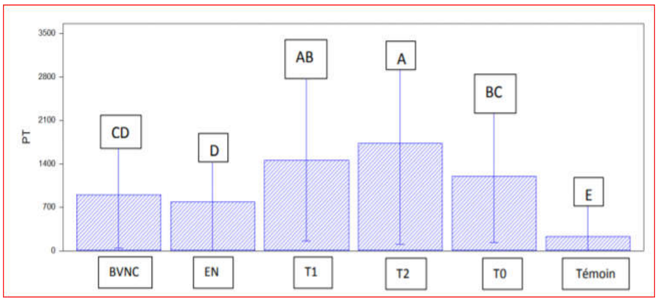

Figure 11. Total weight of tomato fruits in the 2nd season

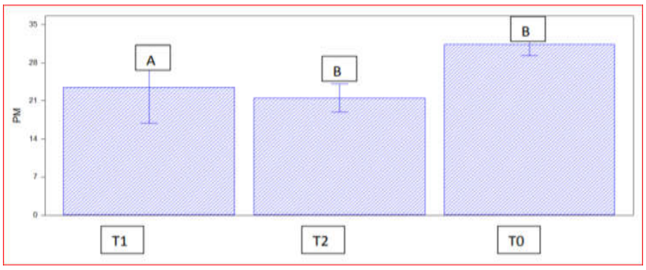

Figure 12 Average weight of tomato plants in the 1st season

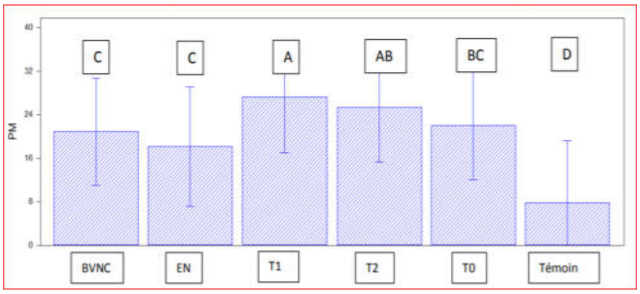

Figure 13. Average weight of tomato fruits in the 2nd season

DISCUSSION

In figure 2, there are 2 groups (A and B) for which the averages are not significantly different from each other. The treatments are grouped into two distinct groups with a coefficient of variance greater than 0.05 (p=0.9). According to the figure on tomato plant height, the plants fertilised with treatments T0 and T2 have greater heights than the plants fertilized with T1. The results of this first tomato campaign, are greater in height than the results of Diallo *et al.* (2018) who worked on tomato growth and yield. These treatments are provided with interesting P and K (Table 1).

The presence in significant quantities of these nutrients favoured the development of these aerial parts because according to Toundou (2016) phosphorus and potassium favour the development of aerial parts of tomato plants. In figure 3, plant heights are significantly different between treatments, there are five (05) groups (A, B, C, D and E) for which the averages are not significantly different from each other. The vegetable beds fertilised with treatments T0, T1 and T2 show taller plants than in the beds that received non-composted faecal sludge (NCFS), chemical fertilizer (CF) and the no-input plot. This high plant growth may be related to high nitrogen content in treatments T0, T1 andT3 as reported by some authors such as Mouria *et al.* (2010) and Toundou (2016) who showed the positive effect of different doses of household waste composts on tomato growth.

Tableau 1. Agronomic value of compost treatments

Parameters	Unités	BB	T0	T1	T2	Example Cofie (2009)
Physico-chemical						
pH (1 :10)		6..., 03	6..., 4	6..., 5	6..., 2	7..., 6
EC (1 :10)	µs/cm	1690	985	1307	1243	1.., 4-1.., 9.103
Stability						
C	%	22..., 14	6..., 8	6. 80	6..., 30	14-15
MO	%	38..., 2	12	12	11	20-21
C/N		10..., 6	11.., 1	11.., 1	11	13.., 1
AH	%	0.., 08	0.., 04	0.., 08	0.., 042	-
AF	%	0.., 5	0.., 6	0.., 82	0.., 58	-
AH/AF		0.., 2	0.., 1	0.., 1	0.., 1	-
Nutrients						
N	%	2.., 09	0.., 6	0.., 6	0.., 56	1.., 2-2.., 1
P	%	1.., 3	1.., 1	1.., 7	1.., 9	1.., 1-1.., 3
K	%	0.., 08	0.., 05	0.., 2	0.., 24	0.., 6-0.., 5

Table 2. Fecalcoli form concentrations in compost samples

	Unitsté	T0	T1	T2	Raw sludge
FeacalColiforms	UFC/100g	0	0	0	95 000
Reduction rate	%	100	100	100	

Tableau 3. Helminth egg concentrations in swaths

Samples	Number of Ascaris eggs/g of compost		
	Living (in 10g)	Inactive (in 10g)	Concentrations in eggs /g
Faecal sludge	08	92	0., 8
T0	03	41	0., 3
T1	04	33	0., 4
T2	02	44	0., 2

Tableau 4. Climatic data for the study area (collected from the Sangalkam/ISRA climate station)

STATION SANGALKAM	Apirl	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mars
Monthlytemperature	22., 9	24., 05	26., 26	27., 44	27., 53	27., 98	28., 12	26., 63	22., 64	20., 95	22., 95	25., 35
Monthlyhumidity	74., 73	81., 28	80., 81	80., 39	84., 38	83., 14	80., 74	70., 66	58., 60	64., 47	73., 03	76., 02
Monthlyrainfall	0	0	0., 14	4., 25	6., 39	1., 89	0., 67	0	0	0	0	0

Tableau 5. Tomato yield kg/ha in 1st growing season

Treatments	T0	T1	T2
Tomato yield (kg/ha)	1462	2101	1538

Tableau 6. Tomato yields in kg/ha in the second growing season

Treatments	No-input plot	T0	T1	T2	CF	NCFS
Yield (kg/ha)	13 076	22 847	27 718	24 829	14 879	17 179

In Figures 8 and 9, vegetable beds that received treatment T2, T1 and T0 have the highest value in tomato fruit number compared to the other treatments. The work of Mpika *et al* (2015) on potassium and nitrogen supply on growth and yield of three tomato varieties also indicates an improvement in fruit number on the tomato varieties they tested. The results in Table 5 are in the range of yields found by Diallo *et al* (2018) who worked on tomato growth and yield but are lower than those found by Sogbedji (2016), Soro *et al* (2015) on tomato growth and yield. This could be explained by the period in which the crop is grown. The variety used, the growing conditions, the season may have effects on tomato yield. This could be the basis for outbreaks observed during certain production cycles for most crop pests (Soro *et al*, 2015). Also, according to Beniest (1987), tomato crops perform best in terms of yield during the cool, dry season (December to July). The first cropping season occurred outside this time frame, which could explain the low yields obtained during this period. Also in Table 6, the double yield of the no-input plot (13,076 kg/ha) was obtained in these vegetable beds. These results are in line with the values found by some authors (Sogbedji, 2017; Djidji, 2010; Soro *et al*., 2015; Mpika *et al*. 2015) who have worked on tomato growth and yield. Also, this strong increase in yields obtained with treatments T0, T1 and T2 can be explained by the fact that the increase in height of tomato plants can induce the development of fruiting nodes of tomato plants (Djidji, 2010). The absence of predation can also promote good yield (Soro *et al*., 2015). However, a decrease in yield is observed in the vegetable beds that received chemical fertilisers where the nitrogen content is high because according to Mpika *et al*. 2015, high nitrogen inputs have a depressive effect on the yields of local varieties and the ROMA VF variety. According to these authors, these varieties obey the threshold law. Figure 12 shows the average weight of tomato fruits in the first growing season.

The vegetable beds with treatment T0 gave tomato fruits with the highest average weight. Treatment T1 was the second highest and treatment T2 had the lowest average tomato fruit weight. According to these results, there is no correlation between yield and average tomato fruit weight and these observations are confirmed in the work of Huat (2008) on the variability of crop management systems.

CONCLUSION

This study aimed to determine the agronomic value of using composts based on sewage sludge and vegetable waste. These experiments evaluated the behaviour of tomato under different fertilization treatments to identify nutrient management strategies that optimize its production. Three (03) composts were applied to the local crop, namely tomato. The composts improved the growth performance of tomato plants compared to the no-input plot. Furthermore, between these compost treatments, T1 stands out from the other two treatments (T0 and T2). Chemical fertilisers and raw sludge were used in comparison to the previous treatments. Also from this study it appears that the use of inputs contributes to increase fruit production but favours more the vegetative development. However, outside the favourable periods, the crops do not show any significant difference between treatments. The vegetable beds that received the composts also showed better yields compared to the other treatments. The tomato is sensitive to a good water supply and the compost by its organic matter favours water retention. In both the first and second seasons, the tomato plants that were fertilised with the composts showed their importance in height compared to the other treatments (chemical fertilisers and non-composted faecal sludge). With the yields obtained at harvest, the composts show interesting results for both harvest seasons. Also, this strong increase in yields with composts can be explained, as some authors state, by the fact that the increase in height of tomato plants can lead to an increase in the production of fruiting nodes of tomato plants. The absence of predation can also favour a good yield. In order to better understand these results, it is appropriate to plan other experiments in this area to confirm or invalidate these results.

Conflicts of interest statement: The authors declare that there is no conflict of interest.

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GLOSSARY OF ABBREVIATIONS

ANSD: *Agence Nationale de la Statistique et de la Démographie* (National Agency for Statistics and Demography, Senegal)
NCFS: Non-composted faecal sludge
DAPSA: *Direction de l'Analyse, de la Prévsion des Statistiques Agricoles* (Department of Forecast Analysis and Agricultural Statistics)
CF: Chemical fertilizers
ENSA: *École Nationale Supérieure d´Agriculture* (Higher National School of Agriculture)
Ha: hectare
ISE: *Institut des Sciences de l'Environnement* (Institute of Environmental Sciences)
LEEMUR: *Laboratoire d'Etudes Environnementales des Milieux Urbains et Ruraux* (Laboratory for Environmental Study of Urban Environments)
T0: Control treatment (compost based on faecal sludge)
T1: Treatment 1 (compost based on 2/3 faecal sludge and 1/3 market garden waste)
T2: Treatment 2 (compost based on 1/2 faecal sludge and 1/2 market garden waste)
UCAD: *Université Cheikh Anta Diop de Dakar* (Cheikh Anta Diop University of Dakar)

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