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(RESEARCH ARTICLE)

Comparative effects of composts and chicken droppings on the production of tomato (*Solanum lycopersicum* L.) grown in the soil of Kinshasa

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Abstract

A study was conducted on the valorization of organic waste used as organic fertilizer after composting, in tomato cultivation in urban areas. This study was composed of four treatments: a control (T0) that received no amendment, a compost (T1) produced from green waste of *Manihot esculenta* Crantz and dry leaves of *Ficus bubu*, a compost (T2) based on green waste of *Manihot esculenta* Crantz, dry leaves of Ficusbubu and chicken droppings, and a treatment (T3) composed only of uncomposted chicken droppings. Samples of all four treatments were taken and analysed in the laboratory for chemical and agronomic characterisation. The treatments were distributed in a randomized complete block design. Data collected on root weight, crown diameter, plant height, number of fruits, fruit diameter, fruit weight and average fruit weight per treatment were subjected to analysis of variance and also multivariate analysis (PCA). The results showed that compost 1 (T1), compost 2 (T2) and uncomposted chicken droppings (T3) gave the highest yields (7.6 t.ha-1, 6.6 t.ha-1 and 6.3 t.ha-1 respectively) compared to 3.9 t.ha-1 for the control (T0).

Keywords: Recovery; Organic waste; Composting; Urban agriculture; *Solanum lycopersicum L*

1. Introduction

In recent years, market gardening has become an efficient way to meet urban food demand [1]. However, the decrease in soil fertility due to inappropriate agricultural practices is observed in developing countries such as the Democratic Republic of Congo. In tropical environments, the high pressure on agricultural land leads to a rapid decrease in the stock of organic matter and causes a significant decline in soil fertility and crop yields [2], [3], [4].

Tomato is one of the crops considered to be at risk by Kinshasa's market gardeners. Despite its growing demand and the interesting income it provides per unit area, very few market gardeners grow tomatoes in the Malebo Pool and only in the dry season. It is very demanding in terms of fertilisation and very susceptible to fungal diseases [5]. In intensive agriculture, the alternative to the loss of mineral elements is the use of mineral fertilisers, the excessive cost of which makes them inaccessible to small-scale producers [6]. One of the solutions for these producers is the use of organic fraction waste after treatment by composting. This could contribute both to the sanitation of the urban environment and to the reduction of the quantities of mineral fertilisers used by market gardeners for vegetable production in Kinshasa. These quantities of mineral fertilisers are estimated at an average of 30 kg of urea and 30 kg of N-P-K (Nitrogen-Phosphorus-Potassium) / year / vegetable farmer and cost 1.5 Usd/kg. These high costs are one of the main constraints to market gardening in the provincial city of Kinshasa [7].

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The proportion of different organic residues currently recovered through composting is still relatively small, and Kinshasa's landfills therefore represent an important potential source of organic waste, estimated at around 2.2 million tonnes of waste per year. This waste is made up of 66 % organic matter, of which 94 % is plant waste [8]. The present study tests the hypothesis that composts based on green waste of *Manihot esculenta* Crantz, dry leaves of *Ficus bubu* and chicken droppings, would be one of the best alternatives for tomato production in the edapho-climatic conditions of Kinshasa. This study was conducted to evaluate the impact of composts and uncomposted chicken droppings on tomato yields and to determine the appropriate agricultural amendment for this crop.

2. Material and methods

2.1. Plant material

The study was carried out on tomato from certified plant material (tomato seeds), a Caribbean variety with a round, globe-shaped fruit weighing about 100 g. This variety can be grown all year round and is very well adapted to the climatic conditions of Kinshasa. This variety can be grown all year round and is very well adapted to the climatic conditions of Kinshasa. The recommended sowing in nursery (30-40 days) is 1 gr/m^2 in rows spaced 20 cm apart. Transplanting takes place when the plants have 3 to 6 leaves, every 60 cm x 50 cm, and harvesting takes place 75 days after transplanting, for 4-5 weeks [9].

2.2. Geographical coordinates, climate and soil of the study site

The study was conducted from 5 June to 22 September 2021 at the didactic field of the Faculty of Agronomic Sciences of the National Pedagogical University, located in the city Province of Kinshasa in the Democratic Republic of Congo. The geographical coordinates of this environment are 15°21′15″ South latitude and 4°22′05″ East longitude with an altitude of about 500 m. The site enjoys a humid tropical (Sudano-Guinean) climate of type AW4 of Köppen's classification. The average annual rainfall is 1,500 mm and the average temperature varies between 24 and 25°C. The climate is characterised by two alternating seasons, one rainy season lasting 8 months and a dry season lasting 4 months, usually occurring between the second half of May and mid-September. The heaviest rainfall occurs in November, December and March. July and August are the driest months. The soils of the experimental site are acidic (pH=5.32), and thus belong to the soil type of the city of Kinshasa, classified according to the order of kaolisols, the suborder of hydro-xerokaolisols and the great group of arenoferrals. These soils are essentially sandy in texture with some coarse elements and a clay content generally below 20 %.

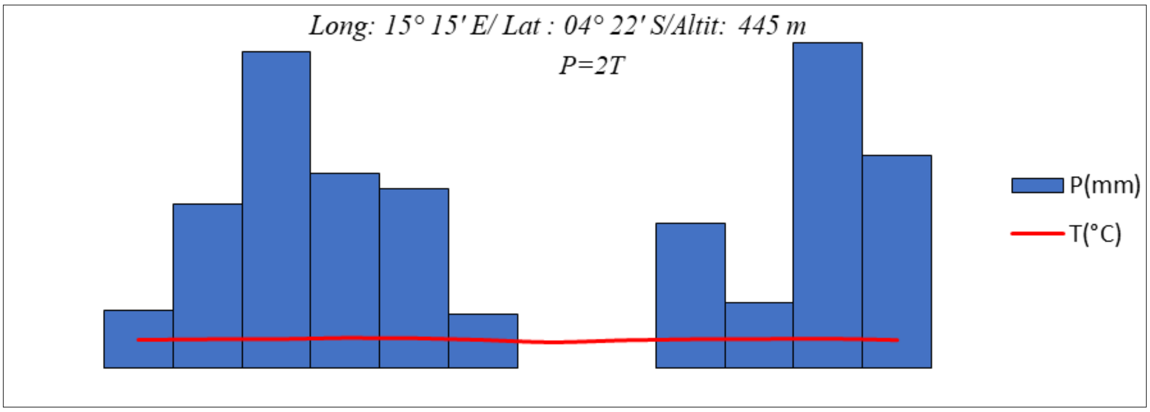


Figure 1 Umbrothermal diagram of the provincial city of Kinshasa for 2021 (Meteorological station of Kinshasa - Binza: Climatology Department)

2.3. Nature of organic waste used for composting

Three categories of putrescible organic waste (green waste from *Manihot esculenta* Crantz, dry leaves from *Ficus bubu* and chicken droppings) were used to produce two types of compost (Table 1 below).

Table 1 Composition and proportion of each compost pile

	Compost 1		Compost 2		
Composition	**Green waste from *Manihot esculenta* Crantz**	**dry leaves of *Ficus bubu***	**Green waste from *Manihot esculenta* Crantz**	**dry leaves of *Ficus bubu***	**chicken droppings**
Proportion	50%	50%	40%	40%	20%
Actual quantity (in Kg)	212		192		

Table 1 shows that the first compost (I) consists of green waste of *Manihot esculenta* Crantz and dry leaves of *Ficus bubu* while the second (II) is a mixture of the first compost and chicken droppings.

2.4. Treatments used

Four treatments were used to evaluate their comparative effects on tomato production. These are the treatments:

- T0: Control (soil of the experimental site)
- T1: Compost based on green waste of *Manihot esculenta* Crantz and dry leaves of *Ficus bubu* (compost 1)
- T2: Compost from green waste of *Manihot esculenta* Crantz, dry leaves of *Ficus bubu* and chickendroppings (compost 2)
- T3: uncomposted chicken droppings

Table 2 Quantities (Kg/h) of compost and/or hen droppings supplied for each treatment

Designation	**Treatments**			
	T0	**T1**	**T2**	**T3**
Compost from green waste of *Manihot esculenta* Crantz and dry leaves of *Ficus bubu*	0	25.000	0	0
Compost from green waste of *Manihot esculenta* Crantz, dry leaves of *Ficus bubu* and chicken droppings	0	0	25.000	0
Non-composted chicken droppings	0	0	0	15.000

2.5. Sowing, maintenance and harvesting

Sowing was carried out on 05 June 2021 at a rate of2 seeds per poquet and 5 cm apart on the line, i.e. 20 poquets per 1 m line. The spacing between two sowing lines is 10 cm. The transplanting of the seedlings from the germinator was carried out on 09 July 2021 at a rate of one plant per poquet. After transplanting, regular watering (once a day) was carried out for a fortnight and afterwards as needed. Manual weeding was carried out to prevent the plantation from becoming overgrown, starting on the 25th day and staking on the 31st day after transplanting, followed by pruning and draining. Fertilisation was carried out on 17 July 2021 with the addition of compost and chicken droppings. The quantities applied for each treatment are shown in Table 2. Harvesting started on 02 September 2021 and was done manually at different stages. The fruits were picked at the fully ripe stage (green-ripe or greenish-red). In total six harvests were carried out. Chemical and agronomic characterisation of the treatments used.

The chemical and agronomic characterisation concerns the following parameters: organic matter and organic carbon content, fertiliser content, pH, C/N ratio and cation exchange capacity (CEC).

Table 3 Composition of composts in total organic matter (TOM) and total organic carbon (TOC) (in %)

Parameters	Treatments				Standard NF U 44-051*
	Control	Compost 1	Compost 2	Chicken droppings	
TOM	1.92	37.616	27.55	80.49	≥ 20%
TOC	1.119	21.87	16.02	46.8	-
TOM/TOC ratio	1.715	1.719	1.719	1.719	= 1.7

*AFNOR; Source : CGEA/CRENK

Table 4 Composition of the different treatments in fertilising elements (in %)

Fertilizer elements	Treatments				Standard NF U 44-051*
	Control	Compost 1	Compost 2	Chicken droppings	
Total nitrogen (N)	0.139	1.23	1.31	2.56	< 3
P_2O_5	0.66609	1.128	1.069	2.914	< 3
K_2O	0.0583	1.908	1.627	2.654	< 3
CaO	0.3002	4.463	3.607	1.609	-
MgO	0.104	0.6034	0.4343	0.4331	-
Na_2O	0.110	0.102	0.050	0.014	-
NPK in total value	0.86	4.266	4.006	8.128	< 7

*AFNOR; Source : CGEA/CRENK

Table 5 PH, C/N ratio and Cation Exchange Capacity (CEC)

Parameters	Units	Treatments				Standard NF U 44-051*
		Control	Compost 1	Compost 2	Chicken droppings	
pH	-	5.32	7.60	7.74	7.66	-
C/N ratio	-	8.050	17.78	12.22	18.28	> 8
CEC	Cmol/kg	3.22	6.39	6.46	4.87	-

*AFNOR; Source : CGEA/CRENK

2.6. Experimental design

The trial was laid out in FISCHER blocks or complete randomised blocks with 6 replicates and 4 treatments. The block consisted of a ridge of 8.9 m2 (6.9 m x 1.30 m). The plants were transplanted onto ridges, spaced 0.4 m apart on the row and 0.4 m between rows, i.e. 16 plants per plot occupying 2.56 m2 (i.e. 0.16 m2 as unit area for each plant). Each block was separated by a 0.6 m wide lane. The replication consisted of 6 ridges (blocks). The total area of the experimental field including the alleys was 73.4 m2 for a total of 384 plants, i.e. a density of about 52,316 plants/hectare. Observations were made from sowing to harvesting; and the various measurements were taken from 4 plants in the middle of each plot as an experimental unit, i.e. 24 plants for each treatment.

2.6.1. Evaluation of growth and production parameters

- Plant height

The average height (in cm) of the plants was measured during flowering; between the ground and the first flower bud, using a tape measure.

- Average crown diameter

The crown diameter (in cm) of the plants was measured with a caliper.

- Below-ground biomass

This is the average weight (in g) of the roots for each plant and each treatment. It was taken using a precision balance.

- Average number of fruits per plant per treatment

The fruits of the useful plants were counted at each harvest for each plant and treatment.

- Average fruit diameter per plant and treatment

Fruit diameter (in cm) was measured with a caliper at each harvest for each plant and treatment.

- Average fruit weight per plant and treatment

The average fruit weight (in g) was calculated from the production per plant or per treatment on the number of fruits of the same plant or treatment. It was taken using a precision scale.

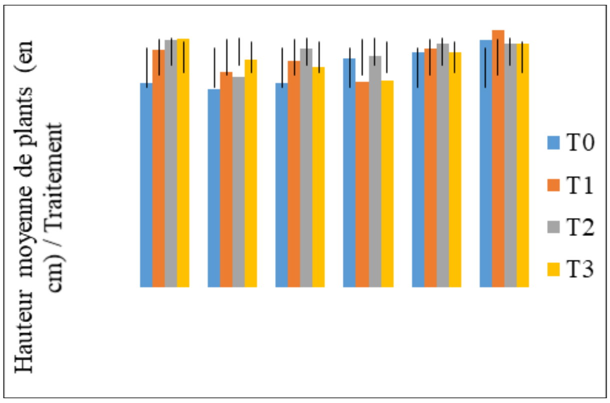
2.7. Statistical analysis

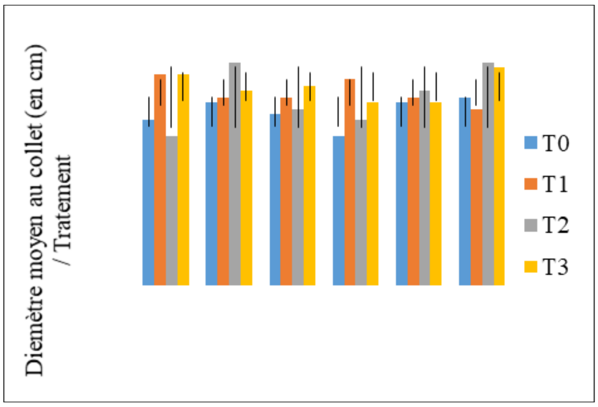
All data collected were analysed using Minitab 19 software. The statistical parameters are used to exploit the results; and for each result a mean u and a standard deviation s are calculated in order to assess the distribution and the deviations of the values obtained from the different methods used. An analysis of variance (ANOVA) was performed for all parameters to show the existence of significant differences between the means. The LSD or least significant difference (LSD) test was used to separate the means at the 5% level. Before performing the analysis of variance, the data for all parameters were subjected to two different tests. The first one concerns the normality of the data (Ryan-Joiner test) and the second one is the equality of variances of the different treatments (Levene test). In addition, a multivariate analysis of the PCA type (Principal Component Analysis) with the R software (version 4.0.2) was carried out in order to group the treatments according to their similarities and to better interpret the differences.

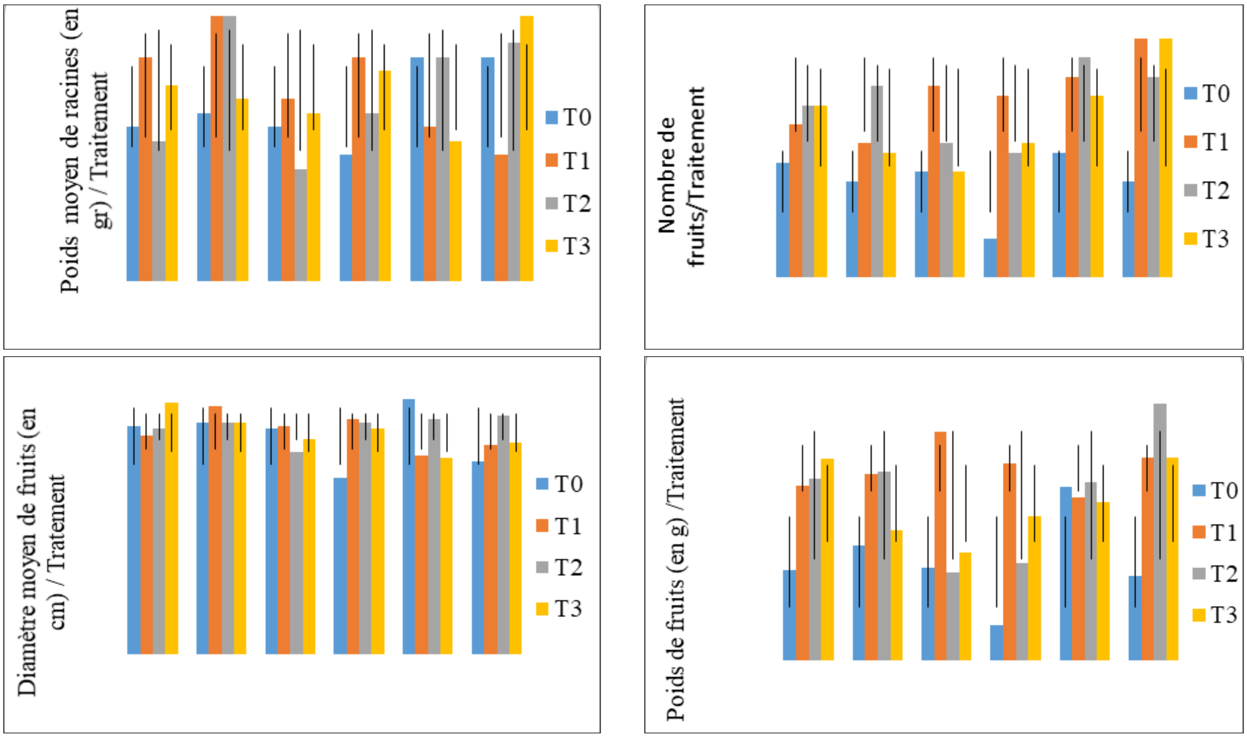
3. Results

3.1. Effects of treatments on growth and production parameters

The results presented below concern parameters related to vegetative growth and fruit yield of tomato. The effects of composts and non-composted chicken droppings on the different tomato production parameters are evaluated.





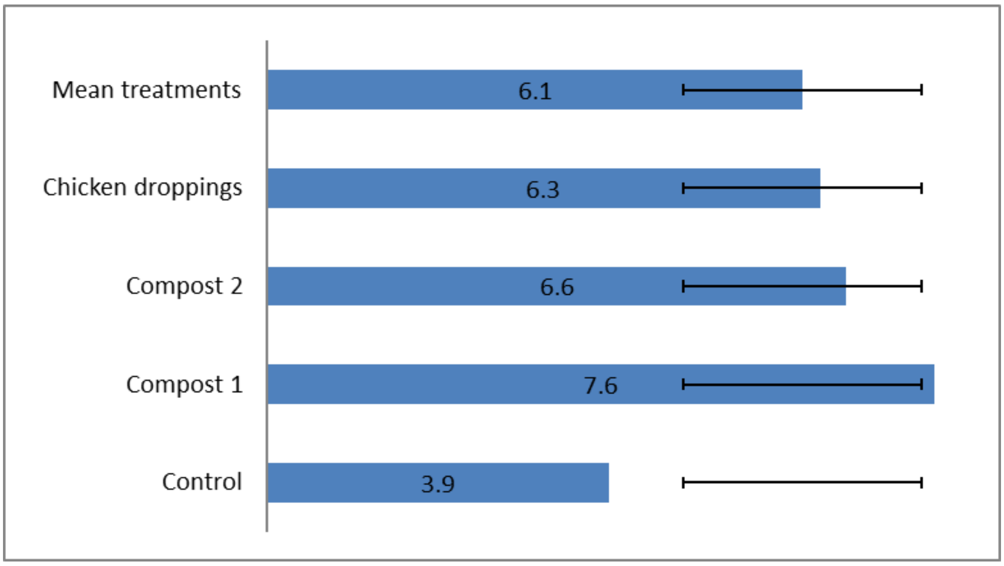


Error bar: Standard deviation

Figure 2 Variations of the different growth and production parameters according to the type of treatments

3.2. Average yields ($t.ha^{-1}$) by treatment

Post-harvest fruit yields ranged from 3.9 to 7.6 $t.ha^{-1}$. Compost 1(T1) had the highest yield (7.6 $t.ha^{-1}$), followed by compost 2 (T2) (6.6 $t.ha^{-1}$) and chicken droppings (T3) (6.3 $t.ha^{-1}$). The control treatment (T0) had a low yield (3.9 $t.ha^{-1}$).



Error bar: Standard deviation

Figure 3 Average yields obtained ($t.ha^{-1}$) according to the type of treatment

3.3. Analysis of variance of growth and production parameters

The analysis of variance of different production parameters indicated a non-significant difference for plant height, root weight, fruit diameter and average fruit weight. It was, however, significant for the parameters neck diameter, number of fruits and fruit weight. The LSD test revealed that the diameter at the crown, the average weight and the average number of fruits harvested from the compost (T1, T2) and chicken droppings (T3) plants are the best and significantly higher than the average weight and the average number of fruits of the control plants (T0).

Table 6 Analysis of variance of the selected parameters for growth and production

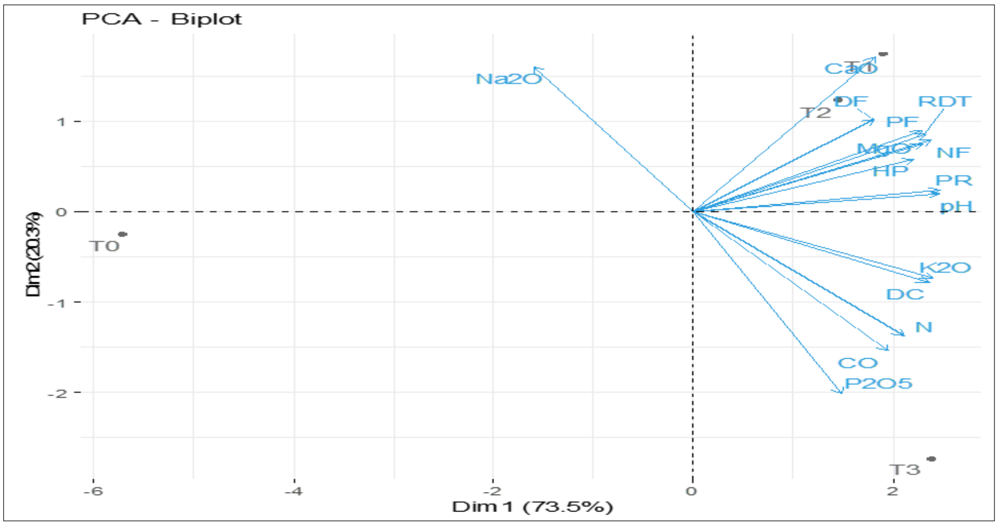
Parameters	Treatments				F	P
	Control (T0)	Compost 1 (T1)	Compost 2 (T2)	Chicken droppings (T3)		
Plant height	47.27 ± 4.36[a]	49.53 ± 3.94[a]	50.78 ± 2.94[a]	49.55 ± 3.29[a]	0.39	0.43
Diameter at collar*	0.76 ± 0.06[b]	0.84 ± 0.06[ab]	0.82 ± 0.13[ab]	0.87 ± 0.06[a]	1.82	0.18
Root weight	62.5 ± 14.4[a]	70 ± 18.4[a]	68.3 ± 21.6[a]	69.2 ± 15.3[a]	0.22	0.88
Number of fruits*	10.0 ± 3.16[b]	19.2 ± 3.9[a]	18.2 ± 3.97[a]	16.7 ± 5.1[a]	6.15	0.004
Fruit diameter	6.68 ± 0.88[a]	6.83 ± 0.55[a]	6.97 ± 0.40[a]	6.8 ± 0.58[a]	0.21	0.889
Fruit weight*	1009 ± 462[b]	1966 ± 234[a]	1693 ± 649[a]	1612 ± 393[a]	4.63	0.013

(*) The difference is significant between treatments.

([a, b]) Means ± Standard deviation; Means that do not share any letters on the same line are significantly different at the 5% probability level ($p<0.05$).

3.4. Principal component analysis of the different variables (PCA)

The Principal Component Analysis below allowed the treatments studied to be grouped on the basis of their composition in chemical elements, growth and production parameters of tomato plants. Axes 1 and 2 contributed 93.8% to the total variation observed. The pH, CO, fertilizing elements (N, K_2O, CaO and MgO) and the parameters Plant height (HP), Diameter at crown (DC), Root weight (PR), Number of fruits (NF), Fruit diameter (DF), Fruit weight (PF) and Yield (RDT) are well represented and therefore correlated to axis 1 (73.5%). These axes allowed us to divide the treatments into three groups. The first group is formed by treatments T1 and T2 which group together nine (9) variables with significant values for nutrient content, vegetative growth and production. The second group is formed by treatment T3 which represents five (5) variables (K_2O, N, CO, P_2O_5 and DC). The third group is the control treatment T0 which has variables with low levels of fertilising elements and consequently a non-significant vegetative growth and production. In addition, there is a negative correlation between P_2O_5 and Na_2O.



Treatments: (T0: Control; T1: Compost 1; T2: Compost 2; T3: Chicken droppings) / **pH, CO** / **Fertilizer elements**: (N, P_2O_5, K_2O, CaO, MgO, Na_2O) / **Parameters**: Plant height (HP), Diameter at the crown (DC), Root weight (PR), Number of fruits (NF), Fruit diameter (DF), Fruit weight (PF), Yied (RDT).

Figure 4 Distribution of treatments according to chemical composition and growth and production parameters of tomato according to axis 1 and 2 of a Principal Component Analysis (PCA)

4. Discussion

Statistical results on vegetative growth (plant height and below ground biomass) indicated a non-significant difference between the treatments under study. Compared to the control treatment, tomato plant growth was little affected by composts ($p>0.05$). These results are in agreement with those of [10] on the length of tomato stems grown on highly diversified compost, and with those of [11] on the same parameters for tomatoes grown on household composts in Kolwezi. However, chemical characterisation of the composts and chicken droppings showed interesting organic matter and NPK contents. According to [12] and [13], potassium and phosphorus are mainly involved in the growth of aerial organs such as leaves and stem. The non-significant difference between the treatments on vegetative growth of tomato would be due to the organic form of nitrogen provided by the composts and chicken droppings, and whose mineral transformation did not coincide with the needs of the test plant during the growth period [14], [15]. Nevertheless, the PCA (Fig. 4) indicates a correlation on axis 1 of all growth parameters in favour of treatments T1, T2 and T3.

For fruit production, the statistical results for diameter revealed a non-significant difference between treatments. Nevertheless, the averages of the different treatments for fruit diameter (6.68 - 6.97 cm) are within the acceptable limits indicated in the technical itinerary sheet for the Caraïbo tomato variety and several other varieties (Auda, Marmandaise, Jaune demi lisse, Jaunegrosselisse, Gloire de France) [9].

Significant variations were recorded for the parameters number of fruits, fruit weight and yield per treatment. The LSD test revealed that the average number and weight of fruits harvested from plants grown from T1, T2 composts and chicken droppings (T3) were the best and significantly higher than the weights and number of fruits from control plants (T0). These results are consistent with the axis 1 correlation observed at the PCA level for the three treatments (T1, T2 and T3) and all production variables (Fig. 4). The number of fruits produced per plant ranged from 4 to 5 (> 4 fruits/plant) for both composts and chicken droppings, while the control treatment was less productive (< 3 fruits/plant) ($p< 0.05$). These results collaborate with those of [11] on tomatoes grown with different doses of household compost. Fruit weight ranged from 1009 g/0.64m^2 (control) to 1966 g/0.64m^2 (compost 1) or from 3.9 t.ha^{-1} (control) to 7.6 t.ha^{-1} (compost 1). The yields obtained with chicken droppings (T3) and the two composts (T1 and T2) are similar to those obtained by [16] (7.7 t.ha^{-1}) with the Caraïbo variety, and those observed by De Lannoy (2001) cited by [10] in tropical regions (5-20 t.ha^{-1}). The yields (number and weight of fruits) obtained with T1, T2 and T3 are higher than the average of all the treatments, and the yield from T0 is lower than the same average. Compared to the control, the addition of composts and chicken droppings significantly increased crop yields; this performance could be explained by the very heterogeneous fertilising value of N-P-K and other mineral elements provided to the plants by the composts and chicken droppings during the experimental period. According to [17], the more variability there is in the substrates, the more the compost generated would contain a varied chemical value in fertilizing elements, and therefore a desirable agronomic value. Positive variations observed (N, P, K, Ca, pH, C/N ratio) confirm the ability of the composts produced to restore soil fertility, as observed by [18] and [19] for the restoration of acid soil properties using household biowaste. Charland et al (2001), quoted in [18], indicate that good compost increases yields compared to unfertilised soils, even when applied at low rates; the quality of the composts and the rates applied directly influence yields; fractioning the applications gives better results.

5. Conclusion

Compared to the control treatment, the statistical results obtained showed that the use of both types of compost increased tomato yield as much as non-composted chicken droppings. Nevertheless, the best yield averages (number and weight of fruits) were obtained with both composts. The yields recorded are, in descending order, 7.6 t.ha^{-1} for compost 1 (T1); 6.6 t.ha^{-1} for compost 2 (T2); 6.3 t.ha^{-1} for non-composted chicken droppings (T3) and 3.9 t.ha^{-1} for the control treatment (T0). Both composts appear to be a reserve of nutrients and thus meet AFNOR standards and can be recommended for tomato production in urban areas. The results obtained and presented in this study show that the objectives initially set were achieved. Nevertheless, there are still many perspectives on this subject, given the diversity of organic matter in the urban environment. Finally, the management of organic waste, by favouring different composting processes, is a solution to ensure the sustainable maintenance of soil fertility in the different cropping systems. The intensification of these processes will enable farmers to make their investments in the preservation and improvement of soil fertility profitable.

Compliance with ethical standards

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Disclosure of conflict of interest

All authors were involved in the study design, experimental design and scientific writing of the article.

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