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Effect of different types of organic fertilizers and composting time on the production of a tomato variety (*Lycopersicum esculentum* Mill.) grown under semi-controlled conditions in Daloa (Côte d'Ivoire)

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Abstract

In order to increase their production, which is far from covering the needs of the local population, farmers opt for the use of chemical fertilizers. However, the use of organic amendment via composting could be less expensive and beneficial for maximizing crop yields. However, the quality of compost depends on the nature of the material used and the composting time. The objective of this study is to determine the best formulations of compost from urban organic waste of the city of Daloa and the composting time favorable to the realization of quality compost. The device used is a split plot with three repetitions divided into three (3) blocks, consisting of two (2) factors (types of fertilizer and composting time). The fertilizers were applied at 100%, 50% and 25% and the composting times were: 2 months, 4 months, 6 months and 8 months. The study found that the F7 formulation (chicken manure, sawdust, rice bran, chapalo residue, charcoal, *Tithonia diversifolia* and household waste and grass clippings) had the best fertilizing properties for a composting time of 6 months. However the best dose applied with this formulation is 100%.

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Introduction

Market gardening is a vital agricultural sector in Sub-Saharan Africa because of the high nutritional value and economic returns it generates. This sector has the potential to serve as an engine for agricultural and economic diversification by directing production to local or export markets (Weinberger *et al.*, 2007). Among these vegetable crops, we can cite the tomato (*Lycopersicum esculentum* Mill.). Indeed, the tomato plays a very important socio-economic role among the Ivorian population (Soro *et al.*, 2007). It presents enormous therapeutic virtues thanks to its varied composition in organic substances and mineral elements. Because of the vitamins, minerals and fiber it provides to the body, it occupies an essential place in the diet (Agassounon *et al.*, 2012). Despite its importance, its production remains low in Côte d'Ivoire and it does not cover the needs of the population (Soro *et al.*, 2007). Factors such as poor cultivation practices, agricultural intensification, deplorable rainfall conditions and especially soil infertility explain this low yield (Diallo *et al.*, 2019). Faced with this problem of soil infertility, chemical fertilizers long used by farmers as a solution to soil restoration has unfortunately had adverse consequences on the environment. According to Mulaji (2011), the exclusive use of chemical fertilizers causes an increase in acidity, a degradation of the physical status and a decrease in soil organic matter. In such a context, organic fertilizers represent a suitable substitute for synthetic chemical fertilizers for sustainable soil fertility management. These inputs are a potential source of nutrients (Niang *et al.*, 2014). However, the nature of the composted organic matter and the degree of maturity strongly related to the composting time are therefore the main factors influencing soil fertility and consequently on plant production (Brinton *et al.*, 1995). The diversity of constituents in compost directly influences its mineralization rate and its ability to provide plants with the ability to resist both soil-borne and foliar diseases (Han, 2000). The amount of carbon mineralized during the composting process depends on the origin of the composts and the age of the compost. The higher the C/N ratio of the substrate to be composted, the richer the composting waste is in organic matter and the higher the fertilizing value of the compost (Hafidi, 2011). Given the importance of the nature of the organic matter to be composted and the composting time in the fertilizing value of compost. This study conducted in Daloa (Côte d'Ivoire) aims to determine the best combinations of compost from urban organic waste of the city of Daloa and the composting time favorable to the achievement of quality compost.

Materials and methods

Study site

The study area is located in the department of Daloa, in the Haut-Sassandra region of west-central Cote d'Ivoire. The department of Daloa is located between 6°53'58'' N latitude and 6°26'32''W longitude. The experimental site is located at the University Jean Lorougnon Guédé. This area is subject to four seasons as follows: a long rainy season from April to mid-July, a short dry season from mid-July to mid-September, a short rainy season from mid-September to November and the long dry season from December to March. It is a humid tropical zone with dense forest vegetation. The edaphic heritage is of ferralitic type.

Plant material

The plant material consists of a variety of tomato. It is a local variety called Buffalo. It was purchased from a specialized structure (Semivoire).

Fertilizer material

The organic fertilizer used during the experiment was compost made up of chicken droppings, sawdust, charcoal, rice bran, chapalo residues, Tithonia diversifolia, grass clippings, and household waste.

Preparation of composts

From a common base mixture (C1) consisting of 100 kg of each of the organic fertilizers (chicken droppings, sawdust, rice bran, chapalo and charcoal residues), seven other different composts were added to the C1 base composition. These mixtures allowed us to obtain the different composts which are F1 (C1+household garbage), F2 (C1+Grass clippings), F3

(C1+*Tithonia diversifolia*), F4 (C1+Grass clippings + household garbage), F5 (C1+ *Tithonia diversifolia*, + household waste), F6 (C1+ *Tithonia diversifolia,* + lawnmower), F7 (C1+ *Tithonia diversifolia*, + household waste + lawnmower). These composts were subjected to four composting times. These times are T1 (2 months), T2 (4 months), T3 (6 months) and T4 (8 months). The composts were made using the heap composting method. Maintenance consisted of turning the pile twice a week for the first two months and once a month for the rest of the time. Regular watering of the piles was done.

Experimental setup

The study was carried out in an above ground culture on a surface of 400 m² (25m x 15m). The device used is a split plot with three repetitions divided into three (3) blocks consisting of two (2) factors (types of fertilizer and composting time). Within each block, four (4) sub-blocks were made. Each sub-block corresponding to a treatment represents the different fertilizers from the same composting time. Three different doses (100%, 50% and 25%) were applied to each treatment at a rate of 100 plants per fertilizer. The doses of 100%, 50% and 25% constitute mixtures of the different composts with the soil in which we have respectively 100 kg of composts for 0 g of soil, 50 kg of compost for 50 kg of soil and 25 kg of compost for 0 kg of soil. The different composting times studied are: 2 months, 4 months, 6 months and 8 months.

Data collection

The data were collected on one hundred (100) plants by type of fertilizer and according to the composting time and doses (Table 1). Girth, number of leaves, leaf area and plant height were recorded on each plant from flowering. The fruits were harvested at physiological maturity. It was carried out in a staggered way and was done twice a week. The average weight of the fruits was determined with an electronic scale.

Statistical analysis

All data collected were analyzed using SATISTICA 7.1 software. A two-factor analysis of variance (ANOVA) was performed for each study and on all parameters to show the existence of significant differences between the means. Test significance was determined by comparing the probability (P) associated with the statistic at the α= 0.05 threshold. When a significant difference was observed between the traits, the ANOVA was completed with the Smallest Significant Difference (SSD) test. The LSD allows us to see the homogeneous groups, since it tells us at what level this significant difference occurs.

Table 1. Summary of measurements to be made during the study.

Parameters Agro morphological	Measurement methods
Number of leaves (NL)	Perform by counting
Circumference at the collar (Cc)	Diameter of the part in contact with the ground using a caliper
Height of the plant (HP)	Distance from the collar to the plant apex
Leaf area (LA)	Length of the leaf (cm) x width of the leaf (cm) x k
Number of fruits (NF)	Counting on each foot of the plant
Fruit weight (FW)	Weighing of the fruits with a scale

Results and discussion

Results

Comparison of the different fertilizers according to the agronomic parameters of the tomato All the agronomic parameters studied (Table 2) were significantly influenced by the different compost formulations (P<0.05).

The F5, F6 and F7 composts were the formulations with the highest values for all the agronomic parameters studied. However, formulation F7 stands out from the other two by presenting the best values with (89.15 ± 15.69^{e}) for height, (45.23 ± 10.44^{e}) for number of leaf, (2.3 ± 0.14^{e}) for neck circumference, (2602 ± 21.96^{ef}) for leaf area, (21.11 ± 8.54^{f}) for number of fruit and (59.23 ± 7.98^{f}) for fruit weight. While the low values were obtained with the control. The intermediate values were observed with C1, F1; F2, F3 and F4.

Table 2. Average agronomic parameters measured on tomato according to the different types of fertilizer.

Formulations	Agronomic Parameter					
	HP	Cc	NL	LA	NF	FW
Temoin	57,85±0,021^{a}	1,45±0,098^{a}	12,5±7,65^{a}	385±08,96^{a}	8,36±1,25^{a}	37,22±2,56^{a}
C1	80,83±13,24^{b}	1,73±0,85^{c}	16,32±1,02^{b}	546,8±75,25^{b}	17,02±6,9^{b}	50,11±3,65^{b}
F1	84,02±19,65^{c}	1,75±0,45^{b}	18,63±11,41^{c}	580±14,89^{cd}	19,05±5,88^{c}	53,11±6,85^{c}
F2	80,98±19,56^{b}	1,71±0,35^{b}	16,50±13,85^{b}	577±35,86^{c}	17,11±6,96^{b}	50,96±7,95^{b}
F3	85,65±17,12^{c}	1,77±0,35^{b}	18,45±18,65^{c}	542±28,54^{b}	21,16±4,95^{d}	55,79±6,36^{cd}
F4	85,54±17,21^{c}	1,72±0,14^{ab}	20,45±19,65^{d}	593±29,86^{d}	19,12±2,98^{c}	53,79±9,65^{c}
F5	88,12±12,35^{d}	2,2±0,12^{d}	22,23±10,54^{e}	596±32,89^{e}	23,01±9,89^{f}	58,18±8,89^{de}
F6	87,10±13,01^{d}	2,1±0,23^{c}	22,01±11,85^{e}	589±27,65^{d}	22,23±2,87^{e}	56,87±8,52^{d}
F7	89,15±15,69^{e}	2,3±0,14^{e}	25,23±10,44^{f}	602±21,96^{f}	25,11±8,54^{g}	59,68±7,98^{f}
F	38,21	23,04	18,96	36,65	25,31	18,96
P	0,032	0,0211	0,028	0,011	0,021	0,001

For each trait, values with the same letters on the line are statistically identical. HP: plant height Cir: neck circumference NL: number of leaves LA: leaf area NF: number of fruits, FW: fruit weight; F: ratio of two standard deviations, P: probability

Comparison of the different doses of fertilizers according to the agronomic parameters of the tomato

The studied agronomic parameters were all significantly influenced by the different applied doses ($P<0.05$) (Table 3). For all composts, the 100% doses presented the highest values in all studied parameters. While the low values were observed with the 25% dose. The formulation F7 is the fertilizer so the application at 100% dose obtained the highest values of these parameters followed by F5 and F6. The low results were recorded with the control.

Table 3. Average agronomic parameters measured on tomato according to different fertilizer doses.

Duration	Formulation	DOSE	HP	Cc	NL	LA	NF	FW
		100%	81,78±13,01ab	1,63±,062^{ab}	15,11±1,85^{c}	523±19,86^{b}	17,02±12,9^{c}	51,01±10,65^{c}
	C1	50%	78,69±0,065^{ab}	1,62±0,084^{ab}	14,65±1,96^{bc}	504,15±12,56^{b}	15,85±5,85^{b}	48,36±4,36^{b}
		25%	71,63±9,14^{a}	1,60±1,047^{ab}	13,68±0,048^{ab}	495,63±10,33^{a}	12,58±8,36^{a}	45,5±2,98^{a}
		100%	82,45±12,01^{bc}	1,68±0,25^{ab}	15,63±1,21^{c}	555,32±11,65^{bc}	18,56±1,69^{d}	54,29±12,36^{d}
	F1	50%	76,12±11,52^{ab}	1,61±0,096^{ab}	14,21±2,96^{ab}	530,35±15,86^{bc}	16,85±6,87^{b}	52,99±5,98^{e}
		25%	71,25±15,2^{a}	1,57±0,85^{a}	13,08±1,98^{ab}	493,21±09,63^{a}	15,21±4,21^{ab}	50,32±3,65^{f}
		100%	78,29±0,065^{ab}	1,64±0,45^{cd}	15,02±18,65^{b}	522±14,89^{b}	17,85±05,89^{c}	51,45±16,85^{c}
	F2	50%	78,69±0,065^{ab}	1,63±0,35^{cd}	15,01±3,85^{c}	545,63±7,65^{bc}	16,25±4,25^{b}	48,98±3,6^{b}
		25%	76,11±9,21^{ab}	1,61±0,11^{ab}	14,52±4,01^{b}	501,52±15,63^{b}	12,01±7,69^{a}	45,58±6,38^{a}
		100%	85,02±19,65^{cd}	1,72±0,14^{d}	16,31±2,56^{ab}	577,35±15,86^{c}	18,71±5,36^{d}	56,01±4,25^{g}
	F3	50%	84,65±08,65^{bc}	1,65±0,025^{ab}	13,01±4,05^{ab}	501,12±11,36^{b}	17,25±6,36^{c}	54,36±7,25^{h}
		25%	74,96±13,98^{a}	1,62±0,05^{ab}	12,01±2,16^{a}	403,63±9,63^{ab}	15,98±4,25^{ab}	44,21±6,33^{i}
		100%	80,98±19,56^{b}	1,75±0,23^{b}	15,95±3,65^{c}	542,63±18,54^{b}	18,72±3,65^{d}	54,26±7,95^{h}
	F4	50%	77,54±10,54^{ab}	1,73±0,047^{ab}	15,65±5,78^{c}	500,77±15,96^{b}	17,9±5,96^{bc}	52,24±3,61^{e}
		25%	71,21±8,41^{a}	1,71±0,052^{b}	12,25±4,02^{a}	401,65±10,95^{a}	15,89±6,35^{b}	50,25±11,36^{f}
		100%	88,12±12,35^{d}	1,82±0,25^{cd}	17,23±5,54^{b}	596±12,89^{c}	20,10±1,95^{f}	58,41±5,89^{k}
	F5	50%	85,02±19,65^{cd}	1,77±0,12^{bc}	14,31±4,05^{ab}	510,52±15,96^{ab}	18,1±6,58^{d}	56,12±11,65^{g}
		25%	77,01±11,4^{ab}	1,58±0,014^{a}	12,01±2,16^{a}	412,63±88,96^{a}	16,25±1,15^{b}	45,65±9,85^{a}
		100%	87,10±13,01^{c}	1,81±0,35^{de}	16,88±1,85^{cd}	560,27±17,65^{b}	19,01±1,69^{e}	57,41±5,89^{j}
	F6	50%	84,32±10,54^{bc}	1,74±0,09b	14,41±2,16^{ab}	507,8±20,48^{ab}	17,95±6,87^{c}	54,58±3,96^{h}
		25%	77,08±8,36^{ab}	1,58±0,12^{a}	13,23±1,41^{a}	489±101,63^{a}	16,5±4,21^{b}	48,53± 9,6^{b}
		100%	89,15±15,69^{e}	1,85±0,14^{e}	19,44±5,36^{e}	602±21,96^{e}	23,04±7,54^{g}	60,38±7,98^{k}
	F7	50%	85,54±17,21^{cd}	1,82±0,25^{cd}	18,01±6,52^{d}	589,25±53^{cd}	20,11±6,39^{f}	57,06±3,52^{j}
		25%	78,69±0,065^{ab}	1,77±0,65^{bc}	17,98±8,21^{a}	563,74±120,87^{d}	17,25±5,69^{c}	50,96±3,25^{f}
	F		8,99	369,87	6,37	9,15	3,27	10,23
	P		0,001	0,001	0,001	0,001	0,001	0,001

For each trait, values with the same letters on the line are statistically identical. HP: plant height Cir: neck circumference NL: number of leaves LA: leaf area NF: number of fruits, FW: fruit weight; F: ratio of two standard deviations, P: probability

Comparison of composting time of F7 compost according to agronomic parameters of tomato

Table 4 shows the results of the different composting times on the agronomic parameters. It can be seen that all agronomic parameters were significantly influenced by the different composting times (P < 0.05). Both the 6 and 8 month composting durations obtained statically identical values. Furthermore, both also recorded the highest values for each parameter studied. The lowest values were obtained with the 2 months composting duration. However, the average values were observed with the 4 months duration.

Table 4. Average agronomic parameters measured on tomato according to different composting times.

	Agronomic parameter					
Formulation	HP	Cc	NL	LA	NF	FW
2 MONTHS	$62{,}07 \pm 14{,}95^{a}$	$1{,}47 \pm 0{,}84^{a}$	$12{,}8 \pm 2{,}6^{a}$	$232{,}7 \pm 83{,}25^{a}$	$10{,}01 \pm 4{,}28^{a}$	$42{,}3 \pm 4{,}23^{a}$
4 MONTHS	$86{,}77 \pm 15{,}36^{bc}$	$2{,}3 \pm 0{,}52^{b}$	$24{,}99 \pm 3{,}56^{b}$	$400{,}3 \pm 85{,}96^{b}$	$23{,}54 \pm 2{,}65^{b}$	$58{,}53 \pm 5{,}65^{b}$
6 MONTHS	$88{,}83 \pm 13{,}24^{c}$	$2{,}45 \pm 0{,}85^{c}$	$30{,}32 \pm 1{,}02^{c}$	$550{,}8 \pm 75{,}25^{c}$	$27{,}52 \pm 6{,}9^{c}$	$67{,}23 \pm 3{,}65^{c}$
8 MONTHS	$88{,}71 \pm 11{,}56^{c}$	$2{,}44 \pm 0{,}45^{c}$	$29{,}98 \pm 2{,}5^{c}$	$548.56 \pm 60{,}74^{c}$	$27{,}14 \pm 7{,}87^{c}$	$67{,}02 \pm 4{,}65^{c}$
F	4,91731	0,21166	23,78713	18,61055	15,59482	11,15769
P	0,026	0,045	0,01	0,019	0,002	0,00

For each trait, values with the same letters on the line are statistically identical. HP: plant height Cir: neck circumference NL: number of leaves LA: leaf area NF: number of fruits, FW: fruit weight; F: ratio of two standard deviations, P: probability

Discussion

Influence of the composition of the different composts on the agronomic parameters of the tomato

The formulation F7 obtained the best values for all the agronomic parameters studied. This could be explained by the strong presence of lignins in the plants that accelerate their maturation. These results are similar to those of Cedric *et al.* (2003) who confirm that lignins play a very important role in the theory of humification. They are considered as a possible source of humic substances. Cobat *et al.* (1998), confirm that lignin is a precursor of humic substances. Moreover, plant debris is richer in organic matter than household waste. Indeed, the C/N ratio of plant debris is higher than that of household waste. However, the higher the C/N ratio, the richer in organic matter the composted waste is Chitsan *et al.* (2008). Composts resulting from the combination of plant debris and household waste thus have a high fertilizing power compared to those having received these inputs individually. Similarly, Goyal *et al. (*2005) stated that humification is slower for composts derived from household waste than for composts from plant debris. The high nitrogen, phosphorus and potassium contents of F7 are also responsible for the better results obtained with this one. These results corroborate those of Yin *et al. (*2012) who showed that nitrogen availability promotes height growth of plants. Potassium and phosphorus are also involved in stimulating growth via leaf elongation (Hopkins *et al.*, 2003) thus promoting vegetative development of the tomato plant. The low phosphorus, potassium and nitrogen contents obtained with C1 and F2 are responsible for the poor vegetative development observed with these formulations. Jordan-Meille *et al. (*2004) attest that a low content of these elements would slow down the growth by reducing the leaf surface.

Moreover, the C/N values lower than 25 (C/N < 25) obtained with F5; F6 and F7 justify the strong fertilizing power of these composts. These results corroborate those of Roletto *et al. (*1985) who indicate that a C/N ratio lower than 25 is favourable to plant development. For these authors, the carbon to nitrogen ratio is an indicator of the capacity of an organic product to decompose. If this C/N ratio is higher than 25 (C/N >25), the microorganisms will draw nitrogen from the soil reserves instead of releasing it. On the other hand, a C/N ratio lower than 25 (C/N <25) favors the release of nitrogen, making it available to the plant. The low values obtained with the control indicate that the absence of organic matter is accompanied by an acidification of the soil, a reduction of the biomass and a weak microbial activity. All this will result in a decrease in crop yields.

Influence of the dose of the different composts on the agronomic parameters of the tomato

The different doses applied during this study all significantly influenced the parameters analyzed. The 100% and 50% doses of F7 compost obtained the highest values. This result would be due to the good maturity of F7. These results corroborate those of Larbi *et al. (*2006), which show that the quality of the composts and the doses applied directly influence the agro-morphological performance of the crops. Indeed, the trials of incorporation of compost in the substrate of tomato culture at different dose induce a clear improvement of the quantitative but especially qualitative parameters of plants. According to Fuchs *et al. (*2003), compost influences the living conditions, improves the stable humic complex, soil structure, aeration and mineralization of fertilizing elements. According to Mouria *et al. (*2010), a good organic matter content of compost has a synergistic effect with fertilizing elements. However, the low values obtained with the application of 25% of F7 compost compared to the 50% and 100% doses would be due to the increase of salinity in the crop substrate. The high salinity levels in the 50% and 100% dose substrates would be compensated by the high organic matter content.

This high amount of organic matter would promote an increase in water holding capacity that would allow good plant growth (Chen and Inbar, 1993). In addition, substrates containing 25% F7 would be poor in nutrients. According to Kitabala *et al. (*2016), if the amount of fertilizer elements provided by the organic matter is less than the crop needs, then a decrease in yield occurs. This yield decrease would be due to the fact that the nutrient reserves provided by this dose would be insufficient to ensure good growth and production of the tomato crop.

Influence of composting time (F7) on agronomic parameters of tomato

The agronomic parameters studied were significantly influenced by the composting time. The best results were observed with composting times of 6 and 8 months. This result would be due to the fact that these composts would be more mature than those of two (2) and four (4) months. These results corroborate those of Hartmann *et al. (*2003), who argue that the use of mature composts significantly improves aggregate stability. This stability improves the soil structure, increases its porosity and contributes to a decrease in density by promoting good water infiltration (Timmermann *et al.*, 1999). Similarly, Larbi *et al. (*2006) state that the quality of compost, i.e. its maturity, directly influences the agro-morphological performance of the plant. The pH values obtained (8.01 and 8.03) with the duration of composting (6 and 8 months) are also significant elements revealing the good maturity of these composts. According to Ondo (2011) and Ognalaga *et al. (*2015), these high pH values are a major asset for a better root absorption of nutrients. Indeed, in the presence of the high pH values, exchangeable bases ($ca2+$, $Mg2+$, $K+$, $Na+$) bind to the absorbent complex of the soil thus reducing the number of adsorbed $H+$ ions that are sources of soil acidity (Ye, 2007). These pH values would therefore provide favorable conditions for improving the biological properties of the soil and making the cations contained in these composts available to tomato plants (Temgoua *et al.*, 2012).

However, the low values obtained with the composting time of 2 months would be caused by the immaturity of the compost. According to Cedric *et al. (*2003), acidic pH values are characteristic of immature composts. A high C/N ratio (C/N>30) immobilizes soil nitrogen at the profile of microorganisms that use it to degrade woody substances. The nitrogen is therefore blocked for a certain period in the biological process. The tomato plants have no more available nitrogen and are therefore deficient (Labri *et al.*, 2006).

Conclusion

The physico-chemical parameters of the composts studied all evolved with the composting time. The nature of the substrate to be composted significantly influenced the fertilizing value of the composts studied. The F7 compost (chicken droppings, sawdust, rice bran, chapalo residues, charcoal, *Tithonia diversifolia*, household waste and grass clippings) presented the best fertilizing properties. The application of F7 at the 100% dose was more beneficial for the tomato plant. In addition, the composting time for this maturity is 6 months. For a better tomato yield, it would be possible to propose to the farmers the use of F7 compost applied to the local variety (Buffalo).

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Competing interests

Authors have declared that no competing interests exist.

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