Compost made from cow dung and sawdust improves the physicochemical and biochemical properties of the soil, the production and the nutritional quality of tomatoes (*Lycopersicon esculentum* Mill.)

Abstract

The effect of a compost based on cow dung and sawdust on the production and nutritional quality of tomatoes was evaluated. The compost was prepared by mixing the different constituents in variable mass/mass proportions: 25/75, 50/50, 75/25 and 100/0. The experimental device for growing tomatoes in pots was made in completely randomized random blocks with 5 repetitions, and 3 compost/soil mass/mass proportions (5%, 10% and 15%) for each variant. The physicochemical, biological and biochemical parameters of the compost and amended soils, the production and the nutritional quality of the fruits were evaluated. The C3 variant of compost showed the highest pH (9.88 ± 0.01); C4 presented the highest C/N ratio (21.45 ± 0.42); C2 showed the highest contents of nitrogen, phosphorus, magnesium, calcium, potassium, and sodium, the highest values of bacterial and fungal flora and cellulase, protease, β-glucosidase, acid and alkaline phosphatase activities. Analysis of amended soils showed that: C2 (15%) has the highest pH). C1 (10%) presented the highest C/N ratio (42.12 ± 3.98) and C3 (15%) the highest contents of nitrogen, magnesium ions and calcium. C4 (15%) presented the highest potassium and sodium content. The compost significantly improved tomato production. The C2 (15%) compost was the most productive with 154 ± 3.00 fruits, 10.26 times more than the tomato produced with chemical fertilizer (15.00 ± 1.00 fruits). The Biological tomato showed higher proportions of ash, total sugars, lycopene, vitamin C and polyphenols than the chemical tomato. The results show that the organic treatment improved the physicochemical and biochemical properties of the soil, the production and the nutritional quality of the tomato, which constitutes an efficient method for sustainable agriculture.

Keywords: Tomato, Cow dung, Sawdust, Compost, Biological, Nutritional Quality.

1. Introduction

Malnutrition is the consequence of poverty, hunger, war and natural disasters and more than a billion people suffer from malnutrition **(Cederholm et *al*., 2019)**. In Africa, the estimated number of undernourished people increased from 784 million in 2015 to 821 million in 2017, an increase of 4.5%. In 2017 worldwide, malnutrition affected 151 million

children and 51 million children under five suffered from weight loss **(FAO et *al*., 2020)**. Micronutrient deficiencies have been identified as major public health problems affecting a large part of the world's population, with pregnant women and children under 5 being most at risk **(Manjeru et *al*., 2019)**. On the other hand, many other diseases are known to be associated with malnutrition, such as stroke, Parkinson's disease, mouth and throat diseases. One of the main causes of malnutrition is deficiencies in the minerals: calcium, iodine, iron, selenium, zinc and vitamins such as folate and vitamin A **(WHO and UNICEF, 2017; Galani et *al*., 2020)**. Micronutrients play an important role in human health and can retard growth and cognitive development, impair immunological functioning and increase the risk of non-communicable diseases including skeletal, cardiovascular and metabolic disorder (**Galani et *al*., 2020**). Additionally, it has been reported that approximately half of all anaemias are attributable to iron deficiency depending on geographic environment and disease (**Darnton-Hill and Mkparu, 2015**). One of the main ways to reduce malnutrition could be to increase food intake and grow fruits and vegetables that are rich in micro and macronutrients like tomato, okra, carrot, eggplant, chilli, pepper and tomato (**Dhaliwal et *al*., 2017**).

Tomato *(Lycopersicon esculentum* Mill.) is a plant of the Solanaceae family. This is a fleshy fruit originating from Peru whose world agricultural production is around 18,230,135 tonnes with a yield of 188t/h (**FAOSTAT, 2020**). Cameroonian tomato production stands at 1,279,853 tons with a yield of 12.1 t/h (**FAOSTAT, 2020**). Tomato is an important source of vitamins: A, B3, B6, E and K, minerals and trace elements (copper, manganese, potassium), antioxidants (lycopene) and dietary fibre. A good diet rich in fruits and vegetables has been proven to be an important factor in reducing the risk of cardiovascular disease. The tomato is important in the prevention of prostate and pancreatic cancers, it contains the four major carotenoids (α and β-carotene, lutein and lycopene) and the three powerful antioxidants (β-carotene precursor of vitamin A, vitamins C and E), each of them being beneficial individually, and in groups, they form a synergy (**Keatinge, 2012**). However, its culture faces many parasitic attacks and poor soils, which leads producers to resort to the use of pesticides and synthetic fertilizers. Moreover, current production systems facing high pest pressure in Africa mainly rely on the year-round use of pesticides (**Mottes et *al*., 2017**) that can harm the environment and human health (**Aktar et *al*., 2009**). On the other hand, there are other types of plant treatment that do not cause harm to humans or the environment, but allow good growth and resistance to disease. These treatments being of plant and animal origin are found

in abundance in nature. **Diatité et *al*., (2020)** demonstrated the positive effect of the use of organic fertilizers on tomatoes. According to (**Noumeni, 2016**), inputs of plant origin promote the improvement of agronomic and morphological parameters of fruits. Studies have also shown that the use of composts made from green waste and wood ash as biological inputs in soybean cultivation improve the physicochemical and microbiological parameters of the soil (**Bougnom et *al*., 2020**). It has also been proven that compost made from household waste improves tomato growth parameters and protects it against diseases (**Btissam et *al*., 2010**). Thus, the objective of this study was to evaluate the effect of compost based on cow dung and sawdust on the physicochemical and biochemical properties of the soil, the production and the nutritional quality of the tomato.

2. Materials and methods

2.1. Materials

2.1.1. Biological and soil material

The basic material for the production of compost consisted of cow dung collected at the cattle market in Etoudi (Yaoundé-Cameroon) and sawdust collected in a carpentry in Emana (Yaoundé-Cameroon). The soil samples used were collected in the locality of Nkolbisson (Yaoundé-Cameroon). The Roma VF variety tomato seed used was purchased at the Mfoundi market (Yaoundé-Cameroon), as well as the chemical fertilizer (NPK 10-11-18).

2.2. Methods

2.2.1. Compost preparation

The cow dung and sawdust were dried in the shade for 4 weeks then stripped of their impurities then ground in the mill before being sieved (2mm mesh). The powders were mixed to facilitate the decomposition process when composting in pots at different proportions (w/w) with 5 repetitions each.

Composting was done in closed containers in an aerobic environment for three months inside the greenhouse. The experiment was conducted according to a random experimental design in completely randomized blocks and with the following proportions of cow dung/sawdust w/w: 100/0, 75/25, 50/50 and 0/100. To monitor the progress of the composting process, the following activities were carried out at the composting site: visual observation and turning. After 3 months of composting, the mature composts obtained were subdivided into two parts: the major part was used for soil amendment and the rest was sieved and then dried in the open air for physicochemical, biological and biochemical characterization.

2.2.2. Characterization of the compost produced and the soil/compost mixture

2.2.2.1. Measurement of pH and electrical conductivity

• Determination of pH and electrical conductivity

The pH was measured after dissolving 5g of the sample in 25 ml of distilled water. The method used consisted of preparing a suspension the dried substrate, diluted in 5 times its volume of water (1/5), leaving it to stir for 5 minutes and then letting it rest for at least two hours. The pH reading is made using a pH meter (**M'sadak, 2013**).

• Measurement of electrical conductivity

20g of each sample was taken to which 100 ml of distilled water was added. The solutions were stirred for 30 minutes and then filtered. The specific electrical conductivity of the filtered extract was measured using an HQ 14d brand conductivity meter (HACH).

2.2.2.2 Determination of total organic matter (TOM), total organic carbon (TOC) and total nitrogen (Total N)

• Determination of organic matter and carbon dosage

The determination of total organic matter (TOM) and total organic carbon (TOC) were made according to the method of **M'sadak (2013**). 20g of each substrate were weighed and the samples were put in the oven for 24 hours at 70°C; the calcination of 3g of the sample, previously dried in an oven, at 900°C for at least 6 hours in a muffle furnace was carried out and the determination of the dry residue or mass after calcination was carried out. The TOM content was determined according to the following equation:

$$TOM\ (\%) = ((M1 - M2) / M1) \times 100$$

With M1: Mass before calcination (mg); M2: Mass after calcination (mg).

From the OM, a deduction of the Total Organic Carbon (TOC) content was made by applying the following relationship:

$$TOC\ (\%) = (MO\ (\%) / 1.8) \times 100$$

• Determination of total nitrogen content (Total N)

The total nitrogen content was determined by the Kjeldahl method by mineralization of the sample of mass equal to 5g by concentrated sulfuric acid in the presence of a catalyst (selenium) at 400°C for 2 hours; alkalization of the reaction products was then carried out with a NaOH solution with a concentration of 400 g/l; distillation and titration of the ammonia released were carried out in the last step using a sulfuric acid solution with a concentration equal to 0.05M (**Eaton et *al*., 2005**).

• Determination of the C/N ratio

The C/N ratio was calculated from the organic carbon and nitrogen values according to the formula:

$$\frac{C}{N} = \frac{\text{Organic Carbon \%}}{\text{Total Nitrogen \%}}$$

2.2.2.3. Determination of phosphorus (P) and potassium (K) concentrations

• Phosphorus concentration

The total phosphorus content was determined by the so-called "molybdovanadate" method (**Eaton et *al.*, 2005**). 1 ml of molybdovanadate reagent was added to 25 ml of each previously digested sample. A control consisting of distilled water followed the same treatment. When orthophosphate molecules are present, they react with molybdate in an acidic medium to form the phosphomolybdate complex. In the presence of vanadium, vanadomolybdophosphoric acid which has a yellow colour is formed. The intensity of the colour is proportional to the concentration of phosphates present in the medium. The reading of the optical density was made with a spectrophotometer at the wavelength of 650 nm. The values were presented in the form of orthophosphate (PO_4^{3-}) and expressed in mg/l.

• Potassium concentration

To 25 ml of sample contained in a test tube, were successively added the contents of a capsule of reagent potassium 1 and potassium 2. The mixture was stoppered and homogenized. To the clear solution was added the content of one capsule of potassium reagent 3. After 30 seconds of stirring, the solution obtained was transferred to a 25 ml cell. Another cuvette (the blank) was filled with 25 ml of sample. The reading of the optical density was made with the DR/3900 spectrophotometer at the wavelength of 650 nm. The result was expressed in mg/l.

2.2.2.4. Assay of exchangeable cations (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) and heavy metals

The determination of the content of macroelements and microelements of the different variants of the compost and in the soil was made after the mineralization of the samples. The solutions were prepared by mixing 0.2 g of sample with 4 ml of sulfuric acid (H_2SO_4) 95%. These solutions were then incubated for 5 minutes in a HACH brand digestahl mineralizer, first at low temperature, then by gradually increasing the temperature to 440°C until the mixture cleared. During the incubation, between the 3rd and 4th minute (after boiling), 10 ml of hydrogen peroxide (H_2O_2) was gradually added using a syringe. The mineralized material thus obtained (5 ml) was reduced to 70 ml in a volumetric flask with distilled water. The

Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Pb, Zn, and Cu concentrations were then determined according to standard protocols using a DR 3900 brand spectrophotometer.

2.2.2.5. Determination of fungal and bacterial biomass

• Enumeration of fungal flora

Analysis of the microflora was carried out using the suspension-dilution technique **(Rapilly, 1968)** on agar medium, Sabouraud dextrose agar (SDA) medium supplemented with an antibiotic (gentamicin). In a 250 mL Erlenmeyer flask containing 90 mL of sterile distilled water was aseptically added 10 g of dry compost (after drying at 30°C overnight). This mixture was agitated for 30 minutes to suspend the particles of Compost as well as the spores which were attached to it. The suspension obtained corresponds to the 10^{-1} dilution. Then decimal and successive dilutions were made up to 10^{-8}. 0.1 mL of each dilution was inoculated onto the culture media contained in Petri dishes and incubated at 26° C. for three days.

• Enumeration of bacterial flora

The determination of the total bacterial flora was carried out using the suspension-dilution technique on nutrient agar added to an antifungal (0.5% nystatin). 5g of each sample were placed in a 100 mL Erlenmeyer flask containing 45 mL of sterile physiological water (9g of NaCl/L in 1000 mL of distilled water) and suspended using a magnetic stirrer for 30 minutes. The suspension was then decanted for 20 minutes, then the supernatant was removed, and it constituted the 10^{-1} dilution. From this suspension, decimal dilutions were made up to 10^{-8}. 0.1 mL of each dilution was inoculated onto the culture media contained in Petri dishes and incubated at 26° C. for three days.

The determination of the microbial load was made by counting the colonies and the results expressed in CFU/g of soil according to the formula:

$$N = \frac{\Sigma \text{ colonies} \times Fd1}{Vml \times (n1 + 0{,}1n2)}$$

N: Number of CFU per gram of soil; Σcolonies: Sum of the colonies of the interpretable boxes; V: Volume of deposited solution (1ml); n1: Number of boxes considered at the first dilution retained; n2: Number of boxes considered at the second dilution used; Fd1: Factor of the first dilution retained.

2.2.2.6. Determination of enzymatic activities

• Cellulase activity

The cellulase activity was determined by the method described by **Tabatabaï (1994)**. The enzymatic unit (U) was expressed in g of reducing sugars released per hour. The enzymatic activity (A) corresponds to U/g of compost or soil.

• Protease activity

Protease activity was determined using the method described by **Tabatabaï (1994)**. The enzyme unit (U) is expressed in mg of amino acid released over 2 hours. The enzymatic activity (A) corresponds to U/mg of compost or soil.

• The activity of β-glucosidase

The activity of β-glucosidase was evaluated respectively according to the method of (**Eivazi and Tabatabai, 1988)**. A sample of compost (1 g) was placed in a 50 ml Erlenmeyer flask and treated with 0.25 ml of toluene, 4 ml of MUB (pH 6.0) and 1 ml of the glucoside solution. The flask was shaken for a few seconds to mix the contents, capped and incubated at 37°C. After 1 h the stopper was removed and 1 ml of 0.5 M $CaCl_2$ was added, mixed and treated with 4 ml of 0.1 M THAM, pH 12. The flask was shaken and the compost suspension was filtered through a Whatman N^o 2 folded filter paper. The absorbance of the solution was measured using a Klett-Summerson photoelectric calorimeter equipped with a N^o 4 filter. The maximum absorbance of the measured colour is located at 400 nm.

• Dehydrogenase activity

Dehydrogenase activity was determined by the method described by **Tabatabaï (1994)**.

• Alkaline and acid phosphatases

The phosphatases activities were evaluated by the method developed by **Eivazi and Tabatabai (1988).** Enzyme activity was measured using 1 g of compost or compost-soil mixture and 5 mL of pH 5 or pH 9 buffer containing 10 mM p-nitrophenyl phosphate. After incubation for one hour at 37°C, 1 mL of a 0.5 M $CaCl_2$ solution and 4 mL of 0.5 M NaOH solution was added to the reaction medium. Reading of the optical density at 405 nm of the released p-nitrophenol ($\varepsilon M=1.9\times104\ M^{-1}\ cm^{-1}$) was performed after centrifugation for 10 min at 10,000 rpm. The results were expressed in units per gram of dry matter ($U.g^{-1}$ DM), one unit corresponding to the number of μmoles of p-nitrophenol released per minute. A standard range of p-nitrophenol was produced in each of the two buffers.

2.2.3. Evaluation of the effect of compost on growth parameters and tomato production

2.2.3.1. Creation of the nursery and cultivation of tomatoes

The nursery (seeds of the tomato variety "Roma VF") was carried out in 3 trays containing 15kg of soil/sand sterilized for 21 days with a watering frequency of twice a day. Tomato cultivation was carried out in pots at the University of Yaoundé 1 for 110 days with a watering frequency of twice a day.

2.2.3.2. Soil amendment

The previously sterilized soil was amended as follows, then watered and left to rest for 24 hours and the transplant was carried out 21 days after transplanting (DAT): Positive control (soil amended with NPK 10-11-18 fertilizer), Negative control (soil without amendment). Each component of the compost was mixed into the soil in the proportions 5%, 10% and 15% (w/w).

2.2.3.3. Transplanting the tomato

After soil amendment, the pots were watered and left to rest for 24 hours. The tomato plants were then transplanted individually into the pots and the latter were randomly arranged in completely randomized blocks. The frequency of watering the pots was twice a day (morning and evening) and the harvesting of fruits took place according to maturity.

2.2.3.4. Evaluation of growth parameters of tomato plants and fruit production per plant.

• Determination of growth parameters

The following parameters were determined on the tomato plants each week after transplanting for 42 days: the number of leaves, the height of the plants, the length and width. The leaf area (S) was obtained from the length (L) and the width (l) according to the following formula: Leaf area (Cm^2) = L (Cm) x l (Cm) x K; avec K= 0.72 **(Derkaoui, 2011)**.

• Production evaluation

During tomato cultivation, the number of flowers and fruits was determined by counting 70, 90, and 110 days after transplantation (DAT). The number of ripe fruits was evaluated and their average masses were determined 90 and 110 DAT.

2.2.4. Evaluation of nutritional quality

Three batches of tomatoes (Biological tomato, Chemical tomato, and Market-bought tomato) were washed with distilled water. They were cut into small dice, and a part was reduced to a puree using a blender and stored at -80°C for the analyses of the content of total sugars, vitamin C and lycopene. The other part was dried and then reduced to powder using a mortar and stored in a polyethylene tube at room temperature for the analyses of the other parameters (ash, phenolic compounds, total lipids, crude fibres and minerals

• Determination of water content

The dry porcelain capsule was weighed (Po) using a balance as well as 5g of fresh sample (P1). They were dried in a "Memmert" brand oven at a temperature of 105°C. Weighing was done regularly until a constant weight was obtained. The dry residue was cooled in the atmosphere of a desiccator containing P_2O_5 as a desiccant for 1 hour and weighed (P2). The water content is the average of the contents of the three tests determined according to the following formula:

$$\text{Water content} = \frac{P_1-P_2}{P_1-P_0} \times 100$$

The results were expressed in g per 100 g of fresh material.

• Determination of ash content

A porcelain capsule, carefully washed and rinsed with distilled water and 1% nitric acid, was dried in an oven at 65°C for 1 hour. It was then placed in a "VECSTAR" brand oven at 550° C. for 3 hours to destroy all traces of organic matter. On leaving the oven, it was left to cool in a desiccator for 1 hour. Its weight (P1) was determined. Exactly 3 g of dry matter (P0) of the sample was placed in the dish. The whole was put in the oven at 550°C for 48 hours. On leaving the oven, the capsule containing the ash was left to cool in a desiccator and its weight P2 was determined. The ash content is the average of three determinations and is given by the following relationship:

$$\text{Ash content} = \frac{P_2-P_1}{P_0} \times 100$$

The results were expressed in g per 100 g of dry matter.

• Determination of the hydrogen potential "pH"

Fruits were cut into small pieces and then mashed in a mortar. The pH meter was calibrated successively with buffer solutions of pH 4, 7 and 10. The pH was read at 20° C by immersing the electrode in the sample solution.

• Density determination

According to **James (1980)**, the density is obtained by calculating the quotient of the density of a solution of the same density of distilled water at 20°C. The pycnometer was weighed empty (m0). It is then filled with distilled water. Before weighing, the water level

was adjusted to the gauge line after plugging the pycnometer. After this operation, a solution of the powder obtained was prepared and after filtration, the solution obtained was replaced by distilled water and then weighed.

The density was calculated by the following formula:

$$\text{Density} = \frac{m2 - m0}{m1 - m0} \; X \; 100$$

m0: mass in grams, of the empty pycnometer, m1: mass in grams, of the pycnometer filled with distilled water, m2: mass in grams, of the pycnometer filled with tomato solution

• Dosage of total sugars

In a beaker containing 100mg of sample powder, 10ml of a hydro-alcoholic mixture (1/10 v/v) was introduced; the whole was homogenized for 10 minutes then filtered and evaporated at room temperature. The filtrate obtained was used for the assay. From a standard solution of glucose 1mg/ml, volumes of 0.07; 0.14; 0.21 and 0.28 ml were pipetted and introduced into 10 ml tubes. Then, 0.3 ml of 5% phenol was added as well as 1.8 ml of sulfuric acid; the volumes were then completed with distilled water. The optical densities of the solutions thus obtained were read on a spectrophotometer at 490 nm against blank. In the test tube, 1 ml of hydro-alcoholic extract was then added to 0.4 ml of distilled water and 0.3 ml of phenol 5% (w/w) then the whole was mixed with 1.8 ml of sulfuric acid. In the white tube, was introduced 0.4 ml of distilled water, 0.3 ml of 5% phenol and 1.8 ml of concentrated sulfuric acid. The optical densities were immediately read on a spectrophotometer at 490 nm.

Sugar mass = Sugar content x Material fresh mass

• Dosage of total lipids

The total lipids were extracted with a Soxhlet using the method described by **Goodon (1997)**. The filter papers were dried in an oven at 105°C for 3 hours, and then the weights (PF) were recorded. 2 g of dry samples were weighed and placed in the filter papers, and then the whole was left to dry in an oven for 24 hours. At the end of the drying, the whole was weighed and the weight (PA) was noted. The filter papers containing the samples were then placed in the Soxhlet for 12 hours for the extraction of oils. 12 hours later, the samples were removed from the extractor and dried in an oven at 105°C for 3 hours and the weight (PE) was noted. The results are expressed in g per 100 g of dry matter. The amount of total lipids was determined according to the formula:

$$\% \text{ Total lipids} = \frac{P_A - P_E}{P_A - P_F} \times 100$$

Total lipids mass = Total lipids content x Dry mater mass

• Dosage of phenolic compounds

The phenolic compounds contents of each sample were determined with a reference antioxidant (gallic acid). The content of phenolic compounds in our extracts was calculated from a linear calibration curve (y = ax + b) established with accurate concentrations of gallic acids as a reference standard, under the same conditions as the sample. The phenolic compound content of each sample was obtained by projecting its absorbance on the calibration line produced with gallic acid.

• Dosage of lycopene

15 g of fresh samples were introduced into 25 ml of solution (hexane-acetone-ethanol, (50/50/1). After stirring for 10 min, centrifugation at 10,000 revolutions per min for 30 min was carried out. 1 ml of the organic phase was then extracted and diluted in 10 ml of hexane. In a cell, a sample of the organic phase was introduced and the absorbance was measured at 472 nm. The lycopene content was calculated according to the formula:

$$C(\mu g/g) = \frac{\text{Abs } 472 \times Fd \times 106 \times V}{3450 \times 100 \times P}$$

Fd: Dilution factor, V: Volume of extraction solvent, 3450: Extinction coefficient of hexane, P: Weight of test sample

• Dosage of crude fibres

1 g of delipidated dry matter (P1) was introduced into a 200 ml beaker and 100 ml of 0.26 N sulfuric acid was added. The mixture was heated at 100°C for 30 min, then filtered and washed 3 times with distilled water. Then, 100 ml of 0.23 N KOH was added and the whole was heated for 30 min, then the contents were filtered and washed 3 times with distilled water and 2 times with acetone. The contents of the beaker were dried in a porcelain dish at 105°C for 8 h, then left to cool in the desiccator and weighed (P2). The capsule was then placed in an oven at 500° C. for 3 hours then cooled in a desiccator and weighed (P3). The results were expressed in g per 100 of dry matter according to the formula:

$$\text{Crude fibres content} = \frac{P_2 - P_3}{} \times 100$$

$$\overline{\overline{P_1}}$$

The amount of crude fibre was determined according to the formula:

Crude fibres mass = Crude fibres content x Dry material mass

• Dosage of vitamin C

10 mg of samples were crushed in a mortar and 10 ml of distilled water was added to it. The mixture obtained was homogenized and then centrifuged at 6000 rpm for 10 minutes. The filtrate was collected in a tube. For the test, 1 ml of filtrate was pipetted into a 10 ml tube followed by 0.2 ml of 10% hydrochloric acid and the volume was made up of deionized water. For the blank, 2 ml of distilled water and 0.6 ml of the 1 M sodium hydroxide solution were added to a 10 ml tube. 12 minutes after shaking, 0.6 ml of 10% hydrochloric acid was added and the volume made up of deionized water. The vitamin C concentration of each sample was obtained by projecting its absorbance onto the calibration line. The concentration was expressed in mg per 100 g of fresh sample.

• Determination of Ca, Mg, K, Na, Fe, Mn and Zn content

The determination of the calcium, magnesium, potassium, sodium, iron, manganese and zinc content was done by flame atomic absorption spectrophotometry **(Benakmoun et *al.*, 2008)**. For the determination of the macroelements (Ca, Mg, K, Na), 0.5 ml of each supernatant was diluted in 19.5 ml of strontium chloride solution. For the determination of trace elements (Fe, Mn, Zn), the supernatant was not diluted, approximately 10 ml were used. 2 tubes containing the same quantities of products as all the other tubes were filled with deionized water for each dosing series. Standards, samples and blanks were then passed through a flame atomic absorption spectrophotometer. The calibration line of each standard made it possible to determine the concentration (mg/100g DM) of each mineral by a projection of the absorbances on the corresponding curves.

• Determination of phosphorus content

Phosphorus content was determined by colourimetric spectrophotometry **(Murphy and Riley, 1962)**

• Determination of heavy metal content

The copper (Cu), lead (Pb), and zinc (Zn) content was determined by atomic absorption spectrophotometry according to standard protocols.

2.2.2.6.3. Statistical analysis of results

The results obtained were subjected to statistical analysis for the calculation of means, standard deviations and the search for significant differences using SPSS 23.0 software. The one-way ANOVA test coupled with the Student-Newman-Keuls test was used to assess the Least Significant Difference (LSD) at $P < 0.05$.

3. Results and discussion

3.1 Results

3.1.1. Characteristics of the compost produced

The physicochemical characteristics of the different variants of compost C1, C2, C3 and C4 were determined. Table I below presents the characteristics of the different variants of the compost produced.

Table I: pH, EC, Corganic, N total, C/N, Ptotal, concentrations of exchangeable ions (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) and heavy metals (Pb, Zn, Cu) of compost variants C1, C2, C3 and C4.

Characteristics	T	C1	C2	C3	C4
pH	5.40 ± 0.14^{f}	9.74 ± 0.03^{d}	9.83 ± 0.01^{d}	9.88 ± 0.01^{d}	9.85 ± 0.00^{d}

EC (mS/cm)	0.19±0.01^{ab}	0.57±0.03^{a}	0.63±0.00^{ab}	0.54±0.02^{ab}	0.51±0.01^{ab}
C (g/kg)	3.53±0.19^{e}	32.30±0.82^{e}	40.30±1.41^{f}	34.97±0.62^{e}	31.47±1.03^{e}
Total N (g/kg)	0.89±0.02^{c}	1.63±0.05^{b}	2.83±0.05^{c}	1.67±0.05^{c}	1.47±0.05^{b}
C/N	3.97±0.27^{a}	19.77±0.28^{c}	14.21±0.25^{b}	20.99±0.64^{d}	21.45±0.42^{d}
P (g/kg)	0.10±0.00^{a}	0.54±0.00^{a}	0.67±0.02^{ab}	0.62±0.01^{ab}	0.52±0.01^{ab}
Mg^{2+} (g/kg)	0.05±0.00^{a}	0.09±0.00^{a}	1.07±0.09^{abc}	0.07±0.00^{a}	0.06±0.00^{a}
Ca^{2+} (g/kg)	0.02±0.00^{a}	0.06±0.01^{a}	0.49±0.02^{ab}	0.27±0.01^{ab}	0.26±0.01^{a}
K^{+} (g/kg)	0.02±0.00^{a}	0.08±0.00^{a}	0.11±0.00^{a}	0.05±0.01^{a}	0.03±0.00^{a}
Na^{+} (g/kg)	1.33±0.00^{d}	8.20±0.16^{c}	13.17±1.25^{e}	10.27±0.05^{d}	8.13±0.09^{c}
Pb (mg/kg)	0.40±0.04^{b}	0.45±0.05^{a}	0.70±0.02^{ab}	0.81±0.01^{b}	0.49±0.09^{ab}
Zn (mg/kg)	0.05±0.00^{a}	0.04±0.00^{a}	0.23±0.01^{ab}	0.04±0.01^{a}	0.07±0.01^{a}
Cu (mg/kg)	0.05±0.01^{a}	2.00±0.02^{b}	2.11±0.01^{bc}	1.66±0.01^{c}	1.44±0.01^{b}

Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same row are significantly different at the threshold ($P < 0.05$). Soil T=100% soil (Control), C4=100% cow dung, C3=75% cow dung+25% sawdust, C2= 50% cow dung+50% sawdust, C1= 25 % cow dung + 75% sawdust.

This table shows a significant increase in pH, C, Na^{+}, Cu and the C/N ratio in the different composts compared to soil T (control) whose high values were obtained with C3 (9.88±0 .01), C2 (40.30±1.41g/kg), C2 (13.17±1.25g/kg), C2 (2.11±0.01mg/kg) and C4 (21.45±0.42) respectively. On the other hand, we do not observe any significant difference in the other parameters between the different composts and the control soil. The final values of the C/N ratios for the composts are between 14.21 ±0.25 and 21. 45±0.42.

3.1.2. Microbial biomass and enzymatic activities of compost variants

The table II below presents the total bacterial and fungal concentrations, cellulase, protease, dehydrogenase, ß-glucosidase and acid and alkaline phosphatase activities.

Table II: Microbial biomass, cellulase, protease, dehydrogenase, ß-glucosidase, acid and alkaline phosphatase activities of compost variants.

Characteristics	T	C1	C2	C3	C4
Bacterial flora (10^5 CFU/g)	401.67±0.94^{a}	616.00±1.41^{c}	774.67±1.25^{e}	685.67±7.36^{d}	462.67±1.25^{b}
Fungi flora (10^5 CFU/g)	371.67±8.50^{a}	585.00±7.07^{b}	946.67±1.89^{d}	788.33±1.89^{c}	597.00±1.63^{b}
Cellulose activity (U/mg/h)	13.67±0.47^{a}	20.67±0.94^{b}	29.67±1.25^{c}	23.67±0.94^{b}	16.67±1.25^{a}
Protease activity (U/mg/h)	1.17±0.01^{a}	2.87±0.02^{b}	4.04±0.07^{d}	3.11±0.03^{c}	2.76±0.02^{b}
Deshydrogenase activity (mgTFP/kg sol sec/24h)	40.67±0.47^{a}	42.67±0.94^{a}	51.33±0.47^{b}	77.67±0.94^{d}	65.67±0.94^{c}
ß-glucosidase activity (mgPNP/kg sol sec/h	44.67±0.47^{a}	47.33±0.94^{b}	97.33±0.47^{e}	76.67±0.94^{d}	58.67±0.47^{c}
Acid Phosphatase activity (mgPNP/kg sol sec/h)	263.33±2.36 a	279.00±1.41^{b}	678.67±1.25^{e}	578.67±1.25^{d}	428.67±1.25^{c}
Alkaline Phosphatase activity (mgPNP/kg sol sec/h	346.67±2.36 a	482.67±0.94^{b}	882.67±1.25^{e}	732.67±0.94^{d}	583.33±0.94^{c}

Results *are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same row are significantly different at the threshold (P < 0.05). Soil T=100% soil (Control), C4=100% cow dung, C3=75% cow dung+25% sawdust, C2= 50% cow dung+50% sawdust, C1= 25 % cow dung + 75% sawdust.*

This table shows a significant difference in the bacterial flora of the different composts compared to the control soil, the highest value of which was obtained with the C2 compost (774.67±1.2510^5 CFU/g). We also observe a significant difference in the fungal flora between the different composts and the control soil, the greatest value was obtained with the C2 compost (946.67±1.86 10^5 CFU/g). The increase in bacterial and fungal biomass led to that of cellulase and protease dehydrogenase, ß-glucosidase, and acid and alkaline phosphatase activities significantly between the different composts and the control soil, the high values of which were obtained respectively by the composts. C2 (29.67±1.25U/mg/h), C2 (4.04±0.07U/mg/h, C3:77.67±0.94mgTFP/kgsolsec/24h, C2:97.33±0.47 mgPNP/kgsolsec/h, C2: 678.67±1.25 mgPNP/kgsolsec/h and C2: 882.67±1.25 mgPNP/kgsolsec/h.

3.1.3. Values of pH, electrical conductivity (EC), organic carbon, total nitrogen and total phosphorus concentrations of amended soils.

The values of pH, electrical conductivity (EC), organic carbon, total nitrogen and total phosphorus concentrations were determined in the compost-soil mixtures. The results are shown in Table III below.

Table III: The values of pH, electrical conductivity (EC), organic carbon, total nitrogen and total phosphorus concentrations.

Parameters	Compost/Soil proportions	pH	EC (mS/cm)	C (g/kg)	Total N (g/kg)	C/N	P (g/kg)
C1	5%	5.90±0.08^{b}	0.33±0.00^{a}	33.63±1.25^{bcd}	0.90±0.08^{b}	37.36±2.10^{e}	10.91±0.94^{bcd}
	10%	6.43±0.05^{c}	0.38±0.01^{a}	37.97±1.25^{d}	0.90±0.08^{b}	42.18±3.01^{f}	14.57±1.25^{efg}
	15%	7.47±0.05^{cd}	0.42±0.00^{a}	53.97±0.94^{e}	1.87±0.05^{c}	28.86±0.64^{c}	16.91±1.25^{g}
C2	5%	6.53±0.05^{c}	0.33±0.00^{a}	34.63±1.89^{bcd}	0.93±0.09^{b}	37.23±3.39^{e}	9.74±0.41^{bc}
	10%	7.47±0.05^{cd}	0.36±0,01^{a}	36.97±1.70^{d}	0.93±0.12^{b}	39.75±3.98^{e}	13.14±0.14^{de}
	15%	7.70±0.08^{e}	0.42±0.300^{a}	51.97±1.89^{e}	1.80±0.08^{c}	28.87±0.64^{c}	16.91±1.25^{g}
C3	5%	5.50±0.08^{a}	0.30±0.00^{a}	29.30±0.82^{b}	0.93±0.09^{b}	31.50±4.29^{cd}	9.67±0.42^{bc}
	10%	6.37±0.05^{c}	0.38±0.01^{a}	36.97±1.70^{d}	0.93±0.12^{b}	39.375±6.63^{e}	13.41±0.62^{def}
	15%	7.37±0.09^{d}	0.42±0.00^{a}	51.97±1.89^{e}	1.87±0.05^{c}	27.79±0.31^{c}	16.57±0.94^{fg}
C4	5%	5.47±0.05^{a}	0.33±0.00^{a}	30.97±0.94^{bc}	0.93±0.09^{b}	33.30±4.74^{d}	8.91±0.94^{b}
	10%	6.37±0.05^{c}	0.38±0.01^{a}	35.97±1.25^{cd}	0.93±0.12^{b}	38.67±5.98^{e}	14.57±0.94^{efg}
	15%	7.33±0.05^{d}	0.42±0.00^{a}	51.30±1.41^{e}	1.83±0.05^{c}	28.03±0.75^{c}	13.57±1.25^{def}
	T+	6.43±0.05^{c}	0.67±0.47^{a}	34.63±0.62^{bcd}	1.60±0.08^{c}	21.64±0.67^{b}	12.41±0.36^{cde}
	T-	5.50±0.14^{a}	0,30±0.01^{a}	10.55±0.19^{a}	0.89±0.02^{a}	11.85±1.51^{a}	2.67±0.12^{a}

Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same column are significantly different at the threshold (P < 0.05). C4=100% cow dung, C3=75% cow dung+25% sawdust, C2= 50% cow dung+50% sawdust, C1 = 25% cow dung + 75% sawdust. 5%, 10%, and 15%: compost-soil proportions (w/w). T^{+}=Soil amended with NPK, T^{-}=Unamended soil

The table shows a significant increase in the pH of the amended soil compared to the control soil, the highest value of which was obtained with the C2 (15%) mixture (7.70±0.08). The electrical conductivity shows that there is no significant difference between the amended and control soils. There is a significant increase in the carbon and nitrogen concentration in all the treatments compared to the control soil, the highest values of which were obtained

with the C1 (15%) mixture (53.97±0.94g/kg) and (1.87±0.05g/kg). The C/N ratio and the phosphorus concentration increased significantly between the mixtures compared to the control soil, the highest values were obtained respectively by the C1 (10%) mixtures 42.18 ± 3.01 and C2, C1 (15%): 16.91±1.25.

3.1.4. Concentrations of exchangeable ions (Mg^{2}+, Ca^{2+}, K^{+}, Na^{+}) and heavy metals (Pb, Zn, Cu) in amended soils.

Concentrations of exchangeable ions (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) and heavy metals (Pb, Zn, Cu) were determined in compost-soil mixtures compared to unamended soil. The Table IV below presents the results obtained.

Table IV: Concentrations of exchangeable ions (Mg^{2+}, Ca^{2+}, K^{+}, Na^{+}) and heavy metals (Pb, Zn, Cu) in amended soils.

Parameters	Mg^{2+} (g/kg)	Ca^{2+} (g/kg)	K^{+} (g/kg)	Na^{+} (g/kg)	Pb (mg/kg)	Zn (mg/kg)	Cu (mg/kg)
5%	1.09±0.05^{c}	12.82±0.94^{cde}	0.69±0.09^{b}	2.85±0.15^{b}	0.11±0.01^{a}	0.01±0.00^{a}	0.01±0.00^{ab}

C1	10%	1.50±0.05^{e}	14.82±0.94^{efg}	1.09±0.05^{de}	3.25±0.00^{d}	0.30±0.02^{a}	0.02±0.00^{b}	0.03±0.00^{abc}
	15%	1.52±0.02^{e}	14.15±1.41^{defg}	1.35±0.12^{def}	3.72±0.09^{e}	0.49±0.09^{a}	0.02±0.00^{bcd}	0.03±0.00^{c}
	5%	0.96±0.05^{c}	10.82±0.94^{bc}	0.75±0.05^{bc}	2.97±0.02^{bcd}	0.69±0.80^{a}	0.01±0.00^{a}	0.01±0.00^{a}
C2	10%	1.38±0.11^{de}	12.82±0.94^{cde}	1.12±0.08^{de}	3.18±0.05^{cd}	0.29±0.02^{a}	0.02±0.00^{b}	0.03±0.00^{bc}
	15%	1.42±0.02^{de}	16.65±1.08^{fg}	1.39±0.09^{ef}	3.72±0.09^{e}	0.39±0.02^{a}	0.03±0.00^{d}	0.03±0.00^{c}
	5%	0.97±0.04^{c}	11.48±0.94^{bcd}	0.69±0.09^{b}	2.90±0.07^{bc}	0.11±0.01^{a}	0.01±0.00^{a}	0.01±0.00^{ab}
C3	10%	1.44±0.07^{de}	13.48±0.47^{cdef}	1.12±0.08^{de}	3.28±0.12^{d}	0.30±0.02^{a}	0.02±0.00^{b}	0.03±0.00^{bc}
	15%	1.88±0.12^{f}	16.82±0.94^{g}	1.32±0.14^{def}	3.72±0.09^{e}	0.29±0.09^{a}	0.03±0.00^{cd}	0.03±0.00^{c}
	5%	0.99±0.05^{c}	10.82±0.94^{bc}	0.69±0.09^{b}	2.91±0.07^{bc}	0.10±0.01^{a}	0.01±0.00^{a}	0.01±0.00^{a}
C4	10%	1.20±0.12^{cd}	13.42±0.52^{cdef}	1.05±0.05^{cd}	3.18±0.05^{cd}	0.30±0.01^{a}	0.02±0.00^{bc}	0.03±0.00^{abc}
	15%	1.54±0.04^{e}	16.15±0.82^{fg}	1.59±0.09^{f}	3.75±0.14^{e}	0.35±0.05^{a}	0.03±0.00^{bcd}	0.03±0.00^{c}
	T+	0.41±0..04^{b}	8.82±0.94^{b}	1.15±0.05^{de}	2.82±0.09^{b}	0.25±0.01^{a}	0.05±0.00^{e}	0.08±0.01^{d}
	T-	0.15±0.01^{a}	0.54±0.01^{a}	0.07±0.00^{a}	1.18±0.00^{a}	0.42±0.04^{a}	0.05±0.00^{f}	0.02±0.01^{abc}

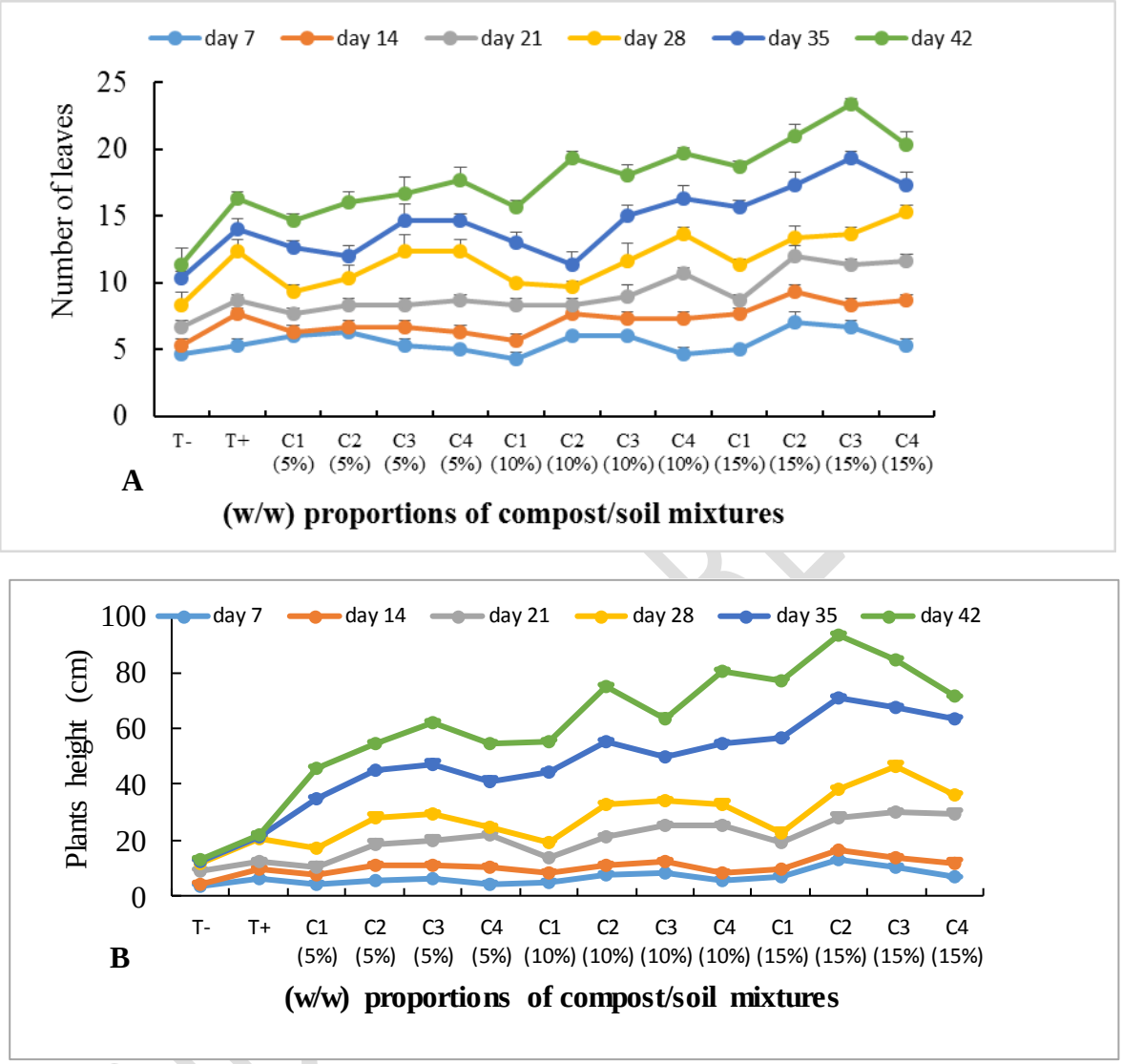
Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same column are significantly different at the threshold (P < 0.05). C4=100% cow dung, C3=75% cow dung+25% sawdust, C2= 50% cow dung+50% sawdust, C1 = 25% cow dung + 75% sawdust. 5%, 10%, and 15%: compost-soil proportions (w/w). 5%, 10%, and 15%: compost-soil proportions (w/w). T^{+}=Soil amended with NPK, T^{-}=Unamended soil

This table shows a significant increase in Ca^{2+}, Mg^{2+}, K^{+} and Na^{+} of the different proportions of treatments compared to the control, the highest values of which were obtained respectively by the C3 treatments (15%): 16.82± 0.94g/kg; 1.88±0.12g/kg, and C4 (15%): 1.59±0.09g/kg; 3.75±0.74g/kg. As far as heavy metals are concerned, we do not observe any significant difference in the lead between the different proportions of the treatments compared to the control, but there is a significant difference in the metals: zinc and copper between these different treatments and the control whose values highest obtained belong respectively to the negative control 0.05±0.00mg/kg and positive 0.08±0.01mg/kg

3.1.5. Evaluation of the effect of compost on growth parameters and tomato production

- **Growth parameters**

The tomato plants were grown in pots in a compost-soil mixture at different mass/mass concentrations. Leaf number, plant height, length, width and leaf area of each plant were determined weekly after transplanting for 42 days. The results are shown in **Figure 1**.



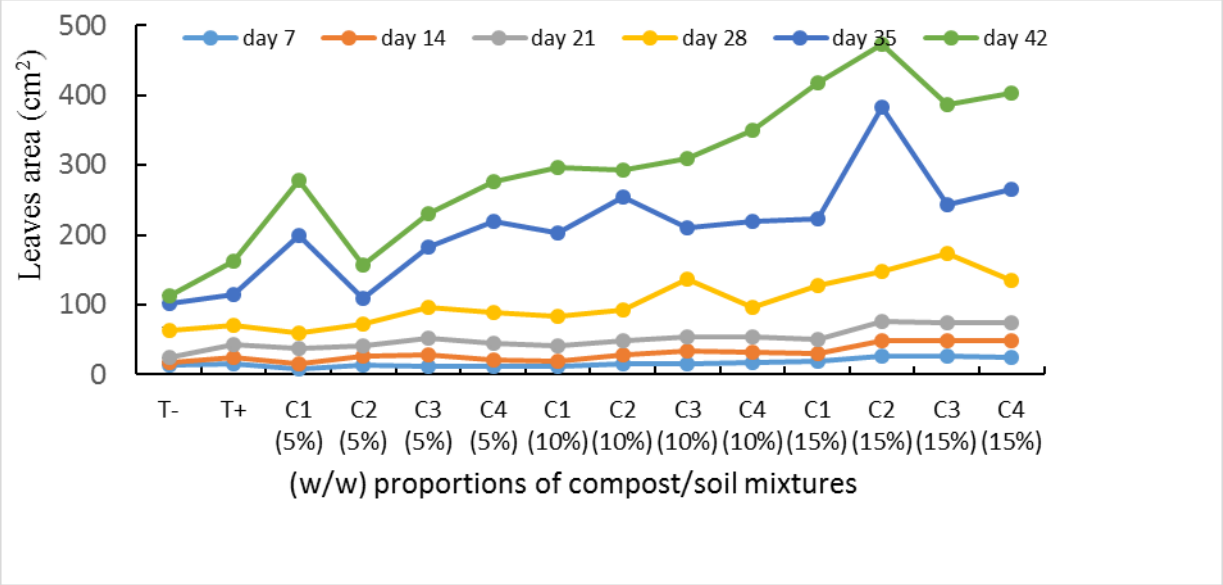
Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same column are significantly different at the threshold ($P < 0.05$). C4=100% cow dung, C3=75% cow dung+25% sawdust, C2= 50% cow dung+50% sawdust, C1 = 25% cow dung + 75% sawdust. 5%, 10%, 15%: compost-soil proportions (w/w). 5%, 10%, and 15%: compost-soil proportions (w/w). T^-=100% unamended soil, T^+ (soil amended by NPK).

Figure 1: Variation in number of leaves (A) and height (B) of tomato plants as a function of the concentration of compost-soil mixtures and as a function of time.

It appears that the number of leaves varies according to the concentration of the compost-soil mixture, on days 7 to 42 the number of leaves of the tomato plants was significantly higher in the C3 mixture (15%) (23.33 ±0.47) leaves compared to positive and negative control soils. (Figure 1A)

On days 7 to 42 the height of the tomato plants was significantly higher in the C2 mixture (15%) (93.33±0.94cm) than in the unamended soils (T^-) and amended with chemical fertilizer (T^+) (Figure 1B).

The surface of the leaves of each plant were determined weekly after transplanting for 42 days. The results are shown in **Figure 2.**



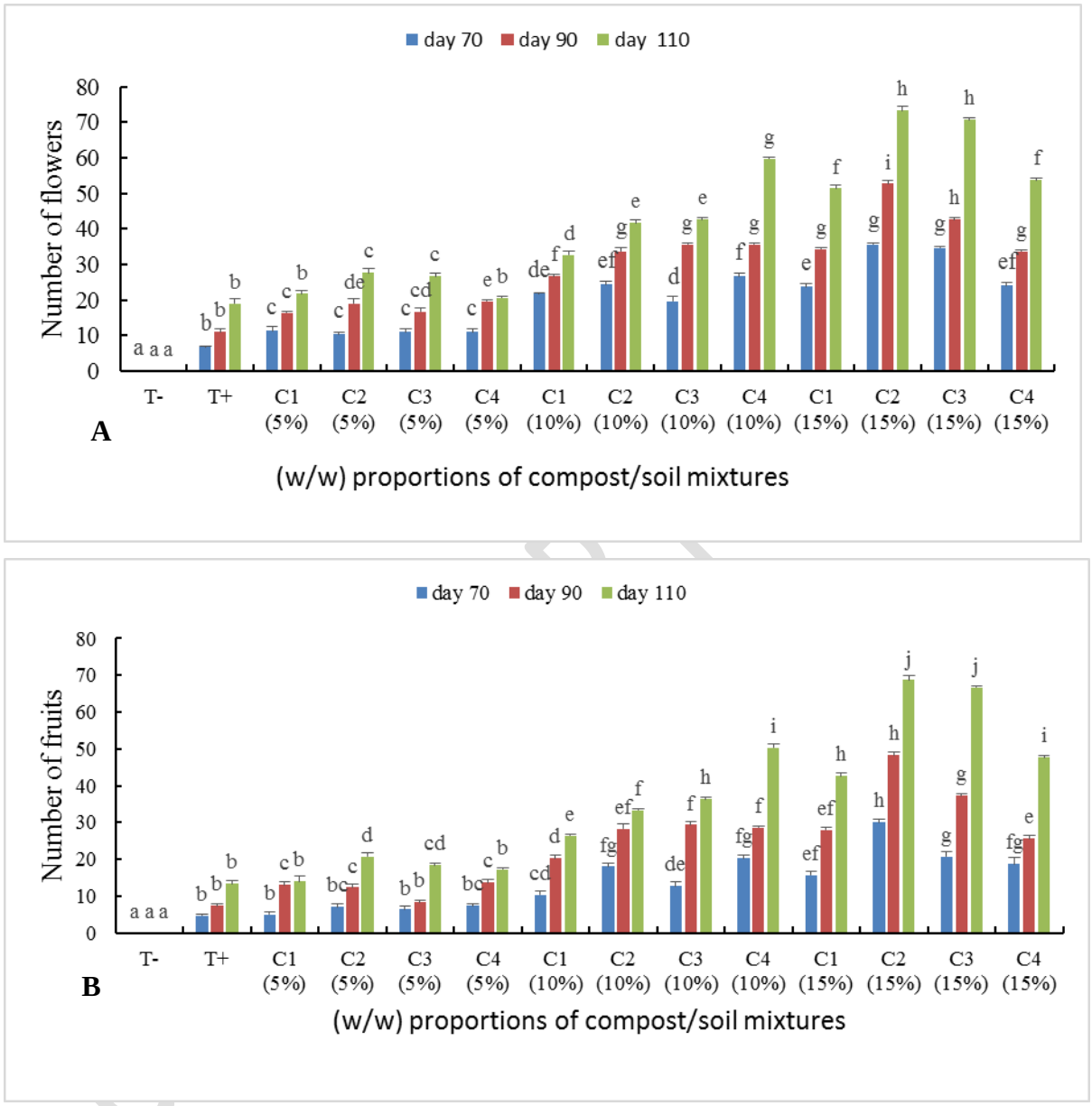
Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same column are significantly different at the threshold ($P < 0.05$). C4=100% cow dung, C3=75% cow dung+25% sawdust, C2= 50% cow dung+50% sawdust, C1 = 25% cow dung + 75% sawdust. 5%, 10%, 15%: compost-soil proportions (w/w). 5%, 10%, and 15%: compost-soil proportions (w/w). T⁻=100% unamended soil, T^+ (soil amended by NPK).

Figure 2: Variation of leaf area of tomato plants as a function of the concentration of compost-soil mixtures and as a function of time.

From this figure, it appears that the leaf area of the plants having received treatments increased significantly until the 42nd day when a leaf area of the C2 mixture (15%) is recorded (473.16±1.44cm^2), we observe that the plants, having received treatments, have an equivalent leaf area 4 times greater than that of the control plants. **(Figure 2)**

- **Production**

The number of flowers and total fruits were determined at 70, 90 and 110 days after transplantation (DAT) and the number of ripe fruits and their mass were determined at 90 and 110 (DAT). The results are shown in **Figure 3.**



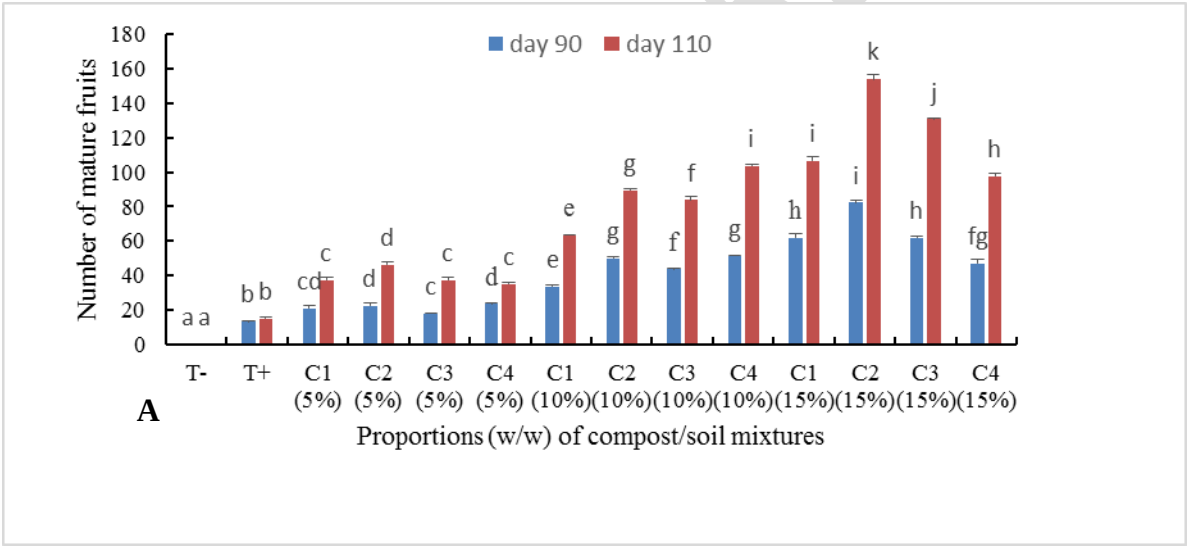
Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same column are significantly different at the threshold ($P < 0.05$). C4=100% cow dung, C3=75% cow dung+25% sawdust, C2= 50% cow dung+50% sawdust, C1 = 25% cow dung + 75% sawdust. 5%, 10%, 15%: compost-soil proportions (w/w). 5%, 10%, and 15%: compost-soil proportions (w/w). T^-=100% unamended soil, T^+ (soil amended by NPK).

Figure 3: Variation in the number of flowers (A) and total fruits (B), of tomato plants as a function of the concentration of compost-soil mixtures and as a function of time.

This figure shows significant variations between the numbers of flowers of the different plant treatments. As could be predicted from the previous results, the negative control plants, which were already lagging in growth compared to the other plants, did not produce any flowers. Plants that have received treatments show a greater number of flowers. With C2(15%), we obtained the hughest number (73.33±1.24) flowers. **(Figure 3A).**

From this figure, it appears that the number of fruits per plant shows significant variations between the treatments. The C2 (15%) followed by C3(15%) mixtures produced (68.66±1.24) and (66.66±0.47) fruits respectively. As shown in the figure above, the control plants (negative), which did not flower, did not produce any fruit and the control plants (positive) produced (13.33 ± 0.94) fruits i.e. 6 times less than treatment C2 (15%). **(Figure 3B)**

The **Figure 4** presents the number of ripe fruits of the tomato plants determined according to the proportions of the mixtures of the compost soil variants and according to the time 90 and 110 days after transplantation (DAT).



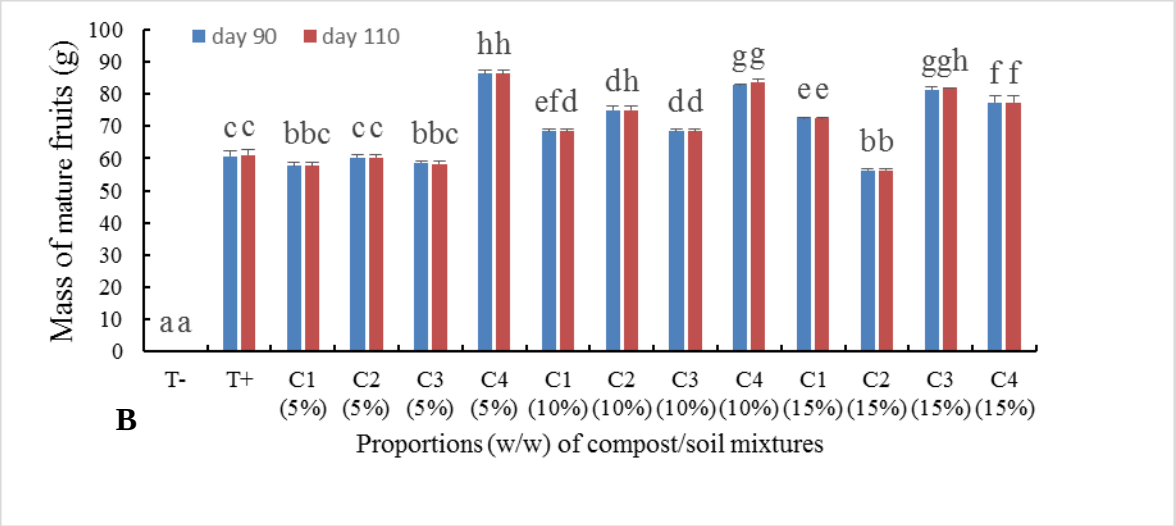


Figure 4: Variation in the number of mature fruits (A) and the mass of ripe fruits (B) of tomato plants as a function of the concentration of compost-soil mixtures and as a function of time.

This figure shows that the number of fruits per plant shows significant variations between treatments. The C2 (15%) followed by C3 -(15%) mixtures produced (154.00±2.94) and (130.00±0.94) mature fruits respectively. As shown in the figure above, the control plants (negative), which did not flower, did not produce any fruit. The positive control plants produced (15.00±0.81) fruits after 110 days, 10.26 times less than the plants treated with C2 (15%). **(Figure 4A)**

From this figure, it appears that for the weight of mature tomato fruits, the results also show that the C4 (5%) treatment had the highest weight (86.33 ±1.22 g) than the positive control weights (61.00 ± 1.30g). **(Figure 4B).**

3.1. 6. Composition of some physicochemical characteristics and nutritional constituents

The table V below represents the composition of some physicochemical characteristics and the nutritional constituents of three batches of tomato: Biological tomatoes, Chemical tomatoes, Market tomatoes.

Table V: Composition of some physicochemical caractéristics and nutritional constituents of three batches of tomatoes

Parameters	Biological tomatoes	Chemical tomatoes	Market tomatoes
Water content (%)	90.16±0.23[a]	94.10±0.14[b]	97.30±0.50[c]
Ash content (%)	13.60±0.14[b]	11.17±0.24[a]	11.55±0.07[a]
pH	4.76±0.09[b]	4.14±0.06[a]	4.68±0.03[b]
Density	1.08±0.00[a]	1.06±0.01[a]	1.06±0.00[a]
Total sugar content (g/100g FM)	3.43±0.09[c]	2.73±0.05[b]	2.03±0.05[a]
Total lipids content (%)	13.85±0.07[a]	14.32±0.45[a]	14.79±0.41[a]
Fibre content (g)	0.14±0.01[b]	0.11±0.00[a]	0.10±0.00[a]
Lycopene content (mg/100g FM)	8.42±0.12[c]	3.68±0.02[b]	2.96±0.06[a]
Vitamine C content (mg/100g FM)	17.97±0.05[c]	14.19±0.27[b]	13.05±0.07[a]
Total phenolics content (mg d'EAG/ 100ml)	108.41±0.84[b]	91.56±0.62[a]	89.56±0.79[a]

Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same row are significantly different at the threshold ($P < 0.05$).
Bio tomatoes: tomatoes obtained with compost; Chemical tomatoes: tomatoes obtained with NPK; Market tomatoes: tomatoes bought in the market.

This table shows a significant increase in water content, ash content, total sugars, lycopene, vitamin C and total polyphenols. The highest values are respectively: the market tomato has 94.3% in water content, the organic tomato has 13.60%, in total sugars, and the organic tomato has the highest value (3.43 ±0.09 mg/100 g fresh material (FM)). Regarding lycopene, vitamin C and total polyphenols organic tomato has the highest values respectively 8.42 ± 0.12mg / 100g FM, (17.97 ± 0.05mg / 100g FM and 108.41 ± 0.84mg of EAG/100ml. On the other hand, we do not observe any significant difference in pH, density, total lipids and crude fibres between the three batches of tomato.

3.1.7. Minerals composition

The **table VI** below represents the analysis of the minerals constituents of three batches of tomatoes: Biological tomatoes, Chemical tomatoes and Market tomatoes.

Table VI: Minerals composition of three tomato batches

Minerals (mg/100g DM)	Biological tomatoes	Chemical tomatoes	Market tomatoes
K	976.67±0.94^{c}	926.67±0.94^{b}	838.67±0.94^{a}
Mg	183.67±0.94^{c}	161.33±0.47^{b}	133.67±0.94^{a}
Ca	5633.33±47.14^{c}	4433.33±47.14^{b}	3133.33±47.14^{a}
Na	122.66±0.93^{a}	127.59±0.84^{b}	121.67±0.47^{a}
Cu	0.25±0.00^{a}	1.24±0.01^{b}	1.37±0.01^{c}
Fe	4.74±0.06^{c}	3.16±0.08^{b}	2.54±0.05^{a}
Zn	3.55±0.04^{c}	2.90±0.00^{b}	2.25±0.07^{a}
P	0.22±0.00^{c}	0.15±0.00^{b}	0.11±0.00^{a}
Mn	5.82±4.72^{a}	1.83±0.04^{a}	2.13±0.05^{a}

Results are presented as means ± standard deviations of 5 replicates. The values assigned by different letters on the same row are significantly different at the threshold ($P < 0.05$).
Bio tomatoes: tomatoes obtained with compost; Chemical tomatoes: tomatoes obtained with NPK; Market tomatoes: tomatoes bought in the market.

From this table, it emerges that the macro mineral composition expressed in mg/100g dry material (DM) shows that potassium, magnesium, phosphorus and calcium have a higher content with a significant difference ($P<0.05$) for the organic tomato (976.67±0.94; 183.67±0.94; 0.02±0.00; and 5633.33±47.14) mg/100g DM respectively. The composition of microminerals such as iron, and zinc, follows the same order as for the macrominerals. We record a significant difference between the three batches of tomatoes, being (4.74±0.06, 3.55±0.04) mg/100g DM respectively the highest values obtained with the organic tomato.

3.2. Discussion

The objective of our work was to evaluate the effect of a compost based on cow dung, sawdust) on the production and the organoleptic and nutritional qualities of the tomato.

The pH of the compost-amended soils was higher than those of the controls. The increase in pH is explained by the fact that in amended soils, there is a flow of protons from the soil to the sites of organic matter, which consequently increases the pH of the soil. The same result

was obtained by (**Okala, 2020**) who observed that soil amendment based on chicken droppings and fishbone increased the pH of soils.

Electrical conductivity (EC) is the concentration of salts in soil, therefore, an increase in cations in soils leads to an increase in electrical conductivity (**Ceglie et *al.*, 2015**). The increase in the concentration of exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) in the various amended soils explains the increase in electrical conductivity (**Kuba et *al.*, 2008**).

A C/N ratio of less than 12 leads to leaching, if it is between 12 and 20 there is neither leaching nor immobilization and if it is greater than 20, there is nitrogen immobilization (**Springob and Kirchmann, 2003**). The C/N values were between 27-42 for the amended soils and 14-21 for the composts, which implies that the composts do not present a risk of nitrogen immobilization or nitrate leaching for the amended soils.

The increase in the concentrations of exchangeable cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) in the amended soils would be due to the contributions by the organic amendments (**Mokolobate and Hyanes, 2002**; **Smith, 2009**). The high calcium concentration in these amended soils is of great interest because the buffering capacity of the soil depends on its quantity and availability, which reduces the potential for soil nutrient leaching (**Mokolobate and Hyanes, 2002**). This result is in line with the work of (**Bougnom et *al.*, 2020**) which showed that compost made from cow dung and wood ash increases the concentrations of exchangeable cations in Bokito and Nkolbison soils.

The increase in the bacterial and fungal biomass of amended soils is the consequence of the improvement of the physicochemical parameters of the soils, following an input of organic matter. According to **Ros et *al.*, (2006)**, the microorganisms finding the necessary substrate for their metabolism on site, the organic amendment will increase the nitrogen and carbon of the biomass as well as the microbial activity over several years.

The increase in cellulase, dehydrogenase, ß-glucosidase, phosphatase and protease activities in amended soils follows the increase in fungal and bacterial biomass. Soil enzymes are mainly of microbial origin, their activities are measurable and respond quickly to any change in soil management **(Dick et *al.*, 1996**). In the same direction (**Caldwell et *al.*, 2006**) stipulated that enzymes are potential indicators of soil quality and are closely linked to the activity and abundance of microorganisms.

The increase in plant growth and production parameters would be attributed to the improvement of the physico-chemical, biological and biochemical parameters of the soil. All these parameters have created favorable growth conditions for the plant, by providing the

nutrients necessary for its growth. Our results are conform to those of **Nguefack et *al*., (2022)** who showed that the contribution of organic matter improves the physicochemical and biological properties of the soil favourable to the growth of the plant, and that the improvement of microbial biodiversity in the rhizosphere can be used as an indicator of soil health, and is associated with improved productivity.

The improvement in tomato growth parameters could also be explained by the fact that the compost improved soil fertility by increasing soil organic C and phosphorus levels, which helped to accelerate plant growth. Nitrogen, phosphorus and potassium from these fertilizers are essential for the growth and development of plants. This corroborates the results obtained by (**Mangoumou et *al*., 2020**) which showed that the development of a protocol for the production of quality tomatoes from plant-sourced inputs increased growth parameters.

Fruit production could be linked to major nutrients (N, P, K) as well as trace elements from compost. Indeed, phosphorus is an important element for fruit production; the quantity of fruit produced by the plant is linked to its size, the rate of leaf cover and the number of branches.

The increase in total ash content of the tomato fruits harvested from pots amended with composts could be due to the application of compost that released organic and inorganic minerals in the soil (**Akinyemi et *al*., 2018**).This is in accordance with the result obtained by **Guilherme et *al*., (2020)** who reported that the ash content of the sweet pepper fruits obtained from the organic agriculture was found significantly greater that those obtained from the conventional agriculture.

The increase in total sugar content observed from of the tomato fruits harvested from the plants grown with compost might be due to the increase of the microorganisms in the soil that had a positive effect in converting the unavailable forms of nutrient elements to available forms. Those microorganisms produced growth-promoting substances resulting in more efficient absorption of nutrients, which are main components of photosynthetic pigments and consequently the carbohydrate (**Mohammed, 2013**). These results are in accordance with those obtained by **Mohammed, (2013) and Copetta et *al*., (2011)** who reported that compost application improved carbohydrate content.

The high fibre content obtained from the organic tomato fruits could be due to its greater organic or inorganic minerals content (**Akinyemi et *al*., 2018**), which makes them essential for little children, pregnant women and nursing mothers. Minerals enhance the

important functions of maintaining acid-base balance and proper osmotic pressure in the bod. Minerals are also required for normal functioning of the nerves and also muscular contraction and relaxation. Hence sweet pepper fruits could be a fair and cheap source of these essential minerals. (**Ihemeje et *al*., 2013**).

The high significant concentration of vitamin C found in fruits harvested from the plants grew with compost in pot experiments was in accordance with the findings of **Taiwo et *al*., (2007)**, who reported that compost application improved vitamin C content of fruits. They are also in agreement with the work reported by **Shahein et *al*., (2015)**, who obtained the highest amount of vitamin C from plots amended with the sheep manure and the lowest amount from the conventional agriculture. The increase in vitamin C observed could be due to the high amount of potassium contained in compost, which play a great role in plant metabolism and many important regulatory processes in the plant (**El-Bassiony et *al*., 2014**). Besides, tomato fruits have exceptionally high vitamin C content, the major water-soluble antioxidant in plant cells, which plays a major role in protecting cells against free radicals and oxidative damage (**Wang et *al*., 2003**). The role of Ascorbic acid in the human diet is thought to be significant in preventing common degenerative conditions (**Pascual et *al*., 2010**).

The significant high concentrations of Ca, Mg, K, Mn, Zn and Na, recorded in the fruits obtained from plants cultivated with compost may be attributed to the quick availability of Ca, Mg, K, Mn, Zn and Na elements and the slow release of minerals by compost during the crop growing cycle. According to **Suge et *al*., (2011)**, the high concentration in minerals could be due to the fact that organic matter improved the minerals cycling and availability to the plants especially, N and P, which improved root development and subsequently vegetative growth. Similar results were reported by **Elsadig et *al*., (2017) and Omar et *al*., (2018).** Moreover, that difference might be due to the presence of nitrogen and potassium in the compost, which may have increased the amount of Ca, Mg, K, Mn, Zn and Na in the tomato fruits. This is in accordance with the findings of **Elsadig et *al*., (2017)**, who reported that by increasing nitrogen levels, the values of microelements content increased in fruits. In addition, the higher concentration of Ca, Mg, K and Na in organic tomato fruits may be due to the compost application, which could enhance soil fertility, resulting in increasing minerals availability and their uptake by plants. Furthermore, the application of compost might provide supplemental exchangeable cations such as potassium, calcium, magnesium and ammonium, mainly due to organic mineralization and release of these basic cations into the soils (**Al-Kahtani et *al*., 2012**). Similar results were also obtained by **Houndji et *al*., (2018)**.

4. Conclusion

This study was undertaken to evaluate the effect of organic fertilizers on the production and the organoleptic and nutritional qualities of tomatoes. Our analyzes show that the various amendments have improved the pH, the concentrations of macroelements (Mg^{2+}; Ca^{2+}; K^{+} and Na^{+}) and total phosphorus. The physicochemical parameters of the soils and the microbial communities (bacteria and fungi) saw their biomass and their metabolic activities cellulase, protease, β-glucosidase, alkaline and acid phosphatases increased. These different modifications, which are good indicators of soil fertility, have resulted in an improvement in the production and nutritional quality of tomatoes.

References

Akinyemi, B.K., Obasi, M.O., Faajir, A. (2018). Effect of postharvest treatments on shelf life and quality of pepper. Asian Journal of Research in Crop Science 00, 1–7. https://doi.org/10.9734/AJRCS/2018/41209.

Aktar, M.W, Sengupta, D., Chowdhury, A. (2009). Impact de l'utilisation des pesticides en agriculture: leurs avantages et leurs dangers. Toxicologie interdisciplinaire, 2 (1), 1-12.

Al-Kahtani, S.H., Soliman, S.S. (2012). Effects of organic manures on yield, fruit quality, nutrients and heavy metals content of Barhy date palm cultivar. African Journal of Biotechnology 11 (65), 12818–12824. https://doi.org/10.5897/AJB12.994.

Benakmoun, A., Abbedou, S., Ammouche, A., Panagiotis, K., Dimitrios, G. (2008). Valorisation of low quality edible oil with tomato peel waste. Food chemistry 110: 684-690pp.

Bougnom BP, Molemb, N.A., Mbassa, G.F., Onomo, E.P., Etoa, F.X. (2020). Effets of cattle manure wood ash compost on some chemical, physical and microbial properties of two acid tropical soils. IJATRE 6 (4), 77.

Btissam, M.A., Ouazzani., Touhami., Allal, D. (2010). Agronomic valorisation of compost and extracts on tomato cultivation, 165-190.

Caldwell, K. S., J. Russell, et *al*. (2006). "Extreme population-dependent linkage disequilibrium detected in an inbreeding plant species, *Hordeum vulgare*." Genetics 172 (1), 557-567.

Cederholm, T., Jensen, G.L., Correia, M.I.T.D., Gonzalez, M.C., Fukushima, R., Higashiguchi, T, Crivelli, A.N. (2019). GLIM criteria for the diagnosis of malnutrition - a

consensus report from the global clinical nutrition community. Journal of cachexia, sarcopenia and muscle 10 (1), 207-217. https://doi.org/ 10.1002/jcsm.12383.

Ceglie FG., Bustamante MA., Ben Amara M. and Tittarelli F. (2015). The challenge of peat substitution in organic seedling production: optimization of growing media formulation through mixture design and response surface analysis. PLoS One 10 (6).

Copetta, A., Bardi, L., Bertolone, E., Berta, G. (2011). Fruit production and quality of tomato plants (*Solanum lycopersicum* L.) are affected by green compost and arbuscular mycorrhizal fungi. Plant biosystems 145 (1), 106-115. https://doi.org/ 10.1080/11263504.2010.539781.

Darnton-Hill, I., Mkparu, U.C. (2015). Micronutrients in pregnancy in low-and middle-income countries. Nutrients 7 (3), 1744-1768. https://doi.org/10.3390/nu7031744.

Derkaoui, K.M. (2011). Les réponses morphologiques, physiologiques et anatomiques des racines de la tomate (*Solanum lycopersicum* L.) vis-à-vis du stress salin. Mémoire de diplôme de Magister, page 80.

Dhaliwal, M.S., Sharma, S.P., Jindal, S.K., Dhaliwal, L.K., Gaikwad, A.K. (2017). Growth and yield of bell pepper as influenced by growing environment, mulch, and planting date. Journal of Crop Improvement 31 (6), 830–846. https://doi.org/10.1080/ 15427528.2017.1391146.

Diatité, B., Dalanda, D.M., Touroumgaye, G., Diédhiou, S., Diallo, A. (2020). Effet de l'application de différentes doses de fertilisants organiques sur la croissance et le rendement de la tomate (*Solanum lycopersicum*). Journal of Animal and Plant Sciences, Elewa BioSciences, 2020, 44 (1), pp.7553-7566. 10.35759/JAnmPlSci.v44-1.2. Hal-02568634.

Dick, R. (1996). Soil enzyme activities as indicators of soil quality. In: Doran. J.W, Coleman, D.C., Bizdicek, D.K., Stewart, D.F., (Eds.).Defining soil quality for sustainable environment. Soil science society of America, Madison, 107-124.

Eaton, A.D., Clesceri, L.S., Rice, E.W., Greenberg, A.E. (2005). Standard methods for the examination of water and wastewater. 21[a] ed. Washington: American Public Health Association, 1082p.

Elsadig, E.H., Aljuburi, H.J., Elamin, A.H.B., Gafar, M.O., 2017. Impact of organic manure and combination of NPKS, on yield, fruit quality and fruit mineral content of Khenazi date palm (*Phoenix dactylifera* L.) cultivar. Journal of Scientific Agriculture 1, 335. https://doi.org/10.25081/jsa.2017.v1.848.

Eivazi, F., Tabatabai, M.A. (1988). Glucosidases and galactosidases in soils. Soil Biology Biochemistry, 20, 601-606.

El-Bassiony, A.M., Fawzy, Z.F., Abd El-Samad, E.H., Riad, G.S. (2010). Growth, yield and fruit quality of sweet pepper plants (*Capsicum annuum* L.) as affected by potassium fertilization. Journal of American Science 6 (12), 722-729. http://www.american science.org.

FAOSTAT. (2020). Food and Agriculture Organization of the United Nations. https:// faostat3. Fao.org/download/Q/QC/E. Consulted on 10-9-2022.

Galani, Y.J.H., Orfila, C., Gong, Y.Y. (2020). A review of micronutrient deficiencies and analysis of maize contribution to nutrient requirements of women and children in Eastern and Southern Africa. Critical Reviews in Food Science and Nutrition 00, 1-24. https://doi.org/10.1080/10408398.2020.1844636.

Goodon, B. (1997). Guide pratique d'analyse dans les industries des cereals. Tec et Doc. 346-354pp.

Guilherme, R., Reboredo, F., Guerra, M., Ressurreiç˜ao, S., Alvarenga, N. (2020). Elemental Composition and Some Nutritional Parameters of Sweet Pepper from Organic and Conventional Agriculture. Plants 9 (7), 863. https://doi.org/10.3390/ plants 9070863.

Houndji, B.V.S., Melila, M., Fagla, B., Ameyran, K., Amouzou, S.K.E. (2018). Valeur nutritionelle des fruits d' *Haematostaphis barteri*, une espece alimentaire, au Nord-Ouest du Benin, menacée de disparition. Journal de la Recherche Scientifique de l'Université de Lomé 20 (3), 11–21.

Ihemeje, A., Ojinnaka, M.C., Obi, K.C., Ekwe, C.C. (2013). Biochemical evaluation of pepper fruit (*Dennettia tripetala*) and its use as substitute for ginger in zobo drink production. Academic research international 4 (6), 513.

James, A. (1980). Plumbing: Installation and design. Resto Publishing Company Science of fluids 6, 26-152.

Keatinge, D. (2012). Vegetables: Less visible, but vital for human health-Why nutrient-dense indigenous vegetables must be on the plate for economic development, food security, and health. AVRDC News Brief, 31 May 2012.

Kuba, T., Tschöll A., Partl C., Meyer K., Insam H. (2008). Wood ash admixture to organic wastes improves compost and its performance. Agriculture, ecosystems and environment 127, 4349.

Mangoumou, N.G., Nguefack, J., Dongmo, L.J.B., Dakole, D.C., Jean Claude Nguepsi, J.C., Moundipa F.P. (2020). Organic Treatment effects on Ferritic soil quality and Tomato

(*Lycopersicon esculentum* Mill.) Yield. International Journal of Environment, Agriculture and Biotechnology, 5(2) PP 366-374. https://dx.doi.org/10.22161/ijeab.52.11

Manjeru, P., Van Biljon, A., Labuschagne, M. (2019). The development and release of 2017.1402751. Maize fortified with provitamin A and carotenoids in developing countries. Critical reviews in food science and nutrition, 59(8), 1284-1293.https://doi.org/10.1080/ 10408398.

Mohammed, G.H. (2013). Effect of Seamino and ascorbic acid on growth, yield and fruits quality of Pepper (*Capsicum Annum* L.). International Journal of Pure and Applied Sciences and Technology 17 (2), 9. www.ijopaasat.in.

Mokolobate, M.S., Haynes, R.J. (2002). Comparative liming effect of four organic residues applied to an acid soil. Biology and Fertility of Soils, 35, 79-85.

Mottes, C., Lesueur Jannoyer, M., Le Bail, M., Guéné, M., Carles, C., Malézieux, E. (2017). Relationships between past and present pesticide applications and pollution at a watershed outlet: The case of a horticultural catchment in Martinique, French West Indies. Chemosphere, 184, 762-773.

M'sadak, Y., Elouer M., El kamel, R. (2013). Evaluation du comportement chimique des composts syvicoles, des tamisats et des mélanges pour la conception des substrats de culture. Revue « Nature et Technologie ». Sciences de l'environnement, 8, 54-60.

Murphy, J. and Riley, J. P. (1962). A modified single solution method for determination of phosphate in natural waters. Analytica Chimica Acta, 27, 31-36.

Nguefack, J., Onguéné, D., Dongmo, L. J. B., Dakolé, D. C., Mangoumou, G. N., Galani, Y. J. H. (2022). Effect of aqueous extract of clove basil (*Ocimum gratissimum* L.) and soil amendement with cassava peels compost on nutrients, pesticide residues, yield and antioxidant properties of sweet pepper (*Capsicum annum* L.). Scientia. Horticulturae. DOI: https://doi.org/10.1016/j.scienta.2021.110872.

Noumeni, C. (2016). Developpement d'un protocole de production des tomates (*Lycopersicon esculentum* Mill.) de qualité à partir des intrants d'origine des plantes. Master, Mémoire de 86pp.

Okala. (2020). Effet de deux biofertilisants sur les propriétés physico-chimiques et biologiques du sol et la production de la tomate. Mémoire de Master, Université de Yaoundé I, 78 pp.

Omar, E.S., Gabal, A.A.A., Alkharpotly, A.A., Radwan, F.I., Abido, A.I.A. (2018). Effect of mineral, organic and bio-fertilization on sweet pepper (*Capsicum annum* L.) grown under

plastic houses conditions. Journal of Advanced Agricultural Research (Faculty of Agricultural Saba Basha) 23, 402-432.

Pascual, I., Azcona, I., Aguirreolea, J., Morales, F., Corpas, F.J., Palma, J.M., Sanchez-Díaz, M. (2010). Growth, yield, and fruit quality of pepper plants amended with two sanitized sewage sludges. Journal of agricultural and food chemistry 58 (11), 6951–6959. https://doi.org/10.1021/jf100282f.

Rapilly, F. (1968). Mycology techniques in plant pathology. Annals of Epiphytes. INRA. 19, 102.

Ros M, Klammer S, Knapp B, Aichberger K, Insam H. (2006). Long-term effects of compost amendment of soil on functional and structural diversity and microbial activity. Soil Use Manage 22:209–218.

Shahein, M. M., El Sayed, S. F., Hassan, H. A., Abou-El-Hassan, S. (2015). Producing Sweet Pepper Organically Using Different Sources of Organic Fertilizers under Plastic House Conditions. In Proceedings of International Conference on Advances in Agricultural, Biological and Environmental Sciences (AABES-2015)72-8). https://doi. org/10.15242/IICBE.C0715107.

Smith S. (2009). A critical review of the bioavaibility and ilpacts of heavy metals in municipal solid waste composts compared to sewage. Environnment 35 (1), 142-156.

Springob, C., Kirchmann, H. (2003). Bulk soil C to N ratio as simple measure of net N mineralization from stabilized soil organic matter in sandy arable soils. Soils Biochemistry, 35, 629-632.

Suge, J.K., Omunyin, M.E., Omami, E.N. (2011). Effect of organic and inorganic sources of fertilizer on growth, yield and fruit quality of eggplant (*Solanum Melongena* L.). Archives of Applied Science Research 3 (6), 470–479. www. scholarsresearchlibrary.com.

Tabatabai, M.A. (1994). Soil enzymes. In: Weaver RW., Angle JS., Bottomley P.S. Methods of Soil Analysis, Part 2. Microbiological and Biochemical Properties. Soil Science Society of America, Madison, Wisconsin, 775-833.

Taiwo, L.B., Adediran, J.A., Sonubi, O.A. (2007). Yield and quality of tomato grown with organic and synthetic fertilizers. International Journal of Vegetable Science 13 (2), 5-19. https://doi.org/10.1300/J512v13n0202.

Wang, S.Y., Bunce, J.A., Maas, J.L. (2003). Elevated carbon dioxide increases contents of antioxidant compounds in field-grown strawberries. Journal of Agricultural and Food Chemistry 51 (15), 4315-4320.

WHO and UNICEF (2017). Report of the Fourth Meeting of the WHO UNICEF Technical Expert Advisory group on nutrition Monitoring (TEAM), Geneva, Switzerland.