Effectiveness of organic fertilizers in improving soil fertility, productivity and quality of carrots (Daucus carota) in southern Côte d'Ivoire.

ABSTRACT

In the context of agricultural resilience to climate change, a strategy of replacing chemical fertilizers with organic fertilizers has been adopted to improve the production of vegetable crops, particularly carrots. This study promotes organic carrot farming in Côte d'Ivoire by applying an organic biofertiliser based on poultry droppings and traditional medicinal plants to the soil. Different doses of this organic biofertiliser, applied to the soil by fertigation (dilution at0.5% (T1), 5% (T2) and10% (T3)),were tested under a crop of carrots*(Daucus carota*) in a completely randomized Fisher block design with 4 replications. The results show that yields varied significantly according to the different doses applied($p<0.05$). High carrot yields of 27.5±1.29 t.ha^{-1} were obtained with treatment T2. However, plant growth indicators (plant height, number of leaves, root length and diameter) weresimilar for the three treatments T1, T2 and T3.According to the results obtained, treatment T2 would be suitable for achieving and maintaining an acceptable level of fertility and ensuring satisfactory yields for the carrot crop.Thus, the use of this biofertilizer should be encouraged for agro-ecological soil fertility management, and may be an alternative to synthetic fertilizers which, due to their high cost, are not accessible to growers.

Keywords: biofertiliser,yield,*Daucus carota*,organicfarming,Côte d'Ivoire

1. INTRODUCTION

Urban agriculture plays a key role in mitigating climate change.This agriculture reduces carbon footprints through local production and short supply chains. In addition, it promotes biodiversity, saves water and greening urban spaces [1].In several West African countries, urban agriculture plays an essential role by feeding local residents. Urban agriculture creates jobs, social ties and islands of coolness in cities [2].However, urban agriculture is increasingly facing difficulties, resulting in the loss of arable land and soil artificialization due to rapid urbanization [3].

Soil artificialization is defined as transformation of agricultural, natural or forested land by development actions. This process can lead to total or partial sealing. This change in land use, which is usually irreversible, has consequences that can be detrimental to the environment and agricultural production [4]. Soil artificializationinducesdecline in urban soil fertility [5]. Thus, to restore the fertility of these soils and their ability to sustain agricultural production, some farmers use massive chemical inputs (fertilizers and biocides) [6].An excess of these biocides has a negative impact on the environment and on human health. Consequently, more sustainable agriculture models advise the use of organicfertilizersand/or inassociationwithsoil biological engineers forsoil fertility enhancement. In these agricultural models, soil fertility management is therefore supported using organic matter from composted agricultural or urban organic waste. It is recognized that these organic wastes improve soil properties, strongly affect nutrient storage and availability in soils. Organic matter in soil increases yield in addition to the reduction the risk of soil and water pollution[7].However, the usage of untreated organic fertilizers arising from the excreta, host of various parasites, induces pollution of urban agricultural soil. These parasites could be transferred in vegetable and green fodders causing serious health problems to human or animals[8].Consequently,in order to avoid the use of untreated organic fertilizers, studies recommend the introduction of some plants in the composting process. Thes plants are known for their beneficial medicinal effects for soil quality control.It has been demonstrated that medicinal plants reduce the risk of crop attack or parasitic infestation [9, 10].Some studies have indicated that theseplantsaregenerallyusedtowardoffpredators(aromaticinsect repellent plants) and fortify the plantation, increasing resistance to pests and diseases. Species, such as *Crotalaria juncea,* also help to improve the fertility of degraded soils and increase crop yields [11]. Introducing traditional medicinal or glucosinolate-rich plants into compost production could therefore be an alternative to the use of chemical fertilizers, but the mixing of organic fertilizersandthese plants for soil quality assessment remain unexplored in urban agrosystem[12].

This study is part of the overallcontextofsettingupanorganicvegetableproductionmechanismusing liquidcompost to fertilize the soil. Liquid compost, or compost tea, is used to soften the soil and produce plants that are more uniform in color, development and vigor[13]. The general objective of our study is therefore to test different doses of liquid compost produced from poultry droppings and traditional medicinal or glucosinolate-rich plants for intensive carrot production on a heavily leached ferralsols in Abidjan.

2. MATERIAL AND METHODS

2.1 Description of the study area

The study was conducted at the experimental site of the NanguiAbrogouaUniversity (UNA) inAbidjan,southernCôted'Ivoire.The choice of this area is justified by the fact that it is a densely populated megalopolis with a high demand for fresh vegetables.Thegeographicalcoordinatesofthestudysiteare5°17'and 5°31' north latitude and 3°45' and 4°22' west longitude (Figure 1). The study area has a sub-equatorial climate, hot and humid, with 4 seasons, including two rainy seasons and two dry seasons. The average annual rainfall is 1,500 mm and the average annual temperature is 27˚C with an average annual humidity of over 80%[14]. The basic vegetation consists of dense forests, subdivided into mesophilic and hydrophilic forests. Finally, the geology is dominated by Neogene sediments, ofcontinentalorigin, covering the ancient crystalline basement. These are mainly ferruginous sands, with varying degrees of clay, and sometimes sandy clays. Ferralsols have developed mainly on these geological formations[15].

Figure1: Locationof the studysite inthedistrict ofAbidjan

2.2 Plant material

The plant material used for this study consists of seeds from a carrot variety (*Daucus carota*) called Amazonia from the Semivoire group® based in Abidjan. The characteristics and agronomic performance of the variety are given in Table 1.

Table1: Characteristics of carrots

Variety	Typeof soil	Cycle (days)	Yield ($t.ha^{-1}$)	Agronomic characteristics	Fruit characteristics
Amazonia	Sandy-silty,silty-sandyand sandy-clay, rich in well-decomposedorganicmatter and nutrients	90-95	20-40	Goodtolerance to alternia	Conical,16-18cm,deeporange external color, faint lenticels, medium red core with fine demarcation.

2.2.1 Biofertiliser

The biofertiliser was obtained from a mixture of 10 kg of poultry droppings, 1 kg of neem leaves, 1 kg of Laos grass leaves, 1 kg of lemongrass leaves and 4 cloves of garlic. The plant leaves and garlic cloves were finely chopped and homogenized with the poultry droppings ina container. Then 100 liters of water were added to the mixture and hermetically sealed to speed up fermentation.The mixture was regularly homogenized every 5 days. After 30 days of fermentation, the resulting mixture was filtered to collect the organic matter-rich solution, which was then used to fertilize the soil.

2.2.2 Experimental setup

The trials were carried out in a completely randomized Fisher block design with 5 replicates (figure 2) and the only factor being the dose of fertilizer solution in 4 modalities (4 doses):

- T0:treatmentwithnosolutionadded (control)
- T1:treatment1,0.5% dilutedsolution
- T2:treatment2,5% dilutedsolution
- T3:treatment3,10% diluted solution

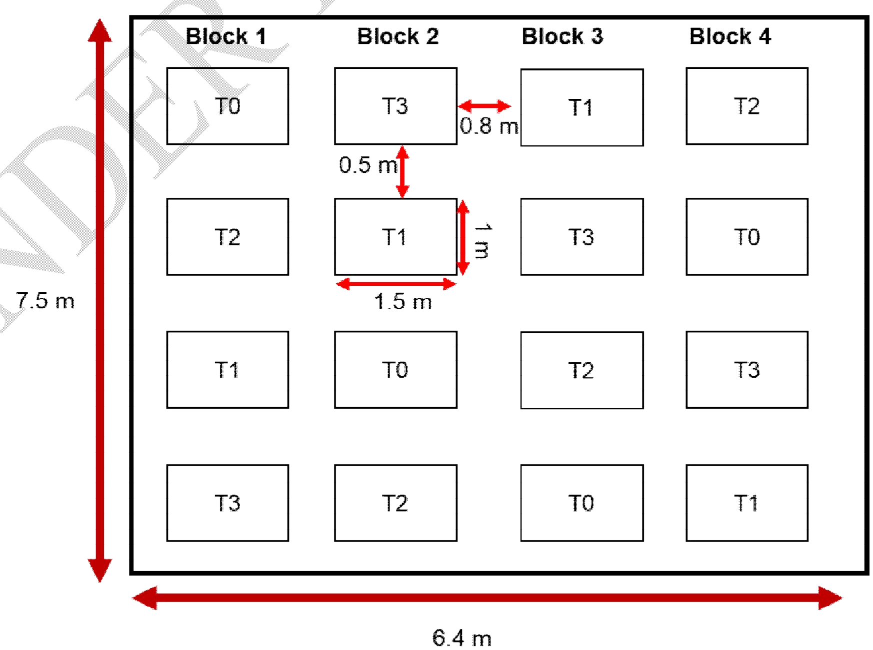

Figure2: Experimental design used in this study

2.2.3 Setting up the crop

After planting beds measuring 1.5 m x 1 m and spaced 0.5 m apart, 3 kg of dried, finely ground pig droppings were sprayed in a single fraction on each bed as fertilizer. The beds were then thoroughly watered to field capacity and covered with dried straw. Seven (7) days after watering the beds, carrot seeds were sown directly on the beds at 20 cm between rows and 10 cm inside the rows, at a density of 133,000 plants per hectare. Conventional watering was carried out with 5 liters of water per day per bed. Fifteen (15)days after sowing, an initial single-dose fertigation with 5 liters of liquid compost per treatment was carried out on each bed. This fertigation was then repeated every 15 days after the firstapplication of fertilizer solution. A manualwedding was carriedouteveryweek.During plant cultivation, agronomic parameters were measured, focusing mainly on average plant height, number of leaves, root length and carrot diameter at 2 cm from the collar. These measurements were carried out on 10 carrot plants per treatment. Ninety (90) days after sowing, the carrots were harvested from an area measuring 0.8 cm x 0.5 cm in the center of the beds to determine the average yield.

2.2.4 Chemical analysis

The physico-chemical parameters of the core samples from each treatment were measured at the end of cultivation. These physico-chemical parameters were moisture content, hydrogen potential (pH) and titratable acidity. Moisture content was determined by the difference in mass, before and after dehydration of 50 g of wet sample ground and oven dried at a temperature of 70˚C for 72 hours. Moisture content was determined according to the equation 1:

$$Soil\ humidity\ (\%) = \frac{m_1 - m_2}{m_1} \times 100 \qquad \text{(Equation 1)}$$

where m_1: the mass (g) of the crushed material before steaming and m_2: the mass (g) of the crushed material after steaming.

The total acidity and pH of the carrot were determined using the method of Duffour*et al* [9]. A quantity of 10 g of carrot shred was added to 90 ml of distilled water. After stirring the suspension for 30 minutes at room temperature, the homogenate was filtered through whatmanpaper, and the pH was measured directly on the collected solution using a pH meter. Total acidity was determined by titration with 0.10 M sodium hydroxide by taking a 5 ml volume of the previous preparation and adding 0.1 ml of 1% phenolphthalein. The totalacidity for each treatment was obtained using the equation 2:

$$C_{H^+} = \frac{v_e \times v_1}{m \times v_0} \qquad \text{(Equation 2)}$$

with C_{H+}: concentration of H^+ in ($mol.g^{-1}$), *v*0: volume of test (ml), *v*1: volume of solution poured in, *v*e: volume of distilled water (liter), m: mass of sample taken (g).

Chemical analyses of the soil and liquid compost were carried out at the soil laboratory of the Institut Polytechnique Félix Houphouet-Boigny (INP-HB) in Yamoussoukro, Côte d'Ivoire. The analyses covered organic carbon, total nitrogen, total potassium and total phosphorus in the fertilizer solution. For the soil, the analyses covered pHeau, organic carbon, total nitrogen, CEC, exchangeable bases and assimilable phosphorus.

2.3 Statistical analysis of data

Excel software was used to enter the data. The various data, i.e. number of leaves per plant, total height, root length, root diameter, root yield on 10 selected plants, hydrogen potential, moisture content and total acidity, whose means and standard deviations were subjected to an ANOVAvarianceratio. Statisticalanalyseswerecarriedoutusing JMPsoftware(version13). The Student-Newman-Keuls test with a threshold of 5% was used to compare the means in pairs.

3. RESULTS

3.1 Characteristics of the initial soil and of the fertilizer solution

The initial soil analysis data are shown in Table 2**.** The results show that the soil has a sandy texture with 75% sand, and a low organic matter content of 5%. Total nitrogen (0.04%) and total phosphorus (0.72%) levels are very low.Similarly, Ca and Mg levels are very low. The K content is also low. Finally, the Na content is negligible. The pH of 5.3 indicates amediocre level of fertility for this soil.

Table2:Characteristicelementsoftheinitialsoilsamplesfromtheexperimental site

Clay	Silt	Sand	MO	C.org	Ntot	Ptot	Ca	Mg	K	Na	pH
(%)							$cmol^+.kg^{-1}$				
19,58	5,15	75,27	5,10	2,27	0,04	0,72	0,50	0,59	0,05	0,03	5,30

The chemical composition ofthe liquid compost is givenin Table 3. Theresultsshowthat the solution is alkaline with high levels of N, P and K. The bases (Ca and Mg) are also well provided for in the preparation.

Table3:Chemicalanalysisofliquid compost (numbers in bracket indicate the standard error)

Dry residue	pH	N	P	K	Ca	Mg
(%)		(%)				
1,02	7,51	5,95	4,07	4,36	2,93	3,83
(0,36)	(0,14)	(0,86)	(0,87)	(0,60)	(0,50)	(0,22)

3.2 Agronomic parameters

3.2.1 Plant height and number of leaves

Figure 3 shows the effect of the three doses of liquid compost on the growth parameters (height and number of leaves) of the carrot. The results indicate that the control (T0) has the lowest average height, significantly lower than the height of the plants in treatments T1, T2 and T3, whose average heights are 62.72±2.81 cm, 68.17±9.40 cm and 63.45±3.70 cm respectively. However, no significant difference was observed with these three treatments according to the Student-Newman-Keuls test at the 5% threshold.

Regarding the number of leaves, the mean values for the number of leaves obtained show that treatments T1, T2 and T3, with respective values of 7.87±1.11, 8.55±0.70 and 7.75±1.06, are not significantly different at the 5% threshold, although treatment T2 recorded the highest mean number of leaves. The control (T0) gave the lowest value of 6.12±0.49 leaves per plant.

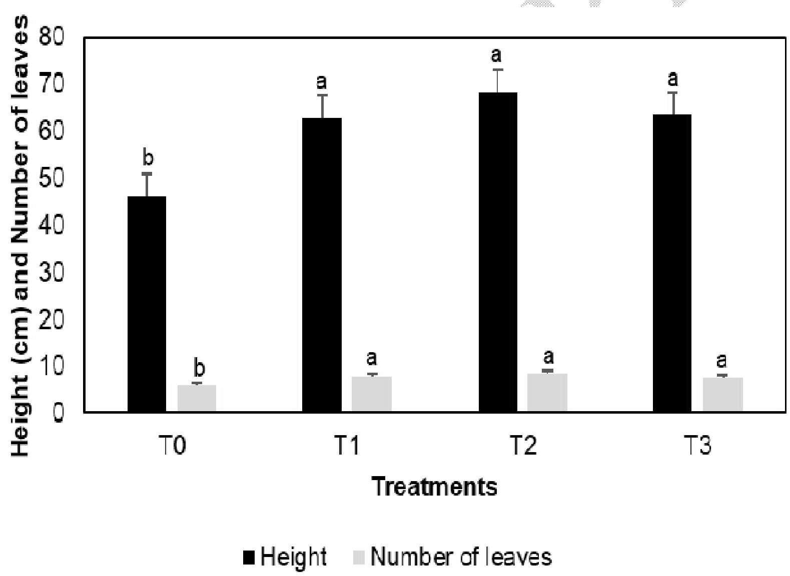

Figure3: Effectsofthethree doses ofliquidcompostoncarrotgrowthparameters (height and number ofleaves).Meansfollowedbythesamealphabeticallettersarenotsignificantlydifferentatthe5%threshold using theStudentNewman-Keulstest.

T0:controlwithnofertiliserapplied;T1:fertiliserappliedat0.5%;T2:fertiliserappliedat5%;T3:fertiliserappliedat 10%

3.2.2 Root length and diameter

Analysisofthemeanvaluesforrootlengthanddiametershowsasignificantdifference betweentreatmentsaccordingtotheStudent-Newman-Keulstestatthe5%threshold(Figure4). The T0 treatment had shorter core lengths and diameters (8.20±1.36cm and15.73±0.76mm respectively). Treatment (T2) gave the highest mean root length and diameter values (15.67±2.10cm; 28.38±1.99mm). However, it is statistically identical to treatments T1 and T3, which respectively have 14.02±0.39cm; 26.25±2.69mm and 13.37±2.01cm; 27.15±3.23mm.

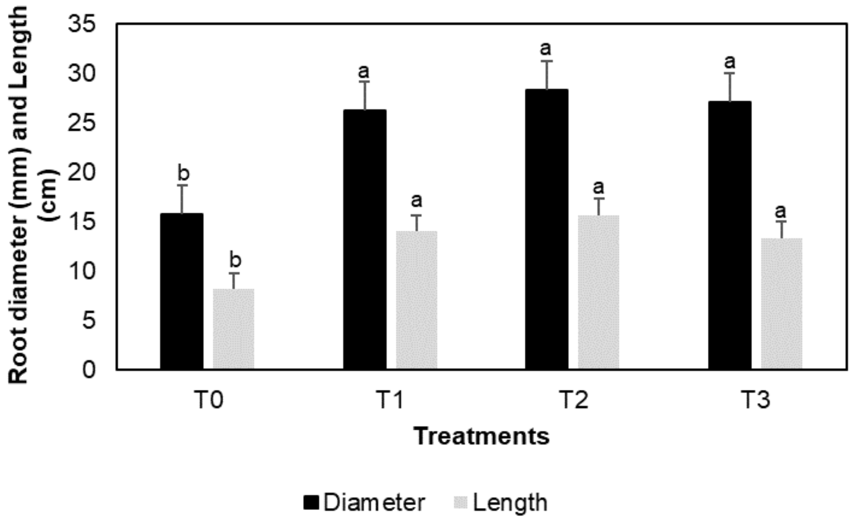

Figure 4: Effects of the three doses of liquid compost on root diameter and length.

Meansfollowedbythesamealphabeticallettersarenotsignificantlydifferentatthe5%thresholdusingtheStudentNewman - Keulstest.T0:control with no fertiliser applied; T1: fertiliser applied at 0.5%; T2: fertiliser applied at 5%.T3:10%fertiliserapplied

3.2.3 Plant yields

Liquid compost had very highly significant effects on carrot yield at harvest (Figure 5), with the highest yield obtained with treatment T2 (27.25 $t.ha^{-1}$). However, no significantdifference at the 5% threshold was observed with treatments T1 and T3 (19.5 t/ha; 22.5 t/ha respectively).Thesetreatmentsgivehigheryieldsthanthecontrol,whichhasanaverageyield of 9.25 $t.ha^{-1}$.

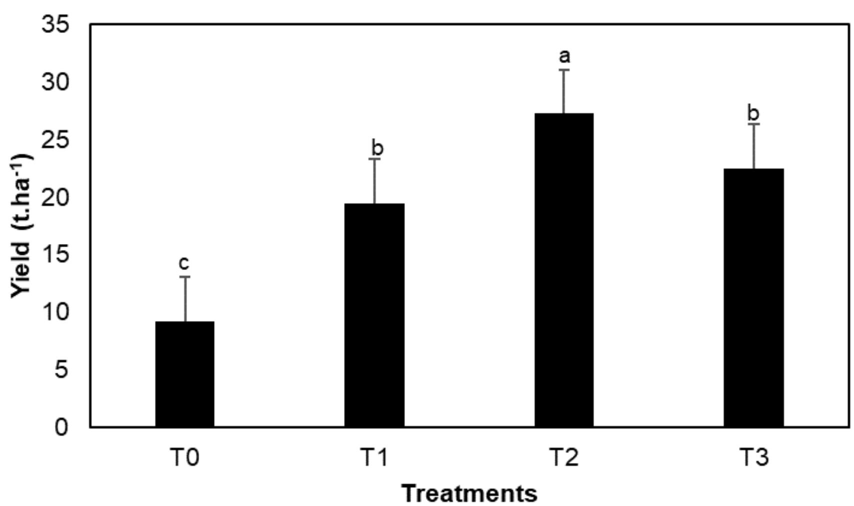

Figure5:Effectsofdifferentdosesofliquidcompostoncarrotrootyield.

Meansfollowedbythesamealphabetical letters are not significantly different at the 5% threshold using the Student Newman - Keuls test. T0: control with no fertiliserapplied; T1: fertiliser applied at 0.5%; T2: fertiliser applied at 5%; T3: fertiliser applied at 10%.

3.3 Physico-chemical parameters of core samples

The results of the physico-chemical parameters are presented in Table 4.They concern the moisture content, hydrogen potential and total acidity of the cores from the different treatments.

The moisture content of the carrots varied between 80.32 and 81.39%.Details of these data show that the rates are significantly different, according to the Student-Newman-Keuls test at the 5% threshold. The lowest moisture content was recorded with treatment T3(80.32±0.23%) and the highest with treatment T2 (81.39±0.54%).Treatments T0 and T1 obtained water contents (80.76±0.47% and 81.12±0.82% respectively) that were statistically identical. Their moisture contents were intermediate between those of the other two treatments.

The pH values of the carrots measured in the four treatments ranged from 5.31 to 5.49. The analysis of variance, using the Student-Newman-Keuls test with a threshold of 5%, revealed that there was no significant difference between the treatments regarding these values.

Analysis of the total acidity results showed that at least two treatments were significantly different in terms of their respective values. The highest value (495±90 µmol H^+ /g) was recordedin treatment T3.This treatment differs significantly fromthe other treatments, which have statistically identical values (T0=270±103 µmol H^+ /g; T1=225±90 µmol H^+ /g; T2=315±90 µmol H^+/g).

Table 4: Average values for physico-chemical parameters of cores according to treatment.

Treatments	Humidity level (%)	Hydrogen potential (pH)	Total acidity (µmol H^+/g)
T0	80.76±0.47^{ab}	5,31±0,21^{a}	270±103,92^{b}
T1	81.12±0.82^{ab}	5,43±0,27^{a}	225±90,00^{b}
T2	81,39±0,54^{a}	5,31±0,11^{a}	315±90,00^{b}
T3	80,32±0,23^{b}	5,49±0,33^{a}	495±90,00^{a}

Means followed by the same alphabetical letters are not significantly different at the 5% threshold using the Student Newman- Keuls testT0: control with no fertiliser applied; T1: fertiliser applied at 0.5%; T2: fertiliser applied at 5%; T3: fertiliser applied at 10%.

4. DISCUSSION

4.1 Influence of application rates on carrot agronomic parameters

The different doses of liquid compost applied had a significant effect on the agronomic parameters of the carrot, namely the number of leaves, plant height, length and diameter ofthe carrots, with the highest values under treatment T2. This implies that the nutrient composition of the liquid compost would be sufficient for soil fertilization under carrot cultivation [16]. In fact, the high nitrogen content of poultry droppings, an essential element for plant development [17], shows a significant contribution of this nutrient to the solution.In addition, the different doses (treatments) had very significant effects on carrot yield. The highest carrot yield was observed with treatment T2 (compost diluted to 5%). The yield with treatments T1 (compost diluted to 0.5%) and T3 (compost diluted to 10%) was not significantly different at the 5% threshold.

The decrease in carrot production under treatment T3 could be explained by the excess nitrogen in this treatment, which was detrimental to the carrot [18].According to Sapkota*et al* [19], fertilization must be measured and limited to avoid excess nitrogen. In this respect, Albornoz[20] have indicated that excessive nitrogen input can lead to a reduction in yield, due to increased development of the stems to the detriment of the leaves. Excess nitrogen in the soil also leads to deficiencies in potassium, calcium, magnesium and other nutrients essential for plant growth. It also leads to a loss of biodiversity, as in the case of mycorrhizal fungi in the root zone. Yet these fungi enable plants to assimilate nutrients more efficiently, since symbiosis with mycorrhizae plays an essential role in phosphorus supply.

In addition, concerns about protecting the environment against the possibility of nitrate pollution of the soil and its accumulation in plants could not suggest such a rate for sustainable carrot production[21, 22]. These results could also be linked to the fertigation method of fertilizer application, which would probably have resulted in a large loss of nutrients through leaching and volatilization in the form of NH_3. A reasonable application of this type of organic fertilizer preparation enriched with poultry droppings at a dose of 5% would make sense for the market gardener.

4.2 Effect of different treatments on physico-chemical parameters

Regular doses of compost improved the quality of carrot physico-chemical properties[16; 23-25]. The moisture content of the carrots obtained in this study was similar to that observed in the literature [26-27]. This good moisturecontent could be explained by the regular supply of water through irrigation, which ensures healthy hydration of the roots. The higher themoisture content, the better the carrot can be stored over a long period (> 6 months) without dehydration. In this respect, the rates obtained with treatment T2 seem to indicate that this dose would be suitable for growing carrots under our experimental conditions.

The hydrogen potential (pH) of the cores indicated that the cores were not very acidic, according to the scale of hydrogen potentials of products [28-29]. In addition, the total acidity values ranged from 225 µmol H^+/g to 495µmol H^+/g, whereasCoulibaly *et al.*[30] and Abbas and Khoudi[31],whohadworkedoncarrotleachate,reportedatitratableacidityofaround200µmolH^+/g. The difference between the total and titratable acidity of carrots is due to the difference in titratable acids, namely ascorbic acid and glutamic acid [28].

5. CONCLUSION

This study was initiated to evaluate the effect of different doses of liquid compost on carrot yield. Agronomic parameters such as height, number of leaves per plant, root diameter and length, and carrot yield were determined. Physico-chemical analysis showed that the soil atthe experimental site is acidic and very poor in organic and mineral elements. In addition, applying compost made from poultry droppings to the soil considerably improved the growth and yield of the carrot plants, starting at a minimum dose of 0.5%. The optimum dose, which gave the best yields (27.5±1.29 $t.ha^{-1}$), wastreatment T2 (5% dilutedsolution). Thisdose had very marked positive effects on the carrot root system. In addition, this dose would be at alow dilution before irrigating the plants, which could be beneficial for all farmers.Last but not least, urban agriculture helps transform degraded areas into green, horticultural spaces. It also enables organic matter to be recycled through composting. However, organic farming emphasizes product quality and respect for the environment, as observed in the results obtained in this study with organic fertilizers. In addition, the results obtained from this study are encouraging and show that T2 treatment could be recommended to growers as an alternative to chemical fertilizers for optimum yield. However, further studies could be carried out on the after-effects of using liquid organic fertilizer, as well as the environmental implications of this fertilizer.

ACKNOWLEDGMENT

This study was financially supported by Ministry of Higher Education and Scientific Research of Côte d'Ivoire through the research grants program. We also thank Professor KOUAKOU Tanoh Hilaire and Dr YAO Koffi Bertin, for their comments and discussions on this manuscript. Authors are grateful to the editor and the two reviewers for their contributions to improve the quality of the manuscript.

DISCLAIMER (Artificial intelligence)

Authors hereby declare that NO generative AI technologies such as Large Language Models and text-to-image generators have been used during writing or editing of manuscripts.

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