

# Organic fertilizer improves soil fertility and enhances carrot (*Daucus carota*) productivity and quality in southern Côte d'Ivoire.

## ABSTRACT

In a context of agricultural resilience to climate change, a strategy of replacing chemical fertilisers with organic fertilisers has been adopted in order 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 at 0.5% (T1), 5% (T2) and 10% (T3)), were tested under a carrot (*Daucus carota*) crop. The results show that yields varied significantly according to the different doses applied. High carrot yields of  $27.5 \pm 1.29 \text{ t}\cdot\text{ha}^{-1}$  were obtained with treatment T2. However, plant growth indicators (plant height, number of leaves, root length and diameter) were similar for the three treatments T1, T2 and T3.

**Keywords:** biofertiliser, yield, *Daucus carota*, organic farming, Côte d'Ivoire.

## 1. INTRODUCTION

Urban agriculture plays a key role in mitigating climate change by reducing carbon footprints through local production and short supply chains, promoting biodiversity, saving water and greening urban spaces. In several West African countries, urban agriculture plays also an essential role by feeding local residents, creating jobs and social ties, and creating islands of coolness in cities. However, with ever-increasing pressure on land due to rapid urbanization, urban agriculture is increasingly facing difficulties, resulting in the loss of arable land and soil artificialization [1].

Soil artificialization is defined as transformation of agricultural, natural or forested land by development actions, which 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 [2]. This process induces decline in urban soil fertility [3]. Thus, to restore the fertility of these urban soils and their ability to sustain agricultural production, some farmers use massive chemical inputs (fertilizers and biocides) [4]. 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 organic fertilizers and/or in association with soil biological engineers for soil fertility enhancement. In these agricultural models, soil fertility management is therefore supported by the use of organic matter from composted agricultural or urban organic waste, which improves soil properties, strongly affects nutrient storage and its availability in soils, increases yield in addition to the reduction of the risk of soil and water pollution [5]. However, the usage of untreated organic fertilizers arising from the excreta of the parasites' definitive hosts either man or animal pollutes the urban agricultural soil and is reflected in its products of vegetables and green fodders causing serious health problems [6]. Consequently, as an alternative to untreated organic fertilizers, studies recommend the use of plants known for their beneficial medicinal effects for soil quality control. It has been demonstrated that medicinal plants

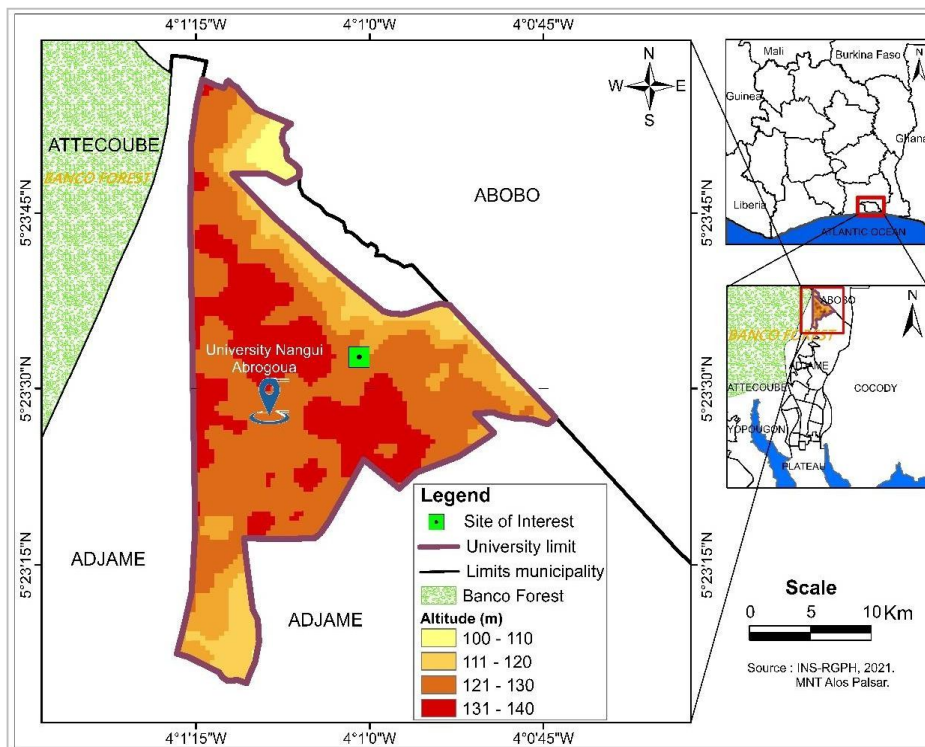
reduce the risk of crop attack or parasitic infestation [7, 8]. Some studies indicated that these plants are generally used toward off predators (aromatic insect repellent plants) and fortify the plantation, increase resistance to pests and diseases. Species, such as *Crotalaria juncea*, also help to improve the fertility of degraded soils and increase crop yields [9]. 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 fertilizers and these plants for soil quality assessment remain unexplored in urban agrosystem.

This study is part of the overall context of setting up an organic vegetable production mechanism using liquid compost 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 [10]. 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 ferralsol in Abidjan.

## **2. MATERIAL AND METHODS**

### **2.1 Description of the study area**

The study was conducted at the experimental site of the Nangui Abrogoua University (UNA) in Abidjan, southern Côte d'Ivoire. The geographical coordinates of the study site are 5°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%. The basic vegetation consists of dense forests, subdivided into mesophilic and hydrophilic forests. Finally, the geology is dominated by Neogene sediments, of continental origin, 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.



**Figure1:** Location of the study site in the district of Abidjan

## 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<sup>®</sup> based in Abidjan. The characteristics and agronomic performance of the variety are given in Table 1.

**Table1:** Characteristics of carrots

Variety	Type of soil	Cycle (days)	Yield (t.ha <sup>-1</sup> )	Agronomic characteristics	Fruit characteristics
Amazonia	Sandy-silty, silty-sandy and sandy-clay, rich in well-decomposed organic matter and nutrients	90-95	20-40	Good tolerance to alternaria	Conical, 16-18cm, deep orange 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 in a 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 set-up

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

- T0: treatment with no solution added (control)
- T1: treatment 1, 0.5% diluted solution
- T2: treatment 2, 5% diluted solution
- T3: treatment 3, 10% diluted solution

### 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 a 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 a distance of 20 cm between rows and 10 cm between 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 first application of fertilizer solution. Manual weeding was carried out every week. 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 m x 0.5 m 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 following formula:

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

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 Duffouret *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 whatman paper 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 total acidity for each treatment was obtained using the following equation:

$$C_{H^+} = \frac{v_e \times v_1}{m \times v_0}$$

with  $C_{H^+}$ : concentration of  $H^+$  in ( $\text{mol.g}^{-1}$ ),  $v_0$ : 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  $pH_{\text{eau}}$ , 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 ANOVA variance ratio. Statistical analyses were carried out using JMP software (version 13). 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 a mediocre level of fertility for this soil.

**Table 2:** Characteristic elements of the initial soil samples from the experimental site

Clay	Silt	Sand	MO	C.org	Ntot	Ptot	Ca	Mg	K	Na	pH
----- (%) -----							----- $\text{cmol}^+ . \text{kg}^{-1}$ -----				

19,58	5,15	75,27	5,10	2,27	0,04	0,72	0,50	0,59	0,05	0,03	5,30
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The chemical composition of the liquid compost is given in Table 3. The results show that 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.

**Table 3:** Chemical analysis of liquid compost.

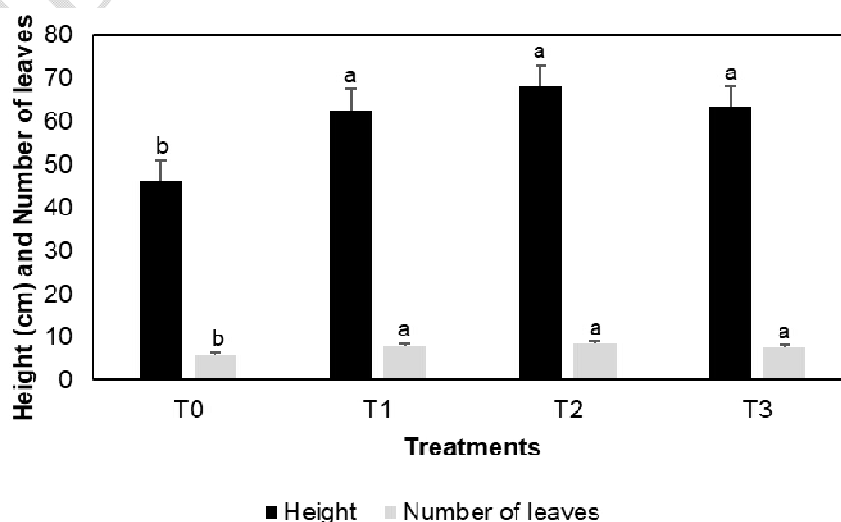
Dry residue	pH	N	P	K	Ca	Mg
(%)		-----				
1,02	7,51	5,95	4,07	4,36	2,93	3,83
0,36	0,14	0,86	0,87	0,60	0,50	0,22

## 3.2 Agronomic parameters

### 3.2.1 Plant height and number of leaves

Figure 2 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  $62.72 \pm 2.81$  cm,  $68.17 \pm 9.40$  cm and  $63.45 \pm 3.70$  cm respectively. However, no significant difference was observed with these three treatments according to the Student-Newman-Keuls test at the 5% threshold.

With regard to the number of leaves, the mean values for the number of leaves obtained show that treatments T1, T2 and T3, with respective values of  $7.87 \pm 1.11$ ,  $8.55 \pm 0.70$  and  $7.75 \pm 1.06$ , 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  $6.12 \pm 0.49$  leaves per plant.

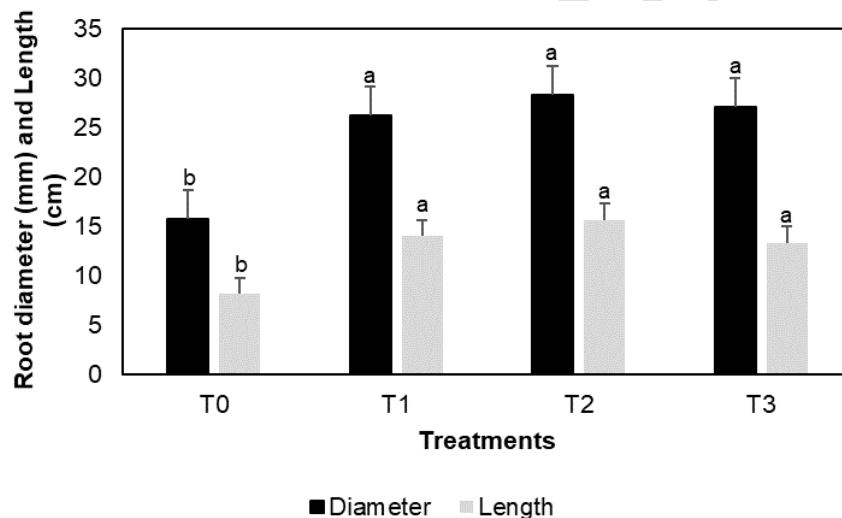


**Figure2:** Effects of the three doses of liquid compost on carrot growth parameters (height and number of leaves). Means followed by the same alphabetical letters are not significantly different at the 5% threshold using the Student Newman-Keulstest.

T0: control with no fertiliser applied; T1: fertiliser applied at 0.5%; T2: fertiliser applied at 5%; T3: fertiliser applied at 10%

### 3.2.2 Root length and diameter

Analysis of the mean values for root length and diameter shows a significant difference between treatments according to the Student-Newman-Keulstest at the 5% threshold (Figure 3). The T0 treatment had shorter core lengths and diameters ( $8.20 \pm 1.36$  cm and  $15.73 \pm 0.76$  mm respectively). Treatment (T2) gave the highest mean root length and diameter values ( $15.67 \pm 2.10$  cm;  $28.38 \pm 1.99$  mm). However, it is statistically identical to treatments T1 and T3, which respectively have  $14.02 \pm 0.39$  cm;  $26.25 \pm 2.69$  mm and  $13.37 \pm 2.01$  cm;  $27.15 \pm 3.23$  mm.

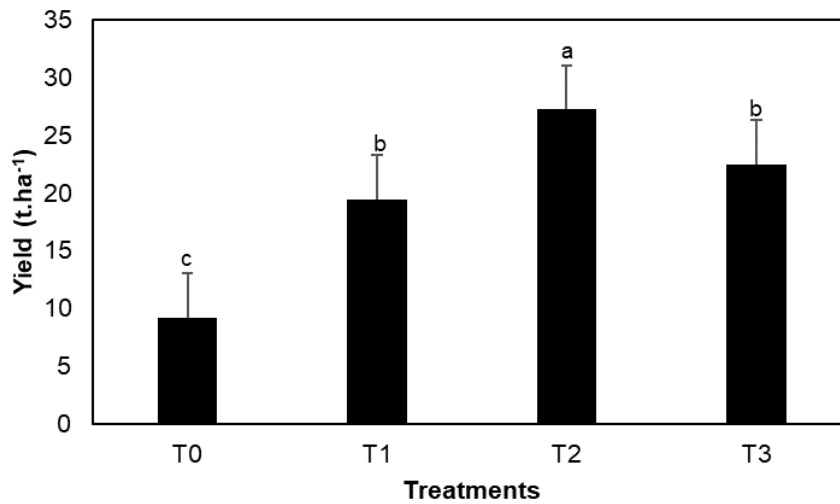


**Figure 3:** Effects of the three doses of liquid compost on root diameter and length.

Means followed by the same alphabetical letters are not significantly different at the 5% threshold using the Student Newman-Keulstest. T0: control with no fertiliser applied; T1: fertiliser applied at 0.5%; T2: fertiliser applied at 5%. T3: 10% fertiliser applied

### 3.2.3 Plant yields

Liquid compost had very highly significant effects on carrot yield at harvest (Figure 4), with the highest yield obtained with treatment T2 ( $27.25 \text{ t} \cdot \text{ha}^{-1}$ ). However, no significant difference at the 5% threshold was observed with treatments T1 and T3 ( $19.5 \text{ t/ha}$ ;  $22.5 \text{ t/ha}$  respectively). These treatments give higher yields than the control, which has an average yield of  $9.25 \text{ t} \cdot \text{ha}^{-1}$ .



**Figure 4:** Effects of different doses of liquid compost on carrot root yield.

Means followed by the same alphabetical letters are not significantly different at the 5% threshold using the Student Newman-Keuls test. T0: control with no fertiliser applied; 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 with regard to 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<sup>+</sup>/g) was recorded in treatment T3. This treatment differs significantly from the other treatments, which have statistically identical values (T0=270±103 μmol H<sup>+</sup>/g; T1=225±90 μmol H<sup>+</sup>/g; T2=315±90 μmol H<sup>+</sup>/g).

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

Treatments	Humidity level (%)	Hydrogen potential (pH)	Total acidity (μmol H <sup>+</sup> /g)
T0	80.76±0.47 <sup>ab</sup>	5,31±0,21 <sup>a</sup>	270±103,92 <sup>b</sup>
T1	81.12±0.82 <sup>ab</sup>	5,43±0,27 <sup>a</sup>	225±90,00 <sup>b</sup>
T2	81,39±0,54 <sup>a</sup>	5,31±0,11 <sup>a</sup>	315±90,00 <sup>b</sup>

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T3	80,32±0,23 <sup>b</sup>	5,49±0,33 <sup>a</sup>	495±90,00 <sup>a</sup>
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Means followed by the same alphabetical letters are not significantly different at the 5% threshold using the Student Newman-Keuls test. T0: control with no fertiliser applied; T1: fertiliser applied at 0.5%; T2: fertiliser applied at 5%; T3: fertiliser applied at 10%.

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## 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 of the 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 [11]. In fact, the high nitrogen content of poultry droppings, an essential element for plant development [12], 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 [13]. According to Sapkota *et al.* [14], fertilization must be measured and limited to avoid excess nitrogen. In this respect, Albornoz [15] 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. 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 [16, 17]. 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  $\text{NH}_3$ . 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 [11; 18-20]. The moisture content of the carrots obtained in this study was similar to that observed in the literature [21-22]. This good moisture content could be explained by the regular supply of water through irrigation, which ensures healthy hydration of the roots. The higher the moisture 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 [23-24]. In addition, the total acidity values ranged from 225  $\mu\text{mol H}^+/\text{g}$  to 495  $\mu\text{mol H}^+/\text{g}$ , whereas Coulibaly *et al.* [25] and Abbas and Khoudi [26], who had worked on carrot leachate, reported a titratable acidity of around 200  $\mu\text{mol H}^+/\text{g}$ . The difference between the total and titratable acidity of carrots is due to the difference in titratable acids, namely ascorbic acid and glutamic acid [26].

## 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 at the 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 ( $27.5 \pm 1.29 \text{ t} \cdot \text{ha}^{-1}$ ), was treatment T2 (5% diluted solution). This dose had very marked positive effects on the carrot root system. In addition, this dose would be at a low dilution before irrigating the plants, which could be beneficial for all farmers.

## REFERENCES

1. Wadumestrigé Dona CG, Mohan G, Fukushi K. Promoting Urban Agriculture and Its Opportunities and Challenges - A Global Review. *Sustainability*. 2021;13 (17), 9609. <https://doi.org/10.3390/su13179609>.
2. Christel A, Dequiedt S, Chemidlin-Prevost-Bouré N, Mercier F, Tripied J, Comment G, Djemiel C, Bargeot L, Matagne E, Fougeron A, Passi JBM, Ranjard L, Maron PA. Urban land uses shape soil microbial abundance and diversity, *Science of The Total Environment*. 2023; 883, 163455, <https://doi.org/10.1016/j.scitotenv.2023.163455>.
3. Sofo A, Zanella A & Ponge JF. Soil quality and fertility in sustainable agriculture, with a contribution to the biological classification of agricultural soils. *Soil Use and Management*. 2022 ; 38(2), 1085-1112. <https://doi.org/10.1111/sum.12702>.
4. Dumat C, Pierart A, Shahid M, Khalid S. Pollutants in urban agriculture: sources, health risk assessment and sustainable management. In: *Bioremediation of Agricultural Soils*. CRC Press. 2019; 61-84.
5. Ayilara MS, Olanrewaju OS, Babalola OO, Odeyemi O. Waste management through composting: Challenges and potentials. *Sustainability*. 2020; 12, 4456. <https://doi.org/10.3390/su12114456>.
6. Rashmi I, Roy T, Kartika KS, Pal, Coumar V, Kala S, Shinoji KC. Organic and inorganic fertilizer contaminants in agriculture: Impact on soil and water resources. *Contaminants in Agriculture: Sources, Impacts and Management*. 2020; 3-41. [https://doi.org/10.1007/978-3-030-41552-5\\_1](https://doi.org/10.1007/978-3-030-41552-5_1).
7. Phokwe OJ, Manganyi MC. Medicinal plants as a natural greener biocontrol approach to “The Grain Destructor” Maize Weevil (*Sitophilus zeamais*) Motschulsky. *Plants*. 2023; 12(13), 2505. <https://doi.org/10.3390/plants12132505>.
8. Greff B, Sáhó A, Lakatos E, Varga L. Biocontrol activity of aromatic and medicinal plants and their bioactive components against soil-borne pathogens. *Plants*. 2023; 12(4), 706. <https://doi.org/10.3390/plants12040706>.
9. de Brito LDCR, de Souza HA, de Araújo Neto RB, de Azevedo DMP, Sagrilo E, Vogado RF, Pereira SC, de Melo FAC, Cavigelli MA. Improved soil fertility, plant nutrition and grain yield of soybean and millet following maize intercropped with forage grasses and crotalaria in the Brazilian savanna. *Crop and Pasture Science*. 2023; 74, 438-448. <https://doi.org/10.1071/CP22251>.
10. De Corato U. Agricultural waste recycling in horticultural intensive farming systems by on-farm composting and compost-based tea application improves soil quality and plant health: A review under the perspective of a circular economy. *Science of the Total Environment*. 2020; 738, 139840.

<https://doi.org/10.1016/j.scitotenv.2020.139840>

11. Valšíková-Frey M, Kačániová M, Ailer Š. Influence of organic fertilizers on carrot yield and quality. *International Journal of Scientific Research*. 2021; 12, 42195-42200.
12. Drózdž D, Malińska K, Wystalska K, Meers E, Robles-Aguilar A. The influence of poultry manure-derived biochar and compost on soil properties and plant biomass growth. *Materials*. 2023; 16, 6314. <https://doi.org/10.3390/ma16186314>.
13. Yadav M, Ghimire S, Dhital M, Tharu RK. Response of carrot (*Daucus carota* Linn.) to different doses and sources of nitrogen in Sindhuli, Nepal. *Fundamental and Applied Agriculture*. 2023; 8, 717-729. <https://doi.org/10.5455/faa.169660>.
14. Sapkota TB, Singh B, Takele R. Improving nitrogen use efficiency and reducing nitrogen surplus through best fertilizer nitrogen management in cereal production: The case of India and China. *Advances in Agronomy*. 2023; 178, 233-294. <https://doi.org/10.1016/bs.agron.2022.11.006>.
15. Albornoz F. Crop responses to nitrogen overfertilization: A review. *Scientia horticulturae*. 2016; 205, 79-83. <https://doi.org/10.1016/j.scienta.2016.04.026>
16. Mustafa G, Hayat N, Alotaibi BA. Chapter fifteen - How and why to prevent over fertilization to get sustainable crop production. Editor(s): T. Aftab, K. R. Hakeem, *Sustainable Plant Nutrition*, Academic Press. 2023; 339-354. <https://doi.org/10.1016/B978-0-443-18675-2.00019-5>
17. Penuelas J, Coello F, Sardans J. A better use of fertilizers is needed for global food security and environmental sustainability. *Agriculture & Food Security*. 2023 ; 12, 1-9. <https://doi.org/10.1186/s40066-023-00409-5>.
18. Djoufack MMT, Kouam EB, Foko EMK, Anoumaa M, Kaktcham PM, Zambou FN. Sensory quality and nutritional composition of carrot (*Daucus carota* L.) genotypes as affected by fertilization in production system in Cameroon. *CABI Agriculture and Bioscience*. 2023; 4, 22. <https://doi.org/10.1186/s43170-023-00166-2>
19. Kuma A. Effect of Different Types of Organic Manures and Mulching Materials on Growth, Yield and Quality of Carrot (*Daucus carota* L.) in DigunaFango District, South Ethiopia. 2023; 33. <http://dx.doi.org/10.2139/ssrn.4851877>.
20. Singh P, Kerketta A, Bahadur V, Topno SE. Response of NPK and organic manures on growth, and root, yield of carrot (*Daucus carota* L.) cv. Nantes. *International Journal of Environment and Climate Change*. 2023; 13, 3432-3437. doi: [10.9734/ijecc/2023/v13i103012](https://doi.org/10.9734/ijecc/2023/v13i103012).
21. Md Saleh R, Kulig B, Hensel O & Sturm B. Investigation of dynamic quality changes and optimization of drying parameters of carrots (*Daucus carota* var. laguna). *Journal of Food Process Engineering*. 2020; 43(2), e13314. <https://doi.org/10.1111/jfpe.13314>.
22. Boadi NO, Badu M, Kortei NK, Saah SA, Annor B, Mensah MB, Okyere H, Fiebor A. Nutritional composition and antioxidant properties of three varieties of carrot (*Daucus carota*). *Scientific African*. 2021; 12, e00801. <https://doi.org/10.1016/j.sciaf.2021.e00801>.
23. Kaur A, Singh Sogi D. Influence of development stages on the physicochemical properties of black carrots (*Daucus carota* L.). *Cogent Food & Agriculture*. 2020; 6, 1841358. <https://doi.org/10.1080/23311932.2020.1841358>
24. Pandey P, Grover K, Dhillion TS, Kaur A, Javed M. Evaluation of polyphenols enriched dairy products developed by incorporating black carrot (*Daucus carota* L.) concentrate. *Heliyon*.

2021; 7. <https://doi.org/10.1016/j.heliyon.2021.e06880>.

25. Coulibaly LF, Touré A, Siéné LAC, Coulibaly NA, SORO YR. Physicochemical and Nutritional Properties of Varieties of Carrot (*Daucus carota*) grown in Region of Korhogo, North of Côte d'Ivoire. International Journal of Environment, Agriculture and Biotechnology. 2018; 3, 792-798. <http://dx.doi.org/10.22161/ijeab/3.3.11>.

26. Abbas S, Khoudi A. Essai de formulation d'une boisson à base de fruits (orange, citron et pomme) et légumes (concombre et carotte) au niveau de NCA Rouïba. Mémoire de Master, Université M'Hamed Bougara Boumerdes, République Algérienne Démocratique et Populaire. 2016 ; 68.

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