Original Research Article

The Combination of Compost Derived Poultry Litter and Vivianite Powder: Appropriate Biological Fertilizer to Improve the Growth and Root Yield of *Daucus carota* L. in the Northern Cameroon

Abstract

Carrot (*Daucus carota* L.) is the most consumed root vegetable in the world. Carrot growers generally uses chemical fertilizers to improve carrot productivity. This study aims to improve the growth potential of carrot in the Northern Cameroon while limiting the use of chemical inputs. The experiment was conducted under field conditions at Maroua and Ngaoundere, respectively in the agro-ecological zone I and II, and during the two consecutive cropping seasons of 2019 and 2020. Results indicate that carrot root growth and production varied depending on fertilizer, agroecological zone and the year of experimentation. Globally, treated plant by the combination of 1 Kg of poultry litter with 10 g of vivianite powder (F1+P10) exhibited significantly ($p<0.05$) the highest growth (plant height, number of leaves per plant) and production parameters (root lenght, root diameter, root dry biomass, root yield). F1+P10 fertilizer increased the foliar production at 60% and 69%, compared to no treated plants in Ngaoundere and Maroua rspectively. This fertilizer increased the root yield at 2% and 41% compared to T+ in Ngaoundere and Maroua respectively in 2019, and at 26% and 68% compared to no treated plants respectively in 2020. The application of the combination of 1 kg of poultry litter and 10 g of vivianite powder per hole at sowing for carrot growth would contribute to improve this root vegetable, to valorize our local material in agriculture while ensuring sustainable agriculture. However, the effect of this natural fertilizer on the nutritional values of carrot needs to be assessed.

Key Word: *Daucus carota* L., Poultry litter, vivianite powder, growth, yield

Comment [U1]: Excellent and great work

Comment [U2]: At least 5 keywords

1.Introduction

Carrot (*Daucus carota* L.) among in the Apiaceae family. It is the most world production root vegetable [1]. Carrot roots are often eaten raw or grated. Carrot is beneficial to health. It represents an interesting food for their content of antioxidant compounds, mainly anthocyanins or chlorogenic acid as well as carotenoids [2]. The high carotenoids content, especially β-carotene is interesting because it is transformed by the human metabolism into vitamin A. Carrots are also a source of many other important compounds and nutrients, including polyphenols, lutein, alpha-carotene, fiber, carbohydrates, vitamins B and C [3]. They are also an excellent source of minerals such as Ca, P, Fe, Na, Cu, Zn and Mg [4].

Carrot is the most consumed root vegetable in the world [5]. Its global production reached 35.5 million tons on 1.2 million hectares through the world in 2013 [6]. The European Union (5.2 million tons) is the second largest producer worldwide after China (18.8 million tons) (FAO, 2014). In India, carrot is grown on an area of 22,538 ha, with an annual production of 4.14 t/ha [7]. In Bangladesh, it is grown on an area of 846 ha with an average annual production of 7.51 t/ha [8]. In Africa, this vegetable crop is widespread in Algeria, Niger, Senegal, Cameroon and several other countries. Morocco is the most African countries carrot producer with a production of 32.38 t/ha on an area of 14,749 hectares. Carrot production is low in Cameroon, however Cameroon exports carrots to Europe (Belarus, Belgium), Gabon, Chad, Congo Brazzaville, CAR, and Equatorial Guinea [9]. Current studies on carrot aim to improve carrot growth and roots nutritional values. [10] studied the influence of poultry litter and NPK (17-17-17) mineral fertilizer on carrot growth in Rwanda and reported that the combination poultry litter and chemical fertilizer has a significant positive effect on carrot productivity. The studies of [11] on organic manure and inorganic fertilizers for sustainable carrot production in Nigeria showed that the application of nitrogen, phosphorus and organic manure significantly increase the agronomic parameters. Indeed, [12], evaluated the effect of levels of nitrogen on carrot productivity in Debigonj, Panchagorh and reported that the application of 100 kg N/ha of this fertilizer improves growth.

The peasant from Cameroon generally uses chemical fertilizers to improve crop production, but their high cost and unavailability make them almost inaccessible to smallholder farmers [13]. In addition, its exclusive use increased soil degradation [14]. In this context, the implementation of low-cost agricultural practices aimed at increasing agricultural production and based on the respects of ecological functionalities is necessary [15]. Our previous studies on field productivity of carrot in Adamawa Cameroon revealed that the application of 1 Kg of compost derived poultry litter per hole better improve carrot growth [16].

To the best of our knowledge, no study has been conducted on the combination of poultry litter and rock powders on carrot productivity in the Northern Cameroon. By using poultry litter and rock powders (vivianite and pyroclasticss powders) for carrot growth, we contribute to solve the problem of soil deficiency in mineral elements, to improve carrot productivity, to valorize the rock deposits and animal wastes that abound the Northern Cameroon while protecting the environment.

The use of fertilizers rich in mineral elements is important for plant production [17]. Poultry litter is less expensive in the Cameroonian market and is known to be an effective resource for fertility maintenance, providing the soil with a wide range of mineral elements [18, 19, 20]. This organic fertilizer reduces losses due to plant pests [21], improves plant growth and production parameters [20, 22]. Organic amendments such as animal wastes play a major role in maintaining soil fertility and consequently in the sustainability of agricultural production [23]. In addition, the Adamaoua region of Cameroon is rich in geominerals like vivianite and pyroclasticss. The beneficial effect of vivianite powder on agricultural production has been demonstrated [16, 24, 25]. Vivianite is very rich in iron and phosphorus $(Fe_3(PO_4)_28H2O)^8$ [26]. Phosphorus is one of the essential macronutrients for plant growth and development

[27]. It is involved in photosynthesis as an energy fixer and transporter, and its deficiency causes major abiotic stress that limits plant growth and crop productivity on many soils around the world [28]. Basaltic pyroclastics are rich in exchangeable bases (Ca^{2+}, Mg^{2+}, Na^{+}, and K^{+}) [29], and are abundant around Lake Tison in Adamawa, Cameroon.

This study aimed to improve the growth potential of carrot in the Northern part of Cameroon while limiting the use of chemical inputs. The interest of this work was that the natural fertilizer formulation based on vivianite powder, pyroclastics powder and poultry litter that better ensures carrot productivity will be recommended for carrot growth.

2. Material and methods

2.1. Description of experimental areas

The study was carried out within the campus of the University of Ngaoundere (Dang), and at Hardé locality in Maroua for two successive years (2019 and 2020). The climates of Ngaounde and Maroua Cameroon are of the Sudano-Guinean and Sudano-Sahelian type respectively. Table 1 shows some agro-pedological characteristics of the studied sites.

In the Sudano-Guinean zone, the study site located at 7°25'119"’ North latitude, 13°33'415,83" East longitude and altitude 1106 m. The vegetation of the cultivated site is herbaceous savannah dominated by *Imperata cylindrica* and *Pennisetum purpureum*, some shrubs such as *Annona senegalensis*, *Hymenocardia acida* and *Terminalia* spp. The Sudano-Guinean zone is characterized by two seasons of equal length: the rainy season runs from mid-March to mid-September and the dry season from mid-September to mid-March. The rainfall is unimodal and ranged from 1200 to 2000 mm, with an average at 1479 mm. The average temperature ranges between 22 °C and 24 °C [30]

In the Sudano-Sahelian zone, the study site located at 09° 3 '9'" North latitude, 10.32° 13' 4" East longitude and 713 m latitude. The cultivated area was herbaceous savannah dominated by *Imperata cylindrica*. The Sudano-Sahelian climate is characterized by high temperatures (28 ° C average per year) with a large irregular rainfall: the duration of the dry season is higher (from November to June) than that of rainy season (from July to October) [30].

Table 1: Agro-pedological properties of the experimental areas

Parameters	**Zones of studied fields**			
	Ngaoundere		**Maroua**	
	Cropping seasons		**Cropping seasons**	
	2019	**2020**	**2019**	**2020**
Color	reddish brown	reddish brown	White	White
Texture	argillaceous	argillaceous	Sandy	Sandy
pH	6.62±0.07	6.25±0.049	5.96±0.20	6.05±0.25
Cond (µS/cm)	53.70±0.61	53.84±0.47	2.73±0.42	3.27±0.79
MO (%)	15.80±0.51	16.02±0.09	5.3±0.21	4.37±0.86
C (%)	8.6±0.36	8.6±0.01	2.73±0.41	3.27±0.79
N (%)	4.01±0.04	4.06±0.05	0.49±0.08	0.38±0.03
P (%)	1.26±0.01	1.28±0.02	0.94±0.07	1.02±0.11
K (%)	0.8±0.05	0.87±0.05	0.72±0.03	0.71±0.02
C/N	2.07±0.02	2.11±0.04	5.6±0.3	9.53±0.2
Mg (%)	0.34±0.02	0.39±0.01	0.24±0.04	0.21±0.02
Ca (%)	0.25±0.03	0.28±0.01	0.38±0.02	0.4±0.03

2.2. Material

2.2.1. *Daucus carota* seeds

Daucus carota seeds, variety Pamela +, (2.5 millimeters long, dark yellow in color) were used. Seeds were bought on local market of Maroua Cameroon. They are produced by Technisem and then imported and distributed in Cameroon by SEMAGRI. This variety was chosen for its early germination, its presents great adaptability to rainy season and has short development cycle (90 days). Using variety presented short development cycle is beneficial for farmers. So that, they may have several harvests per year if they have off-season crops [31].

2.2.2. Fertlilizers

Fertilizers used include: compost derived poultry litter, rock powders (pyroclastic and vivianite) as well as chemical fertilizer.

2.2.2.1. Compost derived poultry litter

The poultry litter were from the Maroua Zootechnical and Veterinary Center in Missinguileo locality. Before use, the poultry litter was composted (figure 1). The drying was carried out in the open air under the sun for 20 days. The poultry litter were weighed on a scale every 5 days until a constant mass was obtained. Composting experiment was conducted in 5 m^2 area. Composting process took place from February to May 2019 and 2020 (05 months). Composting in pile [32] was used in the process. Herbs and shrubs were removed from the composting area. Then, the site was moistened and watered with1.5 L of bin juice as inoculum. Bin juice is rich in various microorganisms involved in the process of organic matter degradation. Then for pile of compost, 2 Kg of leaves from *Tithonia diversifolia* were spread on the ground. 1.5 L of inoculum is sprayed on these leaves and a layer of raw material (50 Kg) is spread on the moist soil. Finally, 1.5 L of bin juice is sprayed on this layer. After this first arrangement, the pile was watered using water. The same process was repeated three times in order to obtain a pile with 150 Kg weight of biodegradable material weight and 1 m height. Finally, pile was covered with a plastic in order to increase internal temperature of background and to allow the thermophilic microorganisms to enter in activities. Watering and turning took place at regular interval of 10 days to maintain moisture and to ensure good poultry litter degradation [32, 33].

Figure 1: Compost derived poultry litter

2.2.2.2. Rock powders

The mineral fertilisers were the rock powders obtained from vivianite (figure 2) and pyroclastic (figure 3). Vivianite were sampled from the Hangloa Basin located at about 25 km in the Northwest of the city of Ngaoundere. Vivianite rock is characterized by a flttened ellipsoid form with their diameters ranging from 20 cm to more than one meter. The chemical analyses of the powder derived from these rocks were conducted earlier by Yaya *et al*. (2015) and gives the following composition: Fe_2O_3 (68.72%), P_2O_5 (9.17%), Al_2O_3 (7.72%), and SiO_2 (9.67%). Thus, the total phosphorus was estimated at about 671.50 mg/kg while the assimilated phosphorus was around 81.13 mg/kg. Studies carried out by [24] indicated that phosphate contained in this mineral can be solubilized. The basalt pyroclastic was collected around Lake Tyson in Ngaoundere Cameroon.Vivianite and basalt pyroclastic rocks were powdered using hammer, and then powders were sieved (0.3 mm) before using in the field.

Figure 2: Vivianite powder from Hangloa, Cameroon

Figure 3: Pyroclastic from Lake Tison, Cameroon

2.2.2.3. Chemical fertilizer

Chemical fertilizerwas bought on the local market in Maroua, Cameroon. The main nutrients of this fertilizer are N, P and K. It is referred to as NPK (20-10-10) chemical fertilizer, meaning that it contained 20% N, 10% P_2O_5, and 10% K_2O. Peasant from the Northern Cameroon commonly use this chemical fertilizer for carrot growth.

3.3. Methods

3.3.1. Experimental design and treatments

Field experimentation was carried out during two cropping seasons 2019 and 2020 in the both agroecological zones of Northern Cameroon (Sudano-Guinean zone and Sudano-Sahelian zone). In each of the both study areas, the experimental area measured 312 m^2 area (24 m × 13 m). The experimental field was ploughed at 40 cm depth and the elementary units of 2 m^2 area (2 m × 1 m) were formed, 33 experimental units were formed. The space between two consecutive elementary plots in a block was 1 m and two consecutive blocks spaced at 2 m. Two consecutive carrot plants in a plot spaced at 0.2 m × 0.4 m and there were 20 hole per elementary plot. A 11x2 factorial design with 11 fertilizer formulas (10 g of vivianite powder, 15 g of vivianite powder, 10 g of pyroclastic powder, 15 g of pyroclastic powder, 1 Kg of compost derived poultry litter, the combination of 1 Kg of poultry litter with 10 g of vivianite powder, the combination of 1 Kg of poultry litter with 15 g of vivianite powder, the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder, the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder, 10 g of chemical fertilizer NPK 20-10-10 : positive control, negative control) and 02 study area (agro-ecological zone I and agro-ecological zone II of Cameroon) and three replications were used. 02 levels of poultry litter (0 and 1 kg), 03 levels of vivianite powder (0, 10 and 15) and 03 levels of pyroclastic powder (0, 10 and 15) were applied per hole.

3.3.2. Data collection, Sampling and statistical analysis

Fifteen (15) days after sowing, the seedling emergence rate was evaluated. During the vegetative phase, growth parameters (plant height, number of leaves per plant) were evaluated at a regular time interval of 7 days. At maturity, production parameters (root diameter, root lenght, root biomass and root yield (t/ha)) were assessed. 30 carrot plants were sampled.

The results are statically analyzed using Statgraphics plus 5.0 software, which performs analysis of variance (ANOVA). The correlation test was performed to determine the correlation between the different parameters and Duncan's test to judge the difference between the means of the treatments.

3. Results

3.1. Seedling emergence rate at 15 days after sowing

Figure 4 shows the seedling emergence rate of carrot according to fertilizers (10 g of vivianite powder (P10), 15 g of vivianite powder (P15), 10 g of pyroclastic powder (Py10), 15 g of pyroclastic powder (Py15), 1 Kg of compost derived poultry litter (F1), the combination of 1 Kg of poultry litter with 10 g of vivianite powder (F1+P10), the combination of 1 Kg of poultry litter with 15 g of vivianite powder (F1+P15), the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder (F1+Py10), the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder (F1+Py15), chemical fertilizer (T^+), negative control (T^0)), the study area and the year of experimentation.

Carrot plants emerged at 10 days after sowing in all treatments and in each of the both study areas. Statistical analyses revealed a significant effect ($p<0.05$) of fertilizers, the study area as well as the years of experimentation on the seedling emergence of carrot plants at 14 days after sowing. A significant interaction ($p<0.05$) was also observed between fertilization and the experimental zone on the seedling emergence rate as well as between fertilization and the year of study.

Concerning the cropping season 2019, the highest carrot plant emergence rate (58.33 ± 2.88 %) in Ngaoundere is recorded on F1+Py15 plots, while the highest value of this parameter in Maroua is observed on F1+P10 plots (42.77 ± 2.54%). In the Sudano-Guinean savannah zone of Adamaoua Cameroun, F1+Py15 fertilizer increased carrot plant emergence by 36.38% and 38.15% respectively compared to T+ and T0. On the other hand, in the Sudano-Sahelian zone of Far North Cameroon, F1+P10 fertilizer increased seedling emergence by 26.23% and 28.32% compared to T^{+} and T^{0}. The highest seedling emergence rate was observed in the Sudano-Guinean zone (58.33%) compared to the Sudano-Sahelian zone (42.77%). Carrot seedling emergence was 1.36 fold higher in the Adamaoua region than the Far North Cameroon region.

Regarding the 2020 cropping year, the seedling emergence rate of carrot varied from 32.26 ± 2.07% to 47.68 ± 1.50% respectively for T^{0} and F1+P15 in the Maroua region and from 42.57 ± 1.79% for T^{0} to 65.14 ± 1.16% for F1+Py15 in the Ngaoundere region. In the T+ plots, the seedling emergence rate was 35.33 ± 2.08% in the Sudano-Sahelian zone of the Far North and 42.77 ± 0.96% in the Sudano-Guinean zone of Adamawa Cameroon. The seedling emergence rate recorded on F1+P15 from Maroua area was 1.35 and 1.48 fold greater than that from T^{+} and T^{0} treatements respectively. The value of this parameter from Ngaoundere was 1.52 and 1.53 fold greater than that from T^{+} and T^{0} respectively.

The F1+P10, F1+P15 and F1+Py15 fertilizers were the most suitable for carrot seedling emergence in the both study areas. The beneficial effect of these fertilizers on carrot seedling emergence was very important in Adamaoua and during the second cropping season year (2020).

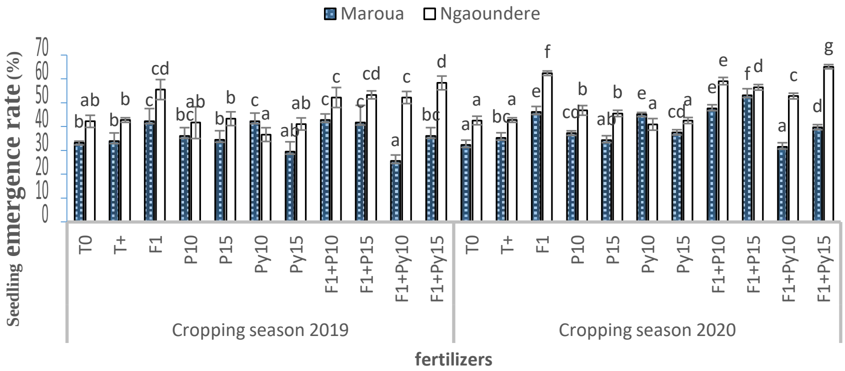


Figure 4 : Seedling emergence of carrot according to fertilizer, study area and experimental year

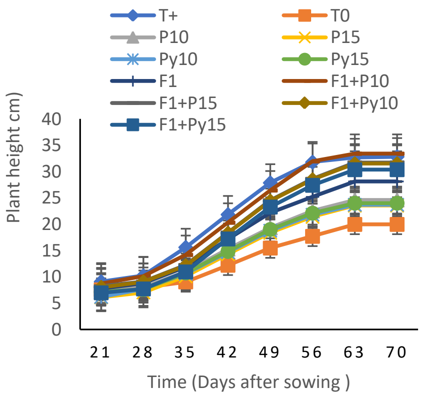
P10 :10 g of vivianite powder, P15: 15 g of vivianite powder, Py10: 10 g of pyroclastic powder, Py15: 15 g of pyroclastic powder, F1: 1 Kg of compost derived poultry litter, F1+P10: the combination of 1 Kg of poultry litter with 10 g of vivianite powder, F1+P15: the combination of 1 Kg of poultry litter with 15 g of vivianite powder, F1+Py10: the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder, F1+Py15: the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder, T+: chemical fertilizer, T0: negative control. the values of the bands related to a crop season assigned by the same letter are not significantly different.

3.2. Effect of fertilizer, study area and experimental year on carrot growth: plant height and number of leaves per plant

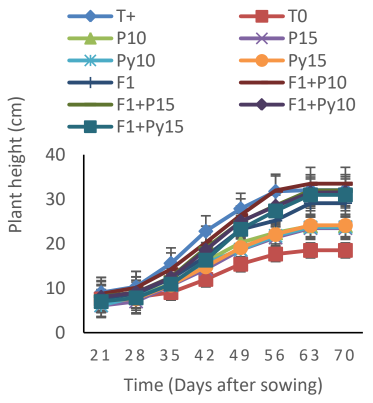
The analysis of variance performed at 70 days after sowing showed a significant difference ($p<0.05$) between fertilizers (10 g of vivianite powder (P10), 15 g of vivianite powder (P15), 10 g of pyroclastic powder (Py10), 15 g of pyroclastic powder (Py15), 1 Kg of compost derived poultry litter (F1), the combination of 1 Kg of poultry litter with 10 g of vivianite powder (F1+P10), the combination of 1 Kg of poultry litter with 15 g of vivianite powder (F1+P15), the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder (F1+Py10), the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder (F1+Py15), chemical fertilizer (T^+), negative control (T^0)) on the plant height (figure 5) and number of leaves per plant (figure 6). There was also a significant effect ($p<0.05$) of the both experimental areas on plant height and leaf production of carrot plants at maturity. No significant effect of the year of experimentation was observed on the studied growth parameters. However, the analysis of variance reveals a significant interaction ($p<0.05$) between fertilizers and agro-ecological zones on the studied growth parameters.

At 70 days after sowing, carrot plants grown on F1+P10 plots were the tallest (33.46 ± 0.08 cm and 34.65 ± 0.39 cm respectively in Maroua and Ngaoundere). F1+P10 plants were 1.67 and 1.50 fold taller than T^0 plants in Maroua and Ngaoundere respectively.

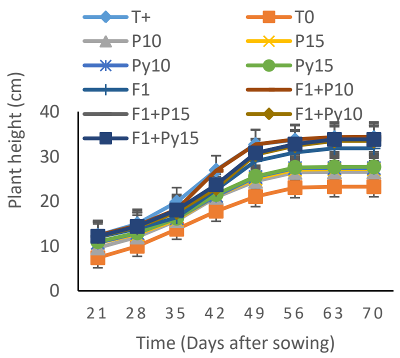
At maturity, the highest number of leaves per carrot plant (15.00 ± 1.41 leaves/plant) was observed on F1+P10 plots in the Far North Cameroun region while the lowest value (9.00 ± 1.00 leaves/plant) of this parameter was observed on T^0 plots in the same study area. The F1+P10 fertilizer increased leaf production of carrot plants by 60% and 69% comapared to T^0 under Sudano-Guinean climate of Adamawa Cameroon and Sudano-Sahelian climate of Far North Cameroon respectively.



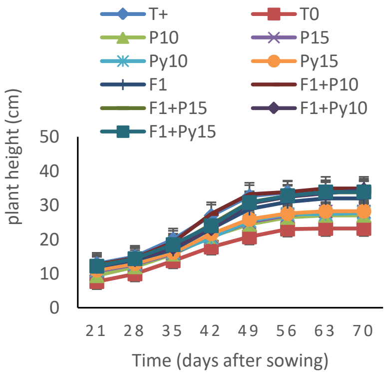
5a) Evolution of plant height from Maroua in the cropping season 2019



5b) Evolution of plant height from Maroua in the cropping season 2020



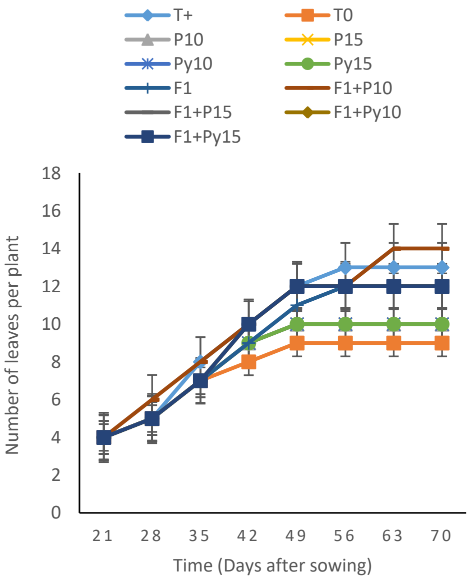
5c) Evolution of plant height from Ngaoundere in the cropping season 2019



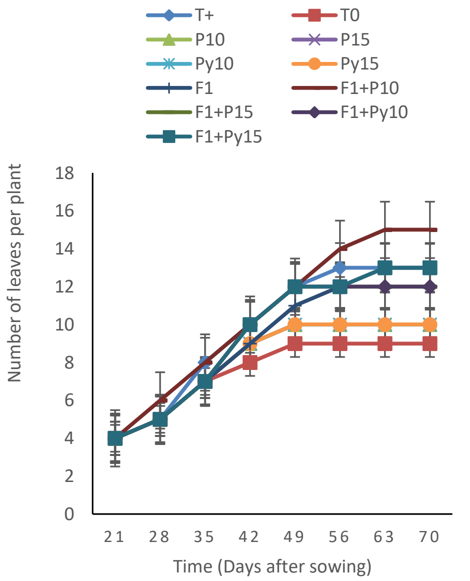
5d) Evolution of plant height from Ngaoundere in the cropping season 2020

Figure 5 : Evolution of caroot plants height depending on fertilizer and study area

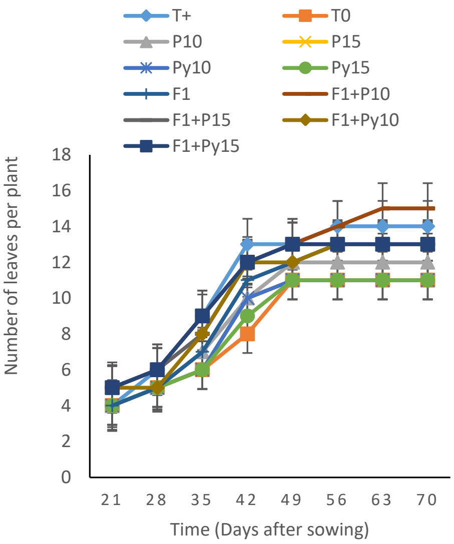
P10 :10 g of vivianite powder, P15: 15 g of vivianite powder, Py10: 10 g of pyroclastic powder, Py15: 15 g of pyroclastic powder, F1: 1 Kg of compost derived poultry litter, F1+P10: the combination of 1 Kg of poultry litter with 10 g of vivianite powder, F1+P15: the combination of 1 Kg of poultry litter with 15 g of vivianite powder, F1+Py10: the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder, F1+Py15: the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder, T^+: chemical fertilizer, T^0: negative control.



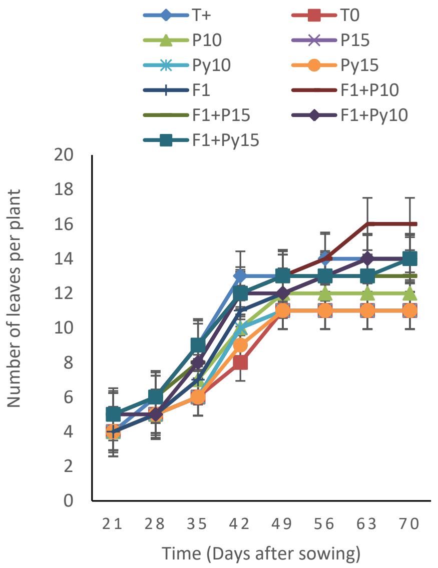
6a) Evolution of leaf production from Maroua in the cropping season 2019



6b) Evolution of leaf production from Maroua in the cropping season 2020



6c) Evolution of leaf production from Ngaoundere in the cropping season 2019



6d) Evolution of leaf production from Ngaoundere in the cropping season 2020

Figure 6 : Evolution of caroot leaf production depending on fertilizer and study area

P10 :10 g of vivianite powder, P15: 15 g of vivianite powder, Py10: 10 g of pyroclastic powder, Py15: 15 g of pyroclastic powder, F1: 1 Kg of compost derived poultry litter, F1+P10: the combination of 1 Kg of poultry litter with 10 g of vivianite powder, F1+P15: the combination of 1 Kg of poultry litter with 15 g of vivianite powder, F1+Py10: the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder, F1+Py15: the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder, T^{+}: chemical fertilizer, T^{0}: negative control.

3.3. Effect of fertilizer, study area and experimental year on carrot production

3.3.1. Lenght and diameter of carrot roots

At 95 days after sowing (DAS), statistical analyses revealed a significant influence ($p<0.05$) between fertilizers (10 g of vivianite powder (P10), 15 g of vivianite powder (P15), 10 g of pyroclastic powder (Py10), 15 g of pyroclastic powder (Py15), 1 Kg of compost derived poultry litter (F1), the combination of 1 Kg of poultry litter with 10 g of vivianite powder (F1+P10), the combination of 1 Kg of poultry litter with 15 g of vivianite powder (F1+P15), the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder (F1+Py10), the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder (F1+Py15), chemical fertilizer (T^+), negative control (T^0)), agroecological zones and years of experimentation on carrot root lenght and root diameter (table 1). There was a significant difference ($p<0.05$) between fertilizers and agro-ecological zones relative to carrot root biomass. On the other hand, no significant influence was observed on the root biomass on the year of experimentation. There was also a significant interaction ($p<0.05$) between fertilizers and agroecological zone on the one hand and between fertilizers and the year of experimentation on the other hand (table 2).

For the 2019 cropping year, and particularly in each of the both agro-ecological zones, the highest values for root lenght (19.47±2.24 cm for Maroua and 29.16±2.16 cm for Ngaoundere) and root diameter (16.05±0.89 cm for Maroua and 18.76±2.00 cm for Ngaoundere) are observed on the F1+P10 plots. The smallest values of these parameters are recorded on the T^0 plots, which root lenght is 1.16 fold and 1.43 fold smaller than that of F1+P10 roots in Maroua and Ngaoundere respectively.

Regarding the cropping season 2020, in the both study areas, plots treated with F1+P10 fertilizer had the highest carrot root lenght (21.13 ± 1.63 cm and 30.50 ± 1.71 cm under Sudano-sahélian and Sudano-Guinean climate respecyvely) and root diameters (17.03 ± 0.76

cm and 19.60 ± 1.67 cm under Sudano-sahélian and Sudano-Guinean climate respecyvely) compared to T^0 and T^+ plots. Carrot root lenght from treated plot wirh F1+P10 was 1.21 and 1.09 fold greater than T0 and T+ restpectively in Far North Cameroon. However, root lenght from treated plant by F1+P10 fertilizer was 1.46 fold and 1.41 fold greater than that from T^0 and T^+ in Adamaoua respecyively.

Table 2: Root length, root diameter and root biomass according to fertilizers, study area and the year of experimentation

Parameters	Fertilizers	Ngaoundere		Maroua	
		Cropping seasons		Cropping seasons	
		2019	**2020**	**2019**	**2020**
Root length (cm)	T+	20.70±2.05^{b}	21.60±1.42^{b}	17.80±1.66^{de}	19.43±1.52^{c}
	T0	20.43±2.02^{b}	20.93±1.77^{b}	16.85±1.87^{abc}	17.50±1.93^{ab}
	P10	20.23±2.09^{b}	20.93±1.63^{b}	16.61±1.96^{a}	16.86±1.88^{a}
	P15	18.73±1.74^{a}	19.46±1.38^{a}	17.47±1.66^{bcd}	17.93±1.53^{b}
	Py10	18.10±2.69^{a}	18.76±2.12^{a}	16.95±1.83^{ab}	17.35±1.49^{ab}
	Py15	20.60±2.55^{b}	21.13±2.25^{b}	17.71±1.92^{bcd}	17.93±1.72^{b}
	F1	28.20±2.32^{de}	29.73±1.70^{de}	17.71±1.97^{bcd}	19.36±1.92^{c}
	F1+P10	29.16±2.16^{e}	30.50±1.71^{e}	19.47±2.24^{f}	21.13±1.63^{e}
	F1+P15	27.40±1.63^{d}	29.33±1.15^{d}	18.47±2.06^{ef}	20.46±1.79^{de}
	F1+Py10	27.16±2.05^{d}	29.03±1.79^{d}	18.09±1.94^{de}	19.96±1.75^{cd}
	F1+Py15	25.13±1.65^{c}	26.93±0.98^{c}	17.80±1.53^{cde}	19.56±1.45^{c}
Root diameter (cm)	T+	10.76±1.83^{d}	11.48±1.22^{c}	12.90±0.99^{cd}	13.21±0.72^{ef}
	T0	7.71±1.59^{a}	8.56±1.35^{a}	9.00±1.22^{a}	9.41±1.12^{ab}
	P10	12.10±1.54^{e}	12.58±1.31^{d}	9.00±1.05^{a}	9.46±1.01^{b}
	P15	10.33±1.93^{cd}	10.76±1.76^{c}	8.65±1.22^{a}	8.93±1.08^{a}
	Py10	9.41±1.44^{bc}	9.85±0.99^{b}	10.60±0.96^{b}	10.85±0.84^{c}
	Py15	9.11±1.51^{b}	9.60±1.06^{b}	10.75±1.03^{b}	11.08±0.95^{cd}
	F1	16.66±2.6^{g}	17.43±1.95^{f}	12.75±1.13^{c}	13.08±0.84^{e}
	F1+P10	18.76±2.00^{i}	19.60±1.67^{h}	16.05±0.89^{e}	17.03±0.76^{g}
	F1+P15	13.33±1.09^{f}	14.13±1.02^{e}	13.10±1.10^{cd}	13.50±0.89e^{f}
	F1+Py10	17.75±2.05^{h}	18.72±1.28^{g}	10.45±1.81^{b}	11.38±1.77^{d}
	F1+Py15	17.68±1.80^{h}	18.25±1.51^{g}	13.35±0.57^{d}	13.66±0.44^{f}
Root biomass (g)	T+	25.24 ± 0.20^{bc}	23.57± 0.61^{b}	27.86±1.46^{d}	29.19± 0.91^{fg}
	T0	15.93± 0.27^{a}	17.89± 0.93^{a}	11.91±1.16^{a}	10.57 ± 1.45^{a}
	P10	31.54 ± 1.55^{de}	32.21± 2.46^{d}	20.89 ± 1.63^{d}	22.55 ± 0.49d^{e}
	P15	23.05 ± 1.23^{b}	23.72± 2.20^{b}	13.38 ± 2.07^{b}	15.36 ± 0.37^{b}
	Py10	29.83 ± 1.05^{d}	30.43± 0.78^{c}	16.72 ± 0.22^{c}	17.38 ± 0.75^{c}
	Py15	32.82 ± 1.06^{e}	33.49± 0.63^{d}	20.38 ± 0.22^{d}	20.45 ± 0.22^{d}
	F1	35.15 ± 1.37^{f}	37.82± 1.52^{e}	25.53 ± 0.89^{e}	27.62 ± 2.55^{f}
	F1+P10	44.53 ± 0.67^{i}	45.70± 1.00^{h}	30.81 ± 0.29^{g}	32.48 ± 0.93^{h}

	F1+P15	42.02 ± 0.36^{h}	42.62± 0.25^{g}	28.38 ± 0.47^{f}	30.72 ± 0.24^{g}
	F1+Py10	38.65 ± 0.07^{g}	39.05 ± 0.77^{f}	29.69 ± 0.39^{fg}	31.36 ± 1.03^{g}
	F1+Py15	38.20 ± 1.21^{g}	38.54±1.39^{ef}	29.32 ± 0.60^{fg}	30.50 ± 0.91^{g}

P10 :10 g of vivianite powder, P15: 15 g of vivianite powder, Py10: 10 g of pyroclastic powder, Py15: 15 g of pyroclastic powder, F1: 1 Kg of compost derived poultry litter, F1+P10: the combination of 1 Kg of poultry litter with 10 g of vivianite powder, F1+P15: the combination of 1 Kg of poultry litter with 15 g of vivianite powder, F1+Py10: the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder, F1+Py15: the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder, T+: chemical fertilizer, T0: negative control. the values of the column related to a parameter assigned by the same letter are not significantly different.

Root yield

Figure 7 shows the carrot root yield depending on fertilizers (10 g of vivianite powder (P10), 15 g of vivianite powder (P15), 10 g of pyroclastic powder (Py10), 15 g of pyroclastic powder (Py15), 1 Kg of poultry litter : the combination of 0.5 Kg of compost derived poultry litter and 0.5 Kg of poultry litter (F1), the combination of 1 Kg of poultry litter with 10 g of vivianite powder (F1+P10), the combination of 1 Kg of poultry litter with 15 g of vivianite powder (F1+P15), the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder (F1+Py10), the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder (F1+Py15), chemical fertilizer (T^{+}), negative control (T^{0})), the year of experimentation and agro-ecological zone. The analysis of variance showed a significant effect ($p<0.05$) of fertilizers and agroecological zone on carrot root yield. On the other hand, no significant effect of the year of experimentation is revealed on carrot root yield. However, a significant interaction ($p<0.05$) between fertilizers and agroecological zones on carrot root yield recorded.

The highest carrot root yield (76.85 ± 0.84 t/ha) was obtained in the Sudano-Guinean zone of Cameroon on treated F1+P10 plants. The highest root yield (39.41 ± 0.49 t/ha) in the Sudano-Sahelian zone was from F1+P10 plots. F1+P10 fertilizer increased the root yield at 2% and 41% compared T^{+} in Maroua and Ngaoundere respectively in the cropping season 2019, 26% and 68% compared to T^{0} in Maroua and Ngaoundere respectively in cropping season 2020.

Indeed, the F1+P10 fertilizer is the best adapted to carrot production in each of the both study zones. However, the Sudano-Guinean zone seems to be the most favorable to the adaptability of this fertilizer by giving a high yield compared to the Sudan-Sahelian zone.

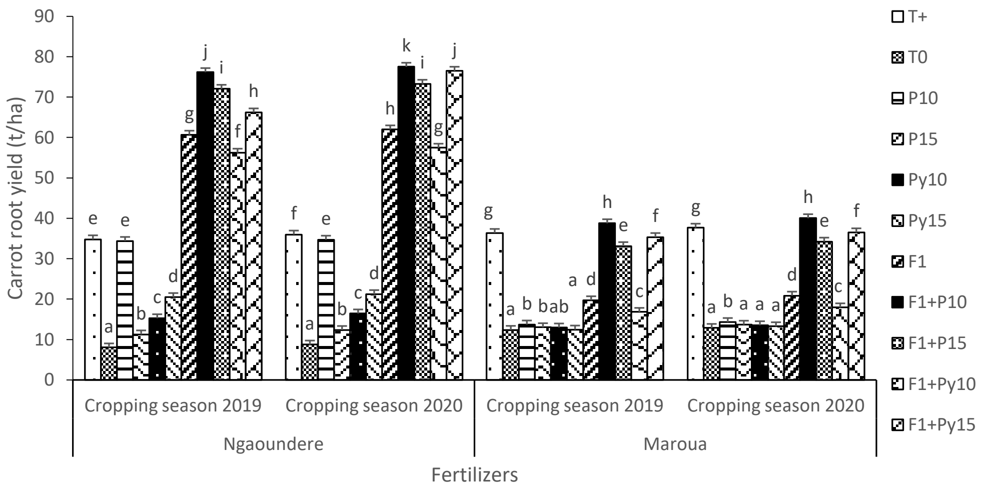


Figure 7 : Carrot root yield

P10 :10 g of vivianite powder, P15: 15 g of vivianite powder, Py10: 10 g of pyroclastic powder, Py15: 15 g of pyroclastic powder, F1: 1 Kg of compost derived poultry litter, F1+P10: the combination of 1 Kg of poultry litter with 10 g of vivianite powder, F1+P15: the combination of 1 Kg of poultry litter with 15 g of vivianite powder, F1+Py10: the combination of 1 Kg of poultry litter with 10 g of pyroclastic powder, F1+Py15: the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder, T+: chemical fertilizer, T0: negative control. the values of the bands related to a crop season assigned by the same letter are not significantly different

4. Discussion

It is observed in this study that the carrot seedlings emergence took place at 10 days after sowing, this result corroborates the work of [10] who studied the influence of chicken droppings and mineral fertilizer NPK (17-17-17) on the growth and production of carrot in Rwanda and reported that the carrot seedling emergence took place between 08 and 15 days after sowing. The beneficial effect of poultry litter observed on carrot seedling emergence could be explained by that this organic fertilizer is rich in phosphorus. This phosphorus would have influenced the carrot seeds emergence. Indeed, [34], studied the dynamics of phosphorus in the soil-plant system in Algeria and showed that phosphorus acts on roots development by activating rhizogenesis. Plant emergence is an indicator of survival and growth. The higher seedling emergence suggest the better plant growth.

It this work, carrot plants height varied from 19.25 ± 1.02 cm on T^0 plants to 33.46 ± 0.08 cm on F1+P10 plants in the Maroua and from 23.22 ± 0.02 cm on T^0 plants to 34.65 ± 0.39 cm on F1+P10 plants in Ngaoundere. These results obtained on carrot plants height corroborate partially the data found in literature: [10] reported that carrot plant height varied from 34.12 cm for plants that received no fertilizer to 45.59 cm for amended carrot plants by chicken droppings in Rwanda. In addition, the studies of [12] in Debigonj, Panchagorh on the effect of phosphorus on carrot growth and production showed that carrot plant height varied from 47.36 cm to 44.76 cm.

Leaf production recorded in the present work varied from 9.00 ± 1.00 leaves/plant for T^0 plots to 15.00 ± 1.41 leaves/plant for F1+P10 plots in Maroua and from 11.00 ± 0.00 for T^0 plots to 16.00 ± 0.70 for F1+P10 plots in Ngaoundere. This result partially corroborates those of [35] in Côte d'Ivoire on the study of influence of compost and synthetic chemical fertilizer on the growth of four carrot varieties, these authors reported that amended carrot plants with compost had an average number of leaves per plant of 10.00. Plant height is an important parameter for yield. The study of several authors revealed that there is a positive and significant correlation between plant height and leaf production. Leaves are the organs responsible for photosynthesis; increasing the number of carrot leaves would lead to an increase of photosynthetic activity and consequently an increase of carrot production.

In this work, root lenght varied from 16.85 ± 1.87 cm for no treated plants in Maroua in 2019 to 30.50 ± 1.71 cm for treated plants by F1+P10 in Ngaoundere in 2020. These values obtained on carrot root lenght are higher than those reported by [35] who found that carrot roots have an average lenght of 11.57 cm. Furthermore, the studies of [16] in Ngaoundere

(Cameroon), on the influence of pre-treatment of chicken droppings and vivianite powder on carrot revealed that carrot root lenght varied from 12.26 ± 2.37 cm to 17.95 ± 2.89 cm.

Root dry biomass obtained in this work ranged from 11.24 ± 1.30 g for T^0 to 31.65 ± 0.61 g for F1+P10 in Maroua, while the values of this production parameter in Ngaoundere varied from 16.91 ± 0.60 g for T^0 to 45.12 ± 0.84 g for F1+P10. The beneficial effect of F1+P10 treatment on carrot root dry biomass observed in the present study partly corroborates the work of several authors [36, 37, 38] who reported that chicken droppings increase carrot root growth.

The values of carrot root yields obtained in this work partly corroborate the work of [16] who reported that the average carrot root yield was 13.46 ± 0.64 t/ha on treated plots by chicken droppings. The work of [39] in Benin, revealed that the application of organic fertilizers on ferralitic soil improves carrot yield.

It is observed in the present study that the fertilizers used improved the growth and development of carrot compared to the negative control (plants that received no fertilizer). This could be justified by the low availability of nutrients in the growing soil. The use of mineral or organic fertilizers would have improved the soil physico-chemical properties of study site and consequently the carrot growth potential. In addition, the work of several authors [16, 31, 40, 41] revealed that organic fertilizer has a positive effect on crop productivity. Indeed, organic fertilizers play a major role in maintaining soil fertility and thus sustainability of agricultural production.

The natural fertilizers (poultry litter, vivianite and pyroclastics powders) used in this work are rich in mineral elements necessary for plant growth. The beneficial effect of poultry litter on growth and production parameters of carrot is thought to be related to the combined effect of improved soil properties and nutrient mineralization. In addition, local resources such as organic wastes applied to tropical soils (acidic and mineral-poor) can provide the necessary nutrients for plant growth [14].

The compost derived poultry litter contents on N, P, Ca, Fe, Al, and Mg are 1.07±0.03%; 0.51±0.02%; 1.01±0.09%; 0.50±0.09%; 0.63±0.03%; and 0.20±0.02%, respectively. This litter would have improved the physical characteristics of the soil at our study site as well as its biological composition. [23] studied the growth of crops fertilized with poultry litter and revealed that this organic fertilizer provides nitrogen to the soil, which would promote chlorophyll accumulation in the leaves. Indeed, the photosynthesis phenomenon requires chlorophyll, and thus a higher chlorophyll content suggests the intensification of photosynthetic activities with the consequent increase in plant productivity. In this context, it would be interesting to investigate the influence of the natural fertilizers used in this study on leaves chlorophyll content to better explain the beneficial effect of these fertilizers on carrot growth. In addition, poultry litter prove to be favorable to the growth of microorganisms that will induce an activation of nutrient solubilization [42]. The chemical analysis of the vivianite powder used in this study was performed by [24]. From the work of these authors, it is found that this vivianite is composed of: Fe_2O_3 (68.72%), P_2O_5 (9.17%), Al_2O_3 (7.72%), SiO_2 (9.67%), total phosphorus (671.50 mg/kg) and assimilated phosphorus (81.13 mg/kg). As for basal pyroclastics, they are rich in exchangeable bases (Ca^{2+}, Mg^{2+}, Na^+ and K^+) (Gove, 2014). These mineral elements in this rock powder would have improved the chemical properties of growing soil, and thus the improvement of carrot productivity.

It was also observed in this work that the combination of compost derived poultry litter with vivianite powder or pyroclastics powder increases the growth potential of carrot better than poultry litter without any combination. The rock powders used would have improved the phosphorus content of compost derived poultry litter, which would have corrected the deficiencies of these mineral elements in the growing soil, and then the improvement of carrot growth.

Conclusion

Carrot root growth and productivity varied depending on fertilizer, agroecological zone and the year of experimentation. Globally, treated plant by the combination of 1 Kg of poultry litter with 10 g of vivianite (F1+P10) powder exhibited significantly ($p<0.05$) the highest growth and production parameters compared to other treatments (10 g of vivianite powder, 15 g of vivianite powder, 10 g of pyroclastic powder, 15 g of pyroclastic powder, 1 Kg of poultry litter, combination of 1 Kg of poultry litter with 15 g of vivianite powder, combination of 1 Kg of poultry litter with 10 g of pyroclastic powder, the combination of 1 Kg of poultry litter with 15 g of pyroclastic powder, chemical fertilizer and no treated plants). F1+P10 fertilizer increased the seedling emergence rate at 1.35 and 1.48-fold in Maroua compared to chemical fertilizer and no treated plant respectively. F1+P10 fertilizer increased the foliar production at 60% and 69%, compared to no treated plants in Ngaoundere and Maroua rspectively. This fertilizer increased the root yield during the 2019 crooping season at 2% and 41% compared to T+ in Ngaoundere and Maroua rspectively, at 26% and 68% compared to no treated plants in 2020 in Maroua and Ngaoundere respectively. F1+P10 fertilizer is best suited for carrot production in the both study area. The application of the combination of 1 kg of poultry litter and 10 g of vivianite powder per hole at sowing for carrot growth would contribute to improve this root vegetable, to valorize our local material in agriculture while ensuring sustainable agriculture.

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