

Original Research Article

The combination of vivianite powder and compost derived poultry litter: appropriate biological fertilizer to improve *Daucus carota* L. nutrients

Abstract

Aims: To improve the nutritional values of carrot in the Great North Cameroon by using natural fertilizing.

Study Design: A 11x2x2 factorial design with 11 origins of carrot roots (fertilizing) (T0, T+, P10, P15, Py10, Py15, F1, F1+P10, F1+P15, F1+Py10 and F1+Py15), 02 harvest areas (Maroua and Ngaoundere (Cameroon)) and 02 harvest years (2019 and 2020).

Place and Duration of Study: Laboratory of Biodiversity and Sustainable Development, University of Ngaoundere Cameroon, September 2019 and September 2020.

Methodology: Nutrient parameters of carrot roots (moisture, vitamin C, carotenoids, fiber, carbohydrates and ash of carrot roots contents) were assessed according to standard methods.

Results: Globally, carrot nutritional values varied significantly ($p < 0.05$) depending on fertilizer, harvest area (Ngaoundere and Maroua Cameroon), and harvest year (2019 and 2020). The carrot nutrient contents from Maroua Cameroon were higher than those from Ngaoundere. The highest carrot nutrients content was from F1+P10 plots (combination of 1 Kg of poultry litter with 10 g of vivianite powder). In Maroua, roots from treated carrot plants with F1+P10 fertilizer are 1.55 and 1.24 fold richer in carotenoids than those from T0 and T+ plants respectively in 2019 ; in growing year 2020, the carotenoid contents of F1+P10 roots were 1.52 fold and 1.29 fold higher than those of T0 and T+ plants. In Ngaoundere, Vitamin C content of carrots from F1+P10 fertilizer is 1.79 fold higher than that of T0 plants and 1.18 fold higher than that of T+ plants in 2019, while in 2020 the value of this parameter was 1.69 fold and 1.47 fold higher than that of T0 and T+ plants respectively. The F1+P10 fertilizer increased total carbohydrate content at 51.88 % compared to T0 and 20.03 % compared to T+ in Maroua, and at 27.59 % and 7.95 % compared to T0 and T+ respectively in Ngaoundere.

Conclusion: By used F1+P10 natural fertilizer for carrot growing, we contribute to improve the nutritional values of this vegetable crop, but also to valorize our local resources in biological agriculture, as well as to protect the environment.

Key word : *Daucus carota* L., nutritional values, fertilizing, harvest area, harvest year

1. INTRODUCTION

Daucus carota L., also known as carrot, is a member of the Apiaceae family. Carrots are rich in health-promoting compounds such as antioxidants, mainly anthocyanins and carotenoids [1]. The high content of carotenoids, especially β -carotene, is of interest, as this β -carotene is converted by human metabolism to vitamin A. Carrots are a source of many other important compounds and nutrients: polyphenols, fiber, carbohydrates, vitamin B and vitamin C [2].

The world production of carrots reached for the year 2020, 41 million tons on approximately 1.2 million hectares area in the world [3]. The European Union (5.50 million tons) is the second largest producer after China (18.80 million tons) [4]. Five countries (China, the United States, Uzbekistan, and Poland) produce 60% of the world's carrot quantity [4]. In Africa, Morocco is the first largest producing country (14749 ha) with 32.38 tons/ha of carrot production. Carrot cultivation is fairly widespread in Algeria, Niger, Senegal, Cameroon, and several other African countries [5]. Cameroon exports carrots to Europe (Belarus, Belgium) and to Central African countries [5].

Cameroonian farmers commonly use chemical fertilizers to improve carrot productivity. The overuse of chemical fertilizers contributes to climate change by releasing tons of nitrous oxide, a greenhouse gas more potent than carbon dioxide [6]. It pollutes groundwater and causes soil salinization with adverse consequences on soil fertility and crop quality [7]. Therefore, the use of fertilizers that improves the plants nutritive values while maintaining soil fertility is a necessity. The studies of several authors [8,9,10,11,12,13] revealed that natural fertilizers improve carrot nutritional values. Our previous studies aimed to improve the growth potential of carrot in the Northern Cameroon while limiting the use of chemical inputs. We found that the combination of compost derived poultry litter and vivianite powder better improves carrot growth and root yield. To the best of our knowledge, no work has been done on the combined effect of rock powders and compost on carrot nutritional values. The formulation of a natural fertilizer based on rock powders and compost derived poultry litter for carrot growing in the Northern Cameroon would contribute to improve carrot nutrient contents, to valorize the local materials available for agriculture, and to protect the environment.

Indeed, the Adamaoua Cameroon region is rich in rock deposits such as vivianite and basaltic pyroclastics that can be used in agriculture. The beneficial effect of vivianite on plant nutritional values has been demonstrated [14,15,16]. Vivianite is an iron phosphate oxide with the formula $\text{Fe}_3(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$ [17]. Phosphorus is one of the essential macronutrients for plant

productivity [18]. It is involved in photosynthesis as an energy fixer and transporter, and its deficiency causes major abiotic stress that limits crop productivity and consequently its nutritional qualities [19]. As for basaltic pyroclastics, they are rich in exchangeable bases (Ca^{2+} , Mg^{2+} , Na^+ and K^+) [20]. Poultry litter is less expensive on the Cameroonian market [21]. They are rich in mineral elements necessary for improving plant quality.

The present study aimed to evaluate the combined effect of compost derived poultry litter and rock powders (vivianite and basaltic pyroclastics) on the nutritional values of carrot in the Northern Cameroon. Specifically, to determine: (1) water content, (2) vitamin C content, (3) total carotenoids content, (4) total fiber content, (5) total carbohydrates content, (6) total ash content of carrot roots. The importance of this work is that the formulation of natural fertilizer based on the mixture of poultry litter and rock powders that better improves carrot roots nutritional values would constitute an alternative to synthetic chemical fertilizers for the growing of this root vegetable.

2. MATERIALS AND METHODS

2.1. Carrot roots and their origin

carrot roots of the Pamela+ variety were used. Carrot roots were obtained in field from Ngaoundere Cameroon in the experimental farm of Laboratory of Biodiversity and Sustainable Development of the University of Ngaoundere, and at Hardé locality in Maroua Cameroon in both cropping years 2019 and 2020 [22]. These carrot roots were from 11 fertilizer formulas (negative control : root from no treated plants, positive control : 10 g of chemical fertilizer NPK 20-10-10, 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), fertilizers were applied per plant.

2.2. Determination of carrot roots nutritional values

At harvest, the nutrient parameters (moisture, vitamin C, total carotenoids, total fiber, total carbohydrates and total ash of carrot roots contents) were assessed through the following methods: Concerning the determination of moisture content, fresh carrot roots samples (5 g)

were weight in crucible and submitted to oven-drying at 105° C, until obtaining a constant weight. Vitamine C content was assessed based on titrimetric method according to [23]. Carotenoids content were determined according to [24]. Dietary fiber content was determined according to the method described by [25]. The method of [26] was used for determining the carbohydrate content. Total ash was assessed according to AFNOR [27].

2.3. Statistical Analysis

Means and Data were submitted to analysis of variance (ANOVA) and when the difference was significant ($P < 0.05$), a Duncan multiple range tests was performed to compared means. The statistical package “Statgraphics Plus” was used for this propose. The principal component analysis (PCA) was performed using XLSTAT 2007 to determine the correlation between the different parameters.

3. RESULTS AND DISCUSSION

3.1. RESULTS

3.1.1. Root moisture content

The statistical analysis revealed that moisture content varied depending on fertilizer (negative control : root from no treated plants (T0) ; positive control : 10 g of chemical fertilizer NPK 20-10-10 (T+) ; 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)) and harvest area (Maroua and Ngaoundere Cameroon), no significant effect of both harvest year (2019 and 2020) is revealed on moisture content. Carrot roots from T0 plots ($88.76 \pm 0.73\%$) and P15 plots ($85.63 \pm 0.10\%$) exhibited the highest moisture content in Maroua. Similarly, in Ngaoundere, the highest moisture contents are obtained on T0 plots ($83.09 \pm 0.49\%$) and P15 plots ($76.62 \pm 1.04\%$). The lowest moisture content was recorded from F1+P10 fertilizer ($68.34 \pm 0.99\%$ in Maroua, and $54.90 \pm 0.49\%$ in Ngaoundere). Moisture content of harvested roots on F1+P10 plots in Ngaoundere and Maroua was 1.38 and 1.05 fold less than T+ roots in Ngaoundere and Maroua respectively (Table 1).

Table 1 : Carrot roots moisture content (%) depending on fertilizer, harvest area and harvest year

Fertilizers	Harvest area			
	Ngaoundere		Maroua	
	2019	2020	2019	2020
T+	74.76 ± 0.04 ^g	76.43 ± 1.00 ^f	72.54 ± 0.12 ^d	70.58 ± 0.69 ^c
T0	84.07 ± 0.02 ⁱ	82.11 ± 0.97 ^g	88.09 ± 0.48 ⁱ	89.42 ± 0.98 ⁱ
P10	68.46 ± 0.54 ^e	67.81 ± 0.99 ^d	79.13 ± 0.97 ^f	77.49 ± 0.60 ^e
P15	76.95 ± 0.07 ^h	76.28 ± 2.00 ^f	86.64 ± 0.08 ^h	84.61 ± 0.12 ^h
Py10	70.18 ± 1.05 ^f	69.55 ± 0.06 ^e	83.28 ± 0.16 ^g	82.61 ± 0.96 ^g
Py15	67.18 ± 1.00 ^e	66.51 ± 1.00 ^d	79.61 ± 0.53 ^f	79.55 ± 1.10 ^f
F1	64.78 ± 1.04 ^d	62.18 ± 1.02 ^c	74.49 ± 0.21 ^e	72.38 ± 0.10 ^d
F1+P10	55.51 ± 0.94 ^a	54.29 ± 0.05 ^a	69.16 ± 1.96 ^a	67.52 ± 0.02 ^a
F1+P15	57.95 ± 1.00 ^b	57.38 ± 1.01 ^b	71.62 ± 0.10 ^{cd}	69.27 ± 0.10 ^{bc}
F1+Py10	61.45 ± 1.02 ^c	60.90 ± 0.08 ^c	70.34 ± 0.95 ^{ab}	68.64 ± 0.95 ^{ab}
F1+Py15	61.80 ± 1.01 ^c	61.46 ± 0.04 ^c	70.69 ± 0.21 ^{bc}	69.51 ± 0.96 ^{bc}

T0 : negative control (root from no treated plants) ; T+ : positive control (10 g of chemical fertilizer NPK 20-10-10) ; 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. The values of the column assigned by the same letter are not significantly different.

3.1.2. Carotenoid content

Statistical analyses revealed that carotenoid content varied significantly ($p < 0.05$) according to fertilizer and harvest year. There is a significant interaction ($P < 0.05$) between fertilizing and harvest year on carotenoid content. There is not the significant difference between harvest area on carrot roots carotenoid content (figure 1). During the 2019 growing season, the highest total carotenoid contents in Maroua (60.28 ± 0.08 g/100 g of dry matter) and Ngaoundere (53.37 ± 0.21 g/100 g of dry matter) were recorded on F1+P10 roots. For the 2020 growing year, the highest values of this parameter (66.39 ± 0.17 g/100 g of dry matter in Maroua, and 71.08 ± 0.10 g/100 g of dry matter in Ngaoundere), also are recorded on F1+P10 roots. In Maroua, roots from treated carrot plants with F1+P10 fertilizer are 1.55 and 1.24 fold richer in carotenoids than those from T0 and T+ plants respectively in 2019 ; in growing year 2020, the carotenoid contents of F1+P10 roots were 1.52 fold and 1.29 fold higher than those of T0 and T+ plants. On the other hand, in Ngaoundere, the carotenoid content of F1+P10 roots was 1.92 fold and 1.15 fold higher than that of T0 and T+ respectively in 2019. During

the 2020 growing season in Ngaoundere, F1+P10 fertilizer improves carotenoid content of carrot roots at 32.15% compared to T0 and 22.97% compared to T+.

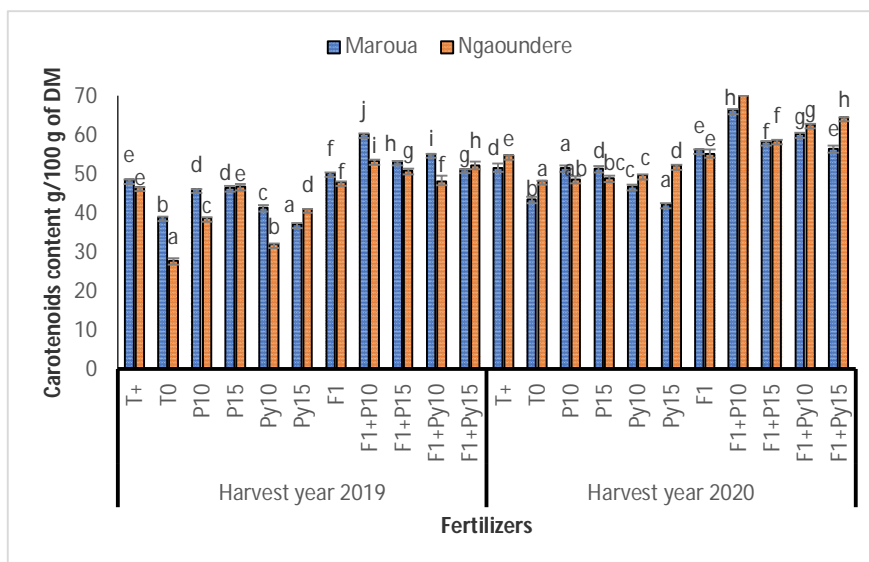


Figure 1 : Carrot roots carotenoids content (%) depending on fertilizer, harvest year and harvest area

DM : dry matter; T0 : negative control (root from no treated plants); T+ : positive control (10 g of chemical fertilizer NPK 20-10-10); 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. The values of the bands related to a harvest year assigned by the same letter are not significantly different

3.1.3. Fiber content

From the analysis of the results, it appears that the fertilizers used and the agroecological zones had significant effects ($p < 0.05$) on the total fiber content of the carrot. On the other hand, no significant effect was observed between the years of experimentation on this parameter. Statistical analysis also revealed a significant interaction ($p < 0.05$) between fertilization and agro-ecological zone on carrot fiber content (figure 2).

The mean values of carrot fiber content from 2019 and 2020 growing seasons ranged from 2.57 ± 0.30 g/100 g of dry matter for T0 roots to 3.65 ± 0.15 g/100 g of dry matter for F1+P10 roots in the Maroua area while in Ngaoundere the carrot fiber contents ranged from 1.93 ± 0.58 g/100 g of dry matter for T0 to 3.25 ± 0.45 g/100 g of dry matter for F1+P10. The average total fiber content of T+ roots was 3.18 ± 0.51 g/100 g of dry matter in Maroua and 2.88 ± 0.26 g/100 g of dry matter in Ngaoundéré. The F1+P10 fertilizer resulted in an increase

in total fiber content of 1.20g/100 g of dry matter and 0.47 g/100 g of dry matter respectively compared to T0 and T+ in Maroua. On the other hand, F1+P10 fertilizer increased carrot roots fiber content at 1.32g/100 g of dry matter compared to T0 roots and 0.37g/100 g of dry matter compared to T+ roots in Ngaoundere.

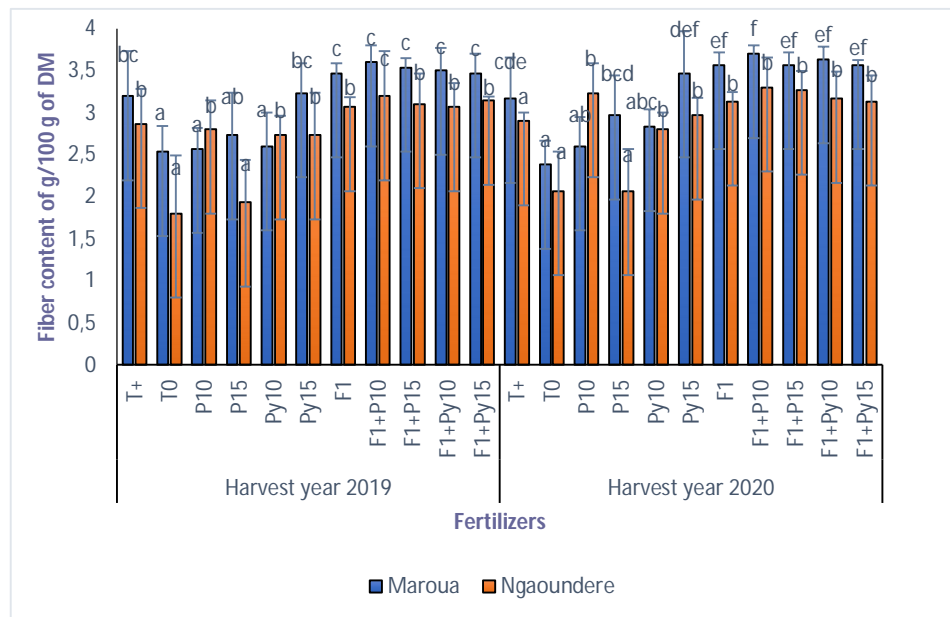


Figure 2 : Carrot roots fiber content (%) depending on fertilizer, harvest year et de la zone agroécologique

DM : dry matter ; T0 : negative control (root from no treated plants) ; T+ : positive control (10 g of chemical fertilizer NPK 20-10-10) ; 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. The values of the bands related to a harvest year assigned by the same letter are not significantly different

3.1.4. Vitamin C content

Statistical analyses revealed a significant effect ($p < 0.05$) of fertilizers, harvest area and harvest year on vitamin C content of carrot. roots Also, a significant interaction ($p < 0.05$) between fertilization and harvest year was recorded (figure 3).

In Maroua, vitamin C content varied from 28.33 ± 1.15 mg/100 g of dry matter for T0 roots to 35.10 ± 0.79 mg/100 g of dry matter in F1+P10 in 2019. However in 2020, the values of this parameter varied from 27.44 ± 0.37 mg/100 g of dry matter for T0 roots to 48.29 ± 0.50 mg/100 g of dry matter for F1+P10 fertilizer. Vitamin C content of T+ plants were 32.17 ± 1.15 mg/100 g of dry matter in 2019 and 43.42 ± 0.23 mg/100 g of dry matter in 2020.

F1+P10 fertilizer increased vitamin C at 19.29% compared to T0 and 8.35 % to T+ in the 2019 crop year. This increasing was 43.18 % compared T0 and 10.08 % compared to T+ in 2020.

In Ngaoundere during the 2019 growing season, the vitamin C content of carrot plants from F1+P10 plots is higher (36.17 ± 1.15 mg/100 g of dry matter), followed by F1+P15 plants (35.00 ± 0.62 mg/100 g of dry matter). T0 roots exhibited the lowest vitamin C content (20.17 ± 1.10 mg/100 g of dry matter) and the vitamin C content of T+ plants was 30.67 ± 2.80 mg/100 g of dry matter. In 2020, vitamin C contents varied from 30.23 ± 0.06 mg/100 g of dry matter for T0 to 51.08 ± 0.10 mg/100 g of dry matter for F1+P10. Vitamin C content of carrots from F1+P10 fertilizer is 1.79 fold higher than that of T0 plants and 1.18 fold higher than that of T+ plants in 2019 ; on the other hand, in 2020, the value of this parameter was 1.69 fold and 1.47 fold higher than that of T0 and T+ plants respectively.

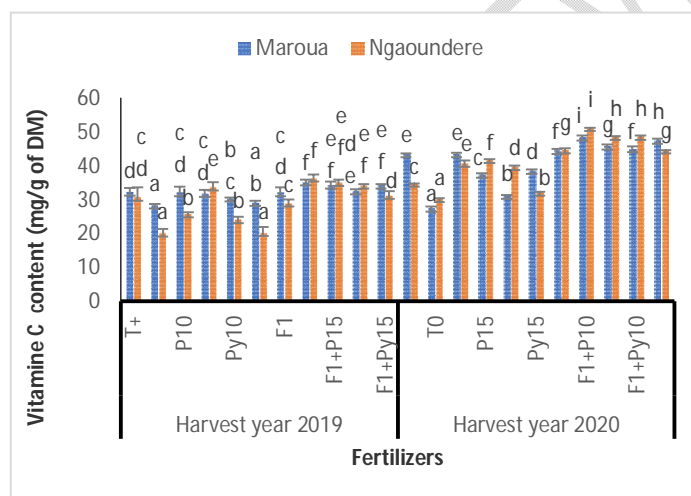


Figure 3: Carrot roots vitamin C content (%) depending on fertilizer, harvest year et de la zone agroécologique

DM : dry matter ; T0 : negative control (root from no treated plants) ; T+ : positive control (10 g of chemical fertilizer NPK 20-10-10) ; 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. The values of the bands related to a harvest year assigned by the same letter are not significantly different

3.1.5. Ash content

Globally, fertilizers, harvest areas and harvest years significantly influenced ($P < 0.05$) the ash carrot root content. Furthermore, there was a significant interaction ($P < 0.05$) between

fertilizers and agro-ecological zones on the one hand, and between fertilizers and harvest year on the other hand relative to ash content of carrot roots (table 2).

For the 2019 cropping year, the highest total ash values obtained in Maroua and Ngaoundere were 12.12 ± 2.51 g/100 g of dry matter for P15 roots and 10.95 ± 1.39 g/100 g of dry matter for Py15 roots respectively. The lowest values of carrot ash content were from T0 roots in each of the both study areas (8.53 ± 0.52 g/100 g of dry matter for Maroua and 8.96 ± 0.13 g/100 g of dry matter for Ngaoundere). The total ash content from T+ roots was 9.56 ± 0.48 g/100 g of dry matter in Maroua and 9.01 ± 0.49 g/100 g of dry matter in Ngaoundere.

For the 2020 cropping season, the highest total ash value was from treated plot with F1+P10 fertilizer (12.62 ± 1.44 g/100 g of dry matter) in Maroua and on treated plots with F1+P15 (13.00 ± 1.00 g/100 g of dry matter) in Ngaoundéré. The ash content recorded on F1+P10 roots was 1.19 fold higher than that of T0 roots, and 1.09 fold higher than that of T+ roots in Maroua, and Ngaoundere ash content of F1+P15 root was 1.19 fold and 1.18 fold richer than that of T0 and T+ roots respectively.

Table 2 : Ash content (g/100g of dry matter) depending on fertilizer, harvest year and harvest area

Fertilizers	Harvest area			
	Ngaoundere		Maroua	
	Cropping season		Cropping season	
	2019	2020	2019	2020
T+	9.01 ± 0.49^{ab}	11.01 ± 1.48^{ab}	9.56 ± 0.48^{cde}	11.56 ± 0.48^{cde}
T0	8.96 ± 0.13^{ab}	10.96 ± 0.14^{ab}	8.53 ± 0.52^{bcd}	10.53 ± 0.52^{abc}
P10	10.75 ± 1.88^c	12.08 ± 0.73^{abc}	8.86 ± 0.04^{bcde}	10.86 ± 0.05^{bcd}
P15	10.82 ± 0.19^c	12.82 ± 0.19^c	12.12 ± 2.51^f	11.46 ± 0.20^{cde}
Py10	10.95 ± 1.39^{abc}	11.62 ± 1.45^{abc}	9.77 ± 1.95^{de}	11.77 ± 0.95^{cde}
Py15	10.04 ± 1.82^{abc}	12.03 ± 0.82^{abc}	6.48 ± 1.35^a	9.15 ± 0.78^a
F1	8.74 ± 0.25^a	10.74 ± 0.25^a	6.66 ± 0.52^{de}	11.65 ± 0.52^{cde}
F1+P10	10.48 ± 0.41^1	12.48 ± 0.42^{bc}	10.62 ± 1.44^{ef}	12.62 ± 1.44^e
F1+P15	10.34 ± 0.67^g	13.00 ± 1.00^c	10.28 ± 0.53^{def}	12.28 ± 0.53^{de}
F1+Py10	9.04 ± 0.65^f	11.04 ± 0.72^{ab}	7.56 ± 0.01^{ab}	9.56 ± 0.01^{ab}
F1+Py15	9.75 ± 26^h	11.74 ± 0.25^{eabc}	7.63 ± 0.05^{abc}	9.63 ± 0.05^{ab}

DM : dry matter ; T0 : negative control (root from no treated plants) ; T+ : positive control (10 g of chemical fertilizer NPK 20-10-10) ; 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. The values of the column assigned by the same letter are not significantly different.

3.1.6. Carbohydrate content

Table 3 shows the total carbohydrate content of carrot roots. The analysis of variance revealed a significant difference ($p < 0.05$) between fertilizers and harvest area on the total carbohydrate content of carrot. However, no significant impact is detected between harvest years on carbohydrate content. There was a significant interaction ($p < 0.05$) between fertilizing and harvest area on total carbohydrate content of carrot (table 3). The highest total carbohydrate content of carrot was from F1+P10 roots. This value is 13.28 ± 0.47 g/100 g of dry matter in Maroua and 9.06 ± 0.15 g/100 g of dry matter in Ngaoundere. The F1+P10 fertilizer increased total carbohydrate content at 51.88 % compared to T0 and 20.03 % compared to T+ in Maroua ; this increasing was at 27.59 % and 7.95 % compared to T0 and T+ respectively in Ngaoundere.

Table 3 : Carbohydrates content (g/100 g of dry matter) depending on fertilizer, harvest year and harvest area

Fertilizers	Harvest area			
	Ngaoundere		Maroua	
	2019	2020	2019	2020
T+	8.17 ± 0.57^{bc}	8.51 ± 0.63^{bc}	10.45 ± 0.16^{fg}	10.78 ± 0.53^{de}
T0	6.22 ± 1.55^a	6.89 ± 1.03^a	6.19 ± 0.67^a	6.58 ± 0.87^a
P10	6.84 ± 0.43^{ab}	7.50 ± 0.82^{ab}	8.47 ± 0.57^{cd}	9.13 ± 1.06^{bc}
P15	6.97 ± 0.27^{ab}	7.31 ± 0.39^a	9.35 ± 0.93^{de}	10.02 ± 0.27^{cd}
Py10	8.81 ± 0.19^c	9.15 ± 0.39^c	6.91 ± 0.08^{ab}	6.58 ± 0.62^a
Py15	7.07 ± 0.41^{ab}	8.74 ± 0.97^c	7.96 ± 0.94^{bc}	8.29 ± 0.50^b
F1	8.04 ± 0.65^{abc}	7.71 ± 0.59^c	10.70 ± 0.22^{fg}	11.03 ± 0.35^{def}
F1+P10	8.56 ± 0.14^c	9.56 ± 0.14^c	12.61 ± 0.60^h	13.95 ± 0.33^g
F1+P15	8.07 ± 0.69^{abc}	8.90 ± 0.33^c	11.38 ± 1.14^g	12.05 ± 0.72^f
F1+Py10	8.28 ± 0.70^{bc}	8.95 ± 0.71^c	11.07 ± 0.13^g	11.73 ± 1.23^{cf}
F1+Py15	8.16 ± 0.17^{bc}	8.83 ± 0.70^c	9.82 ± 0.25^{ef}	11.49 ± 0.37^{ef}

T0 : negative control (root from no treated plants) ; T+ : positive control (10 g of chemical fertilizer NPK 20-10-10) ; 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. The values of the column assigned by the same letter are not significantly different.

3.1.7. Correlation between nutritional parameters of carrot roots

Principal component analysis was used to graphically represent the relationship between the carrot roots nutritional parameters (Figure 4). In this model, studied parameters described a total variation of 72.37%. Thus, the F1 axis expressing the highest level of variation (53.59%) is positively correlated with all parameters. The second axis expresses the lowest level of information (F2 (18.78%) and is positively correlated with ash, vitamin C and carotenoids contents of carrot roots. In contrast, the F2 axis correlated negatively with total carbohydrate and total fiber contents. Furthermore, this analysis showed that vitamin C and carotenoid contents move together, also the same result was reported between carbohydrates and dietary fiber contents. Moreover, there was a positive and significant correlation between total carbohydrates and carotenoids contents ($r=0.59$; $p<0.05$); carbohydrates and dietary fiber contents ($r=0.59$; $p<0.05$); carbohydrates and vitamin C contents ($r=0.50$; $p<0.05$). Also, there was a positive and significant correlation ($r=0.82$; $p<0.05$) between carotenoids and vitamin C contents.

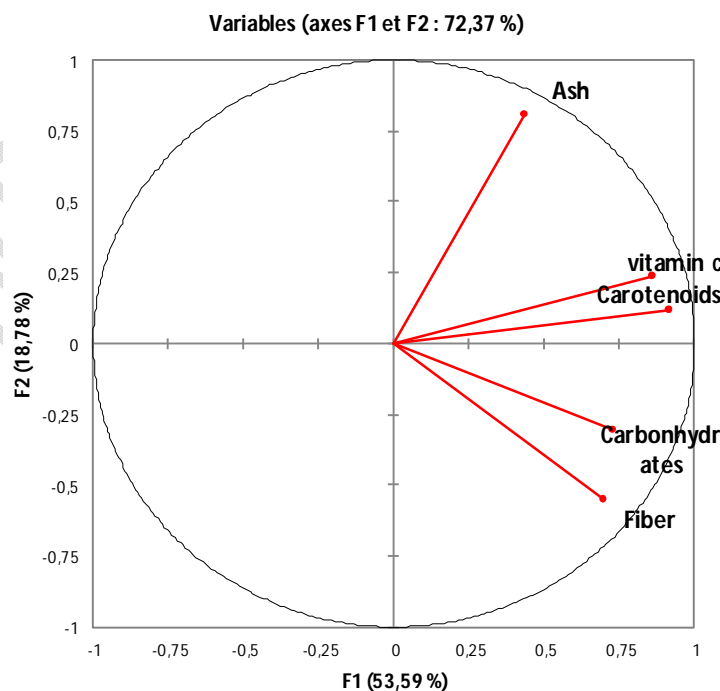


Figure 4 : Correlation between nutritional parameters of carrot roots

3.2. DISCUSSION

It was reported in the current study that carrot root moisture content varied from $54.90 \pm 0.49\%$ for F1+P10 fertilizer in Ngaoundere to $88.76 \pm 0.73\%$ for T0 in Maroua. These results partly corroborate the work of [14] on the effect of poultry litter and vivianite powder on carrot productivity under Guinean high savannah climate of Cameroon and reported that carrot moisture content varied from $70.80 \pm 0.34\%$ to $85.76 \pm 0.42\%$. Furthermore, the studies of several authors [28,29,30] revealed that carrot moisture content varies up to 89%. The low moisture content recorded on treated carrot plant with F1+P10 are favorable for the control of pest attack and would better promote root conservation.

Total carotenoid contents varied from 60.28 ± 0.08 g/100 g of dry matter in Maroua to 71.08 ± 0.10 g/100 g of dry matter in Ngaoundere. These results are different from data found in literature. Indeed, [31] reported that average total carotenoids content of fresh carrot roots was 15 %. This difference would be related to fertilizing. Carotenoids are a source of molecules with essential biological functions [32]. Indeed, they are compounds with, antioxidant properties, they are able to neutralize free radicals in the body. The consumption of carotenoid-rich foods would reduce the risk of suffering from several diseases, such as cancer [33], cardiovascular diseases [34] and some diseases related to aging, like cataract [35]. Also, several carotenoids are precursors of vitamin A, such as β -carotene, which is known for its efficient conversion to vitamin A [36], which is important for fortifying the immune system and promoting healthy cell growth, including reproductive function [37].

Fiber content obtained in this work ranged between 2.57 ± 0.30 g/100 g of dry matter for T0 and 3.65 ± 0.15 g/100 g of dry matter for F1+P10 in Maroua, while in Ngaoundere the values of this parameters varied from 1.93 ± 0.58 g/100 g of dry matter for T0 to 3.25 ± 0.45 g/100 g of dry matter for F1+P10. These results partly corroborate the work of [33] who reported that the average fiber content of carrots is 2.70%. Fibers are important for the body because they intervene in the digestive tract and prevent the absorption of excess cholesterol [38].

It was reported in the current study that vitamin C content of carrot roots ranged between 20.17 ± 1.10 mg/100 g of dry matter and 51.08 ± 0.10 mg/100 g of dry matter. Data recorded on vitamin C content are lower than those found by [39] who revealed that vitamin C content of carrot root from amended compost plot was 7 mg/100g of dry matter. It was reported in this study that natural fertilizers (compost, rock powder) increased vitamin C content compared to no treated carrot plants. This result corroborate data found by several authors [39,14] who reported the beneficial effect of natural fertilizers on increasing the vitamin C

content of carrot roots. The consumption of a vitamin C-rich food has significant roles in the body. Indeed, it contributes to the bone's health, cartilages, teeth and gums. In addition, vitamin C protects body against infections, promotes the absorption of iron from plants and accelerates healing [40]. Still called ascorbic acid, vitamin C is able to prevent scurvy [41].

Ash content of carrot roots obtained in this study ranged between 8.53 ± 0.52 g/100 g of dry matter and 13.00 ± 1.00 g/100 g of dry matter. These values recorded on ash content are higher than those reported by [8] who studied the influence of compost and chemical fertilizer on four carrot varieties in Ivory Coast, and found that average total ash content was 0.89% from treated plots. Ash is an inorganic material present in the plant, it contains various mineral elements such as calcium, potassium, magnesium, phosphorus, manganese, with beneficial effects on human health [42]. It is reported in this work that F1+P10 and F1+P15 roots have high ash contents, thus suggesting that the consumption of carrot from fertilized F1+P10 plots or F1+P15 plots would have better health benefits.

The total carbohydrate contents obtained in Maroua (13.28 ± 0.47 g/100 g of dry matter) and Ngaoundere (9.06 ± 0.15 g/100 g of dry matter) corroborate data reported by [43] who revealed that the average total carbohydrate content of carrot was 10.60%. On the other hand, these values are higher than those reported by [8] who found that the carbohydrate content of carrot was 6.20%. Carbohydrates are essential for muscle and brain function [1]. Indeed, carbohydrates are the most rapidly usable source of energy by the body and are involved in the protein anabolism [2]. Fertilizer stimulates carrot carbohydrate biosynthesis in both study zones. However, the Sudano-Sahelian zone of Far North Cameroon appears to be more favorable to carrot carbohydrate biosynthesis than the high Guinean savannah zone of Adamaoua.

It was reported in the present study that the used fertilizers improved nutritional qualities of carrot compared to negative control (no fertilized plants). This could be justified by the low availability of nutrients in the growing soil. The use of mineral or organic fertilizers would improve the growing soil physico-chemical properties, and consequently carrot nutrient values. Compost is a source of various mineral elements, and thus it improves plant quality [44]. The mineralization of this organic fertilizer would contribute to improve soil fertility, and then the nutritive qualities of carrot roots.

The natural fertilizers (poultry litter, vivianite and pyroclastics powders) used in this work are rich in mineral elements necessary to improve plant productivity. The beneficial effect of poultry litter on the nutritional parameters of carrot would be related to the mineralization of nutrients in the soil. In addition, studies have shown that local resources such as organic waste

applied to tropical soils (acidic and mineral-poor) can provide the nutrients needed for plant productivity [45]. For all combinations, 1 Kg of poultry litter + 10 g of vivianite powder provided the highest nutritional parameters values, thus suggesting that by producing and using F1+P10 fertilizer for carrot cultivation, we are not only contributing to improving the nutritional values of this vegetable crop, but also valorizing our local resources in agricultural while protecting the environment.

4.CONCLUSION

Carrot nutritional values vary depending on fertilizing, harvest area, and harvest year. The fertilizers stimulate carrot nutrient biosynthesis. The carrot nutrient contents from Maroua Cameroon were higher than those from Ngaoundere. The highest carrot nutrients content was from F1+P10 roots. In Maroua, roots from treated carrot plants with F1+P10 fertilizer are 1.55 and 1.24-fold richer in carotenoids than those from T0 and T+ plants respectively in 2019; in growing year 2020, the carotenoid contents of F1+P10 roots were 1.52 fold and 1.29 fold higher than those of T0 and T+ plants. In Ngaoundere, Vitamin C content of carrots from F1+P10 fertilizer is 1.79-fold higher than that of T0 plants and 1.18 fold higher than that of T+ plants in 2019, while in 2020 the value of this parameter was 1.69 fold and 1.47 fold higher than that of T0 and T+ plants respectively. The F1+P10 fertilizer increased total carbohydrate content at 51.88 % compared to T0 and 20.03 % compared to T+ in Maroua, and at 27.59 % and 7.95 % compared to T0 and T+ respectively in Ngaoundere. By produced and used F1+P10 fertilizer for carrot growing, we contribute to improve the nutritional values of this vegetable crop, but also to valorize our local resources in biological agriculture, as well as to protect the environment.

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