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Research Article

Effect of fertilizers' types on yield parameters, sweetness and nutritional quality of carrot (Daucus carota L.) genotypes

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Abstract

Farmers usually rely on various fertilizers to enhance the yield and productivity of crop species. However, these fertilizers are likely to affect performances and qualities traits of crops. To bring out the interaction between agricultural inputs and carrots characteristics, we studied their effect on yield attributes and chemical composition in three varieties of *Daucus carota* L.. Some yield parameters and chemical components of carrot roots were determined.

Carrot's sweetness was also measured using a hedonic test. Fertilizers had a significant effect ($p<0.05$) on both yield attributes and chemical components except moisture content. The results show that chemical components were significantly different between carrot varieties. Interactions between fertilizer treatment and variety were significant for most yield and chemical characteristics. Yield, carbohydrates and carotenoids were significantly higher when using chicken manure as fertilizer. Compost fertilizer enhances important reducing sugars. Treatment using NPK fertilizer induced more proteins and iron. Calcium level was high when using either compost or chicken manure as fertilizer. Better Sweetness was obtained when using chicken manure. Chicken manure or compost; used alone or associated with NPK fertilizer increased agronomic and nutritional characteristics and in carrots.

Introduction

Carrot is a cool-season crop belonging to the Apiaceae family and is one of the major vegetable crops cultivated worldwide [1]. It is good for the eyes health due to the high content of carotenoids, a class of phytochemicals precursors of vitamin A and therefore, help to reduce the risk of vitamin A deficiency [2]. It is also an excellent source of dietary fiber, protein, calcium and vitamins C, K, B1, B2, B6 [3,4]. It is eaten raw (salad), shredded, boiled or cooked as stew or soup [5,6]. It is produced by subsistence farmers because being easy to grow and do not need a large amount of fertilizers [7].

However, the nutritional and organoleptic qualities of carrot may highly depend on genetic, edaphic and cultural factors [8]. Several varieties of carrot are already grown and marketed in Cameroon; factors affecting their nutritional and organoleptic qualities may include the variety as well as some

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agronomic factors such as soil fertilization [9]. Fertilization is an agricultural practice that influences the growth, the yield and the quality of crops. This widespread practice makes use of several types of fertilizers, with chemical fertilizers being the most used to achieve higher yields. However, the use of these chemical fertilizers by farmers has been associated with several human health and environmental problems [10,11]. It is, therefore, necessary to find alternative solutions.

Many studies have shown that carrots grown with organic fertilizers have a better sweetness than those receiving chemical fertilizers [12, 13]. In addition, organic fertilizers can increase the content of nutrients such as β-carotenes [14,15] in their study in Rwanda, found that the combination of 150 kg/ha NPK + 5 t/ha chicken manure treatment gave the highest root yield (11.3 t/ha) followed by 10 t/ha chicken manure treatment (9.13 t/ha) while the lowest root yield (6.017 t/ha) was noticed in control treatment.

[16] showed that carrots are among the preferred vegetables in Cameroon, where several varieties of carrot are marketed and grown. Although the rate of carrots production is not included in the statistical annals of agricultural products of Cameroon, this vegetable has nevertheless been the subject of scientific study. In the Guinean Sudan-Guinean zone [17], found that carrots treated with fertilizers grow rapidly compared to untreated ones. These authors also discovered that the chemical properties of carrots depend on the type and dose of fertilizers. At the end of their study, they reported that further studies on the chemical properties of carrot roots need further investigations. Cultivar choice and cultural practices highly affect carrots qualities. Consumers' choice to eat carrots is largely based on the appreciation of qualities (organoleptic, sensory and nutritional) [1]. Therefore, this study aimed to determine the effect of five types of fertilizers on yield attributes and nutritional quality of three varieties of *Daucus carota* L. mainly grown in Cameroon.

Material and methods

Plant material and study site

Plant material is made up three carrot varieties, namely *New Kuroda*, *Madona* and *Amazonia.* Seeds of these varieties were purchased in a local gardening market. The study was carried out in May 2017 at the Research and Teaching Farm of the Faculty of Agronomy and Agricultural Sciences (FASA) of the University of Dschang (10°04'09'' E, 05°26'70'' N). Soil sample collected on the experimental site before fertilizer application were subjected to analysis of physicochemical properties according to the method described by [18], with results presented in Table 1.

Table 1: Analytical soil values before fertilizer application.

Physical properties	
Sand (%)	60
Limon (%)	10.33
Loam (%)	29.67
Chemical properties	
OC (%)	2.09
OM (%)	3.60
totN (%)	0.16
N (g/Kg)	1.57
Ca (meq/100g)	3.79
Mg (meq/100g)	1.57
K (meq/100g)	0.15
Na (meq/100g) P (meq/100g)	0.07 11.20
CEC (meq/100g)	11.74
AE (meq/100g) C/N	11.20 13.06
pH in water	5.23

Experimental setup

An experimental unit of 1.21 m^2 with a plant spacing of 30cm x 10cm was applied for each carrot variety and each fertilizer application.

The droppings of chickens were obtained from farmers in Dschang, the 'compost' (decomposed household waste) was bought at the composting unit of Dschang urban council, and the chemical fertilizer (12-6-20) was purchased from a phytosanitary product shop. Organic fertilizers were applied seven days before sowing to allow good mineralization of organic matter by soil microorganisms. The six treatments, including the control, were performed in triplicates. Sowing was performed in May 2017, following a split-plot system. Weeds were manually removed when necessary. The plant density per experimental unit was 28 carrot plants spread over four lines and the harvest period was justified by the appearance of signs of maturity such as the senescence of the foliage of carrot plants. Thus, the harvest was made 110 days after sowing. During harvest, six carrot plants collected from the center of each experimental unit were used to determine yield parameters. Those six plants were selected in this way to eliminate the growth effects associated with the borders. Therefore, the first two rows on the left and right sides, and the top and bottom lines were not considered when collecting the samples. However, the other 22 carrot plants were used to assess sweetness and determine the chemical composition of the carrots. It should be noted that the sample quantities used to determine each parameter depended on the nature of the analysis and experimental protocol. The harvested samples were dried at 45°C for 2 days and weighted. These dried samples were crushed, ground (0.5 mm sieve) and stored at room temperature in a sealed plastic bag until chemical analysis.

The six treatments applied consisted of: (1) Compost (10 t/ha); (2) Chicken manure (25 t/ha); (3) NPK fertilizer (12-6-20) (100 kg/ha); (4) Compost + NPK fertilizer (5 t/ha + 50 kg/ha); (5) Chicken manure + NPK fertilizer (12.5 t/ha + 50 kg/ha); (6) Control (no fertilization).

Determination of carrot yield attributes

Yield parameters such as shoulder diameter, length and weight of fresh carrot roots sample were measured using six selected carrot roots from each plot.

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Analysis of the chemical composition of carrot roots

The different chemical analyses were made according to different methods.

The moisture percentage was determined by the method described by [19], the protein content determined by the Kjeldhal method, and the total carbohydrate content determined as described by [20]. Mineral content (Ca, Fe) were determined by the method described by [21]. The reducing sugar content was determined by the reduction of the DNS (3,5dinitrosalicylic acid) according to the method of [22].

Concentrations of carotenoids predominantly present in plasma and in food were determined by the averaging method described by [23].

The oxalate content was determined by oxidation of bromophenol blue by potassium dichromate according to the method described by [24] with slight modification. Briefly, after oxalate extraction by the traditional method described by [25]. The reaction mixture contained 100 – 600µl of standard oxalic acid, 250 µl of 1.00×10-3 M BPB, 400 µl of 0.1 M $K_2Cr_2O_7$ and 450 µl of 1 M H_2SO_4. The final volume was made to 10 ml with distilled water. It was kept in boiling water bath for 10min and the reaction was stopped by adding 1ml of 2 M NaOH. The absorbance was read at 600 nm on spectrophotometer.

Hedonic analysis of carrot roots

The hedonic analysis was performed on carrot roots after harvesting to evaluate the sweetness according to the method of [26] following a scoring questionnaire. This analysis was done using ninety (90) untrained people aged 18 years and over, including 62 men (68.89%) and 28 women (31.11%). Carrot samples from each treatment were randomly given to surveyed people. They were allowed to rinse their mouth with mineral water after tasting each sample to ensure the adequate perception of the hedonic aspect. Sweetness was recorded on the basis of 1 - 9 rating scale (from 1= extremely unpleasant; 2= very unpleasant; 3= unpleasant; 4= rather unpleasant; 5= neither unpleasant nor pleasant; 6= rather pleasant; 7= pleasant; 8= very pleasant; 9= extremely pleasant). The questionnaire contained questions about gender, age and eating frequency of carrot, statements on general usage of carrot and appreciation scale of sweetness.

Statistical analyses

The data generated from the study, expressed as means values, were subjected to the analysis of variance using XLSTAT version 2014.5.03 software. When difference was found, Tukey test at 5 % probability level was applied for means separation of treatments. The principal component analysis was performed on XLSTAT version 2014.5.03 software to select the treatment and variety combination that gave better nutritional parameters.

Results

The ANOVA of the twelve parameters determined in this study is summarized in Table 2. It can be seen from this table that, the treatment had a largely significant effect ($p<0.001$) on yield attributes (length, shoulder diameter and fresh weight of carrot roots) while the varietal effect was not significant ($p>0.05$). It should be noted that the interaction between treatment and variety had a significant effect ($p<0.05$) only on the fresh weight of carrot roots. Except for the moisture content, treatment, variety and interaction between treatment and variety, greatly affected ($p<0.001$) the chemical composition of carrot roots. Concerning carrot roots sweetness, we observed

Table 2: Means squares of analysis of variance for 12 determined parameters in three *Daucus carota* L. varieties in Dschang.

	Treatments (df=5)			Varieties (df=2)			Treatment* variety (df=10)		
Source of variation	MS	F	Significance	MS	F	Significance	MS	F	Significance
Root length (cm)	84.735	27.873	***	2.964	0.975	NS	4.829	1.588	NS
Root shoulder diameter (cm)	8.652	53.994	***	0.058	0.362	NS	0.249	1.558	NS
Root fresh Weight (Kg)	0.848	50.555	***	0.007	0.404	NS	0.038	2.264	*
Moisture content (% FW)	2.304	1.589	NS	2.573	1.775	NS	2.963	2.043	*
Proteins (% DM)	44.725	1735.371	***	25.794	1000.818	***	22.924	889.482	***
Total carbohydrate (% DM)	69.166	212.457	***	1164.269	3576.247	***	49.706	152.681	***
Reducing sugar (g/100g DM)	0.052	209.961	***	0.090	3601.707	***	0.026	105.937	***
Ca (mg/100g DM)	18917.296	5503.761	***	46737.276	13597.652	***	12611.317	3669.112	***
Fe (mg/100g DM)	837.571	10988.917	***	4932.197	64710.355	***	1143.543	15003.269	***
Carotenoids (mg/100g DM)	9.831	190.971	***	21.219	412.211	***	8.193	159.167	***
Oxalate (mg/100g DM)	3312.704	4723.344	***	3363.325	4795.522	***	4272.887	6092.401	***
Sweetness	6.442	2.443	*	0.544	0.206	NS	14.515	5.505	***

*: Significantly different at 0.050 probability level; **: Significantly different at 0.010 probability level; ***: Significantly different at 0.0010;
NS: Non-significant; DM: Dry matter; FW: Fresh Weight

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that the effect of the treatment was significant ($p<0.05$) while the varietal effect was not ($p>0.05$) and the interaction between treatment and variety, was largely significant ($p<0.001$).

Yield attributes of carrot roots

The results of the study revealed that the shoulder diameter, length and fresh weight of the carrot roots differed significantly ($p<0.05$) depending on the type of fertilizer applied while the variety did not have a significant effect ($p>0.05$) on these parameters (Table 2). The means squares of 12 determined parameters in three *Daucus carota* L. varieties grown in Dschang are displayed in Table 3. However, the highest values were obtained with chicken manure and chicken manure + NPK fertilizer combination compared to control and other fertilizers. The difference was not significant ($p>0.05$) between the other treatments compost, NPK, compost + NPK and the control (Table 2).

Chemical composition of carrot roots

Moisture content: As shown in Table 2, fertilizers did not significantly influence moisture content in all the studied varieties of carrots ($p>0.05$). However, the studied carrot has an average of 91% moisture content.

Protein content: The results obtained in this study revealed that the protein content was significantly influenced by the type of fertilizer applied and the cultivar ($p<0.05$) (Table 2). The highest protein content (14.92% DM) was obtained with

Table 3: Effect of fertilizers on yield parameters, chemical composition and sweetness of carrot roots.

Parameters	Treatments						
	Varieties	Compost	Chicken manure	NPK fertilizer	Compost + NPK	Chicken manure + NPK	Control
	Yield attributes(Mean ± SE)						
	New Kuroda	2.36±0.35^{d}	3.99±0.69^{a}	2.60±0.28^{d}	2.52±0.44^{d}	3.44±0.55^{abc}	2.46±0.18^{d}
Root shoulder diameter (cm)	Madona	2.55±0.25^{d}	3.95±0.08^{a}	2.22±0.16^{d}	2.46±0.37^{d}	4.02±0.26^{a}	2.23±0.18^{d}
	Amazonia	2.71±0.56^{bcd}	3.96±0.33^{a}	2.64±0.56^{bcd}	2.62±0.40^{cd}	3.45±0.28^{ab}	2.43±0.62^{d}
	New Kuroda	11.23±1.77^{cd}	16.00±3.17^{ab}	10.78±1.38^{cd}	12.34±1.46^{cd}	13.86±1.42^{abcd}	12.09±1.33^{cd}
Root length (cm)	Madona	10.80±0.83^{cd}	16.48±1.16^{a}	10.35±1.18^{d}	11.29±0.65^{cd}	14.68±0.10^{a}	10.95±1.24^{cd}
	Amazonia	12.57±1.91^{bcd}	16.36±3.75^{a}	11.69±2.36^{cd}	12.50±0.97^{bcd}	14.30±1.39^{abc}	11.98±1.89^{cd}
	New Kuroda	0.190±0.06^{e}	0.73±0.34^{a}	0.22±0.07^{cde}	0.255±0.11^{cde}	0.462±0.16^{bcd}	0.203±0.03^{cde}
Root fresh weight (Kg)	Madona	0.201±0.03^{cde}	0.662±0.05^{ab}	0.156±0.03^{e}	0.197±0.06^{de}	0.724±0.09^{ab}	0.147±0.02^{e}
	Amazonia	0.280±0.13^{cde}	0.718±0.22^{ab}	0.270±0.14^{cde}	0.245±0.07^{cde}	0.466±0.08^{abc}	0.241±0.15^{cde}
Chemical components (Mean ± SE)							
	New Kuroda	91.80±0.47^{a}	90.53±0.68^{a}	92.53±0.98^{a}	91.13±1.35^{a}	90.73±2.43^{a}	92.33±0.27^{a}
Moisture content (% FW)	Madona	91.87±0.10^{a}	91.73±0.37^{a}	91.60±1.29^{a}	91.60±0.78^{a}	92.27±0.92^{a}	91.80±0.47^{a}
	Amazonia	91.53±0.45^{a}	92.33±0.57^{a}	91.73±1.83^{a}	90.87±2.24^{a}	90.07±1.69^{a}	91.13±1.19^{a}
	New Kuroda	9.41±0.19^{j}	10.61±0.29^{hi}	14.92±0.19^{a}	11.81±0.00^{f}	12.75±0.09^{de}	12.62±0.02^{e}
Crude protein content (%DM)	Madona	13.76±0.17^{b}	10.33±0.07^{i}	13.19±0.05^{c}	7.40±0.14^{l}	8.51±0.14^{k}	8.77±0.41^{k}
	Amazonia	11.08±0.06^{g}	11.56±0.18^{f}	12.96±0.01^{cd}	7.22±0.03^{l}	10.87±0.05^{gh}	13.17±0.06^{c}
Total carbohydrate (% DM)	Madona	64.07±0.47^{g}	74.42±0.81^{a}	71.18±0.14^{de}	72.07±0.32^{cd}	74.10±1.24^{a}	73.46±0.05^{ab}
	New Kuroda	72.49±0.08^{bc}	72.57±1.03^{bc}	67.66±0.63^{f}	68.18±0.24^{f}	67.60±0.21^{f}	70.13±0.58^{e}
	Amazonia	57.34±0.52^{k}	64.56±0.91^{g}	61.38±0.19^{h}	60.06±0.24^{i}	63.54±0.41^{g}	58.71±0.19^{j}
	New Kuroda	0.34±0.02^{b}	0.22±0.03^{fg}	0.19±0.00^{ghi}	0.25±0.01^{ef}	0.17±0.01^{i}	0.20±0.02^{ghi}
Reducing sugar (g/100g DM)	Madona	0.33±0.01^{b}	0.20±0.00^{gh}	0.18±0.00^{hi}	0.29±0.02^{c}	0.29±0.00^{cd}	0.27±0.01^{cde}
	Amazonia	0.28±0.01^{cde}	0.25±0.01^{ef}	0.26±0.01^{de}	0.47±0.01^{a}	0.25±0.01^{e}	0.44±0.02^{a}
	New Kuroda	235.79±0.23^{j}	263.15±0.58^{f}	232.15±0.58^{j}	248.17±0.29^{hi}	267.15±0.31^{e}	220.50±4.02^{l}
Ca (mg/100g DM)	Madona	352.50±3.13^{c}	222.50±2.23^{kl}	247.15±1.21^{hi}	214.99±0.44^{m}	225.02±1.31^{k}	244.65±1.02^{i}
	Amazonia	346.87±0.87^{d}	373.51±4.03^{b}	248.37±0.29^{hi}	248.96±1.01^{h}	387.25±1.92^{a}	254.65±1.92^{g}
	New Kuroda	47.58±0.21^{e}	46.07±0.34^{f}	64.39±0.49^{b}	65.47±0.09^{a}	25.11±0.15^{k}	40.82±0.72^{g}
Fe (mg/100g DM)	Madona	22.90±0.13^{m}	28.29±0.17^{h}	27.57±0.25^{i}	24.16±0.18^{l}	24.38±0.16^{l}	22.24±0.19^{n}
	Amazonia	26.01±0.30^{j}	27.73±0.11^{hi}	22.63±0.09^{mn}	53.84±0.18^{d}	58.49±0.22^{c}	19.52±0.08^{o}
	New Kuroda	10.53±0.21^{ef}	11.09±0.36^{d}	8.87±0.13^{h}	9.66±0.04^{g}	11.63±0.36^{c}	10.95±0.07^{de}
Carotenoids (mg/100g DM)	Madona	10.77±0.10^{def}	12.00±0.08^{bc}	11.67±0.30^{c}	12.35±0.11^{b}	11.91±0.28^{bc}	9.24±0.06^{gh}
	Amazonia	11.00±0.20^{de}	14.54±0.17^{a}	12.32±0.22^{b}	10.45±0.36^{f}	11.70±0.24^{c}	11.91±0.27^{bc}
	New Kuroda	70.00±0.89^{e}	53.40±0.47^{g}	25.57±0.81^{l}	58.40±0.77^{f}	27.27±0.84^{kl}	57.00±0.54^{f}
Oxalate (mg/100g DM)	Madona	23.20±0.81^{m}	42.40±0.53^{i}	41.67±1.36^{i}	94.87±0.72^{b}	58.47±0.45^{f}	50.55±0.35^{h}
	Amazonia	73.93±0.81^{d}	79.57±1.34^{c}	28.93±1.00^{j}	29.59±0.81^{jk}	74.12±1.11^{d}	114.26±0.55^{a}
Organoleptic characteristic (Mean ± SE)							
	New Kuroda	5.30±0.24^{cd}	6.57±0.19^{a}	5.00±0.21^{d}	5.60±0.23abcd	6.37±0.22^{ab}	5.77±0.21abcd
Sweetness	*Madona*	6.13±0.21^{abc}	5.53±0.19abcd	6.07±0.18^{abc}	5.70±0.17^{abcd}	5.53±0.22abcd	5.40±0.22^{bcd}
	Amazonia	5.73±0.25abcd	6.10±0.18^{abc}	5.90±0.24abcd	5.17±0.23^{cd}	5.33±0.17^{bcd}	5.90±0.15abcd

[a] The values with different letters in superscript differ significantly ($p<0.05$).
DM: Dry matter;
FW: Fresh Weight

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NPK fertilizer as compared to control and other fertilizers in the *New Kuroda* variety. In the *Madona* variety, two high protein contents (13.76 and 13.19% DM) were recorded respectively with compost and NPK fertilizer compared to control. Combination of compost + NPK fertilizer gave the lowest protein content (7.40% and 7.22% DM respectively in both *Madona* and *Amazonia* varieties) compared to the control. Regardless of the variety, the NPK fertilizer appears to increase the crude protein content.

Carbohydrates: As shown in Table 2, in addition to the varietal effect, fertilizers significantly ($p<0.05$) affected the total carbohydrates content of the carrot varieties. In the *New Kuroda* variety, lowest total carbohydrates contents were obtained with NPK fertilizer (67.66% DM), compost + NPK fertilizer (68.18% DM) and chicken manure + NPK fertilizer combination (67.60% DM) as compared to control (70.13% DM) while high total carbohydrates were obtained with compost (72.49% DM) and chicken manure (72.57% DM) respectively compared to control and other fertilizers. In *Amazonia* variety, chicken manure and chicken manure + NPK combination gave the highest total carbohydrates content (64.56 and 63.54% DM respectively) compared to control (58.71% DM). Regardless of the variety, chicken manure increased the total carbohydrates contents (72.57, 74.42 and 64.56% DM in *New Kuroda*, *Madona* and *Amazonia* varieties respectively). *Madona* variety gave the highest carbohydrates content (74.42 and 74.10% DM with fertilizer chicken manure and chicken manure + NPK fertilizer combination, respectively).

Reducing sugars: Table 2 shows the contents of reducing sugars. Reducing sugars content varies significantly from one variety to another and one treatment to another ($p<0.05$). The highest reducing sugars content as compared to control was obtained with compost in the *New Kuroda* (0.34% DM) and *Madona* varieties (0.33% DM) respectively. In the *Amazonia* variety, fertilizers significantly reduced the reducing sugars content apart from compost + NPK fertilizer (0.47% DM), which showed no significant difference with the control (0.44% DM).

Mineral: Effects varieties and fertilizers on carrot minerals contents are presented in Table 2. In comparison to control, fertilizers significantly increased the calcium content in the *New Kuroda* and *Amazonia* varieties ($p<0.05$). In the latter, the highest calcium content (267.15 and 387.25 mg/100g DM respectively) were obtained with the chicken manure + NPK fertilizer combination. Regardless of the variety effect (Table 4), compost gave the highest calcium content (311.72 mg/100g DM) compared to other treatments and control.

By observing the iron content obtained in the *Amazonia* and *Madona* varieties, the fertilizers significantly increased iron content of these carrot varieties as compared to those obtained with their controls ($p<0.05$). A good illustration of the increase in the iron content of carrots following the application of fertilizers can be visualized in the *Amazonia* variety where the highest iron content (58.49 mg/100g DM) was obtained with chicken manure + NPK fertilizer combination. Nonetheless, the highest iron content (65.47 mg/100g DM) was obtained with *New Kuroda* variety treated with compost + NPK fertilizer combination compared to whole others treatments applied.

Carotenoids: Carotenoids contents presented in Table 2 represent carotenoids mainly present in the human body. They significantly fluctuated depending on the type of fertilizer applied and the type of cultivar ($p<0.05$). These contents vary from 8.89 to 11.52 mg/100g DM in the *New Kuroda* variety; from 9.62 to 12.41 mg/100g DM in the *Madona* variety and from 10.46 to 14.52 mg/100g DM in the variety *Amazonia*. Compared to others fertilizers and to control, chicken manure showed the highest content (14.52 mg/100g DM) with the *Amazonia* variety while the NPK fertilizer showed a low content (8.89 mg/100g DM) with the variety *New Kuroda*. However, compared to control, the *Madona* variety has recorded an increase in these levels as a result of fertilizer application.

Oxalate: The quantification of oxalate was made because of its harmful nature in the absorption of certain nutrients. As shown in Table 3, fertilizers have a significant effect ($p<0.05$) on the oxalate content of carrots. However, the reducing effect of oxalate content by fertilizers was observed with the *Amazonia* variety. In this study, compared to fertilizers applied,

Table 4: Effect of fertilizers treatments on yield, chemical composition and sweetness in carrots.

Parameters	Treatments					
	Compost	Chicken manure	NPK fertilizer	Compost + NPK	Chicken manure + NPK	Control
Yield attributes (Mean ± SE)						
Root shoulder diameter (cm)	2.54±0.38[b]	3.97±0.37[a]	2.49±0.33[b]	2.53±0.40[b]	3.64±0.36[a]	2.37±0.33[b]
Root length (cm)	11.53±1.56[b]	16.28±2.69[a]	10.94±1.64[b]	12.04±1.02[b]	14.28±0.97[a]	11.67±1.48[b]
Root fresh weight (Kg)	0.223±0.07[c]	0.703±0.2[a]	0.215±0.08[c]	0.232±0.08[c]	0.551±0.11[b]	0.197±0.07[c]
Chemical composition (Mean ± SE)						
Moisture content (% FW)	91.73±0.34[a]	91.53±0.54[a]	91.95±1.37[a]	91.20±1.45[a]	91.02±1.68[a]	91.75±0.64[a]
Crude protein content (%DM)	11.42±0.14[b]	10.83±0.18[c]	13.69±0.08[a]	8.81±0.06[d]	10.71±0.09[c]	11.52±0.16[b]
Total carbohydrate (% DM)	64.63±0.36[e]	70.51±0.91[a]	66.74±0.32[d]	66.77±0.26[b]	68.41±0.62[b]	67.43±0.27[c]
Reducing sugar (g/100g DM)	0.32±0.01[b]	0.22±0.01[d]	0.21±0.00[d]	0.33±0.01[a]	0.23±0.00[c]	0.35±0.01[b]
Ca (mg/100g DM)	311.72±1.41[a]	286.38±2.28[c]	242.55±0.69[d]	237.37±0.58[f]	293.14±1.18[b]	239.93±2.32[e]
Fe (mg/100g DM)	32.16±0.21[e]	34.03±0.21[d]	38.19±0.27[b]	47.82±0.15[a]	35.99±0.18[c]	27.53±0.33[f]
Carotenoids (mg/100g DM)	10.77±0.17[cd]	12.54±0.20[a]	10.95±0.21[c]	10.82±0.17[cd]	11.75±0.29[b]	10.70±0.13[d]
Oxalate (mg/100g DM)	55.71±0.84[d]	58.46±0.78[c]	32.06±1.05[f]	60.95±0.77[b]	53.28±0.80[el]	73.93±0.48[a]
Organoleptic characteristic (Mean ± SE)						
Sweetness	5.72±0.23[ab]	6.07±0.18[a]	5.66±0.21[ab]	5.49±0.21[b]	5.74±0.20[ab]	5.69±0.19[ab]

[a] The values with different letters in superscript differ significantly (p< 0.05). DM: Dry matter; FW: Fresh Weigh

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the control of the *Amazonia* variety gave the highest oxalate content (114.17 mg/100g DM).

Root carrot sweetness: The results of the hedonic analysis presented in Table 3 showed that the assessment of the sweetness of studied carrots significantly differed (p<0.05) according to the types of fertilizer and cultivar used. In this experiment, two treatments had greatly distinguished themselves among others: chicken manure and NPK fertilizer when the variety of *New Kuroda* was used. Furthermore, in the *New Kuroda* variety, compared to NPK fertilizer, chicken manure gave the highest scores of appreciation (6.57) corresponding approximately to pleasant appreciation.

Given that fertilization was the secondary factor in this study, Table 4 shows the effect of fertilizers on determined parameters regardless of the variety. Of these presented results, it can be said that chicken manure applied alone or in combination with chemical fertilizer, gave the best performance parameters determined in this study. In addition to the fact that chemical fertilizer gave the highest protein content (13.69% DM), compost and chicken manure gave good contents of chemical components determined in this study, without taking account oxalate content.

Principal component analysis

Principal component analysis (PCA) was performed to select the combination of treatment and variety that gave the best nutritional parameters (total carbohydrates, proteins, reducing sugars carotenoids, calcium and iron).

However, according to the relative interpretation criterion, axes F1 and F2 were used to interpret the results obtained. This is due to the fact that these axes alone account for 56.38% of the cumulative variability and therefore concentrate most of the information in the real point cloud.

Figure 1 shows the scatter plot representing core samples that received different fertilizers based on the nine quantitative parameters related to nutritional and functional properties. It appears from this figure that the *New Kuroda* variety treated with NPK fertilizer (V1T3), the combination compost + NPK fertilizer (V1T4), chicken manure (V1T2) and untreated (V1T6), due to their positions on the positive side (I) of F1 and F2 axes, may have good values for the parameters taken into consideration (total carbohydrates, proteins, reducing sugars, calcium, iron and carotenoids) for the analysis while the untreated *Amazonia* variety (V3T6), treated with NPK fertilizer (V3T3) and chicken manure (V3T2), due to their positions on the negative side (II) of F1 and F2 axes may have poor values for the parameters taken into consideration. Of the differently treated varieties studied, the variety *New Kuroda* (V1), non-fertilized (T6), fertilized with NPK fertilizer (T3), chicken manure (T2), compost + NPK fertilizer (T4), provided the best nutritional parameters considered for this analysis. The combinations V1T3, V1T2, V1T4 and V1T6 can be selected as the ones that gave the best nutritional parameters determined. Therefore, the *New Kuroda* variety could be considered as that showed good nutritional values, and therefore treatments such

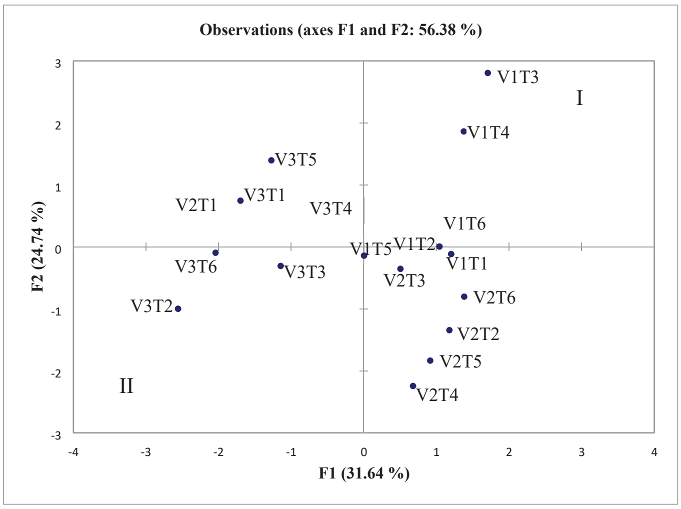

Figure 1: Scatter plot representing core samples that received different fertilizers based on nine quantitative parameters related to nutritional and functional properties.
V1 = New Kuroda; V2 = Madona; V3 = Amazonia; T1 = compost; T2 = chicken manure; T3 = NPK fertilizer; T4 = compost + NPK fertilizer; T5 = chicken manure+ NPK fertilizer; T6 = control

as NPK fertilizer, compost + NPK fertilizer and chicken manure improved the nutritional and functional value of the carrots.

However, the *New Kuroda* variety treated with the compost + NPK fertilizer can be considered as having the best nutritional and functional characteristics determined in this study.

Discussion

Yield attributes of carrot roots

According to the effect of fertilizer on general growth of the core studied, higher values of yield parameter obtained with chicken manure and his combination with NPK fertilizer could be explained by the quality of the nutrients brought by these fertilizers (specially chicken manure) to the soil solution and whose assimilation by the root of carrots was favourable to the growth and therefore to production yield. Indeed, chicken manure provides essential nutrients to plants and thus serve as a soil amendment by adding organic matter that improves nutrient retention [11,27]. According to [28], manure fertilizers provide most of the chemical compound needed for plant growth. The results obtained in this study do not corroborate those obtained by [29] in Ghana who found no significant difference between the application of chicken manure combined with mineral fertilizer and poultry manure on the number of leaves, shoulder diameter, root weight and root length. This difference could be explained by the influence of the nature and the chemical composition of the soil on which the study was performed. Indeed, according to [30], carrot's favourable response to fertilizers also depends on the nature of the nutrients found in the soil.

Chemical composition of carrot root

Moisture: The chemical composition of carrot roots is a varietal feature which can vary widely depending on the environment [31]. However, soil fertility, temperature, and soil

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moisture content can affect the post-harvest moisture content of plants [32]. In this study, all carrots have the same moisture content. This result could be explained by the fact each plant carrot responded in the same way in the absorption of soil water after fertilizer application. Indeed, organic manure by increasing the soil's richness in organic matter and chemical fertilizer by releasing nutrients at a faster rate, both fertilizers improve the availability of soil water and the nutrient retention capacity of the plant [11,27].

Protein: Proteins are involved in several mechanisms of the body; these molecules are mainly made up of nitrogen [33]. The highest content was obtained with the NPK-treated *New Kuroda* variety and the lowest content with the *Amazonia* variety treated with the compost + NPK fertilizer combination. The high levels of protein obtained with NPK fertilizer (inorganic fertilizer) could be due to a quick release of nitrogen and immediate assimilation of the later by the plant. In fact, inorganic fertilizers provide the nutrients that are immediately available to plants and rapidly improve the synthesis of essential nutrients for plant growth [34].

Carbohydrates: Carrot roots are a relatively rich source of carbohydrates, and these are influenced by farming system and genotype. In this study, the highest carbohydrate contents obtained with chicken manure and compost could be explained by the releasing in sufficient quantity (less than 150 kg/ha) of nitrogen and potassium in the soil solution and therefore, absorption by the roots. Indeed, according to [35], appropriate nitrogen and potassium fertilizers are essential for high sugar yield, but an excess of these nutrients decrease sugar content. Furthermore, potassium is involved in the synthesis of carbohydrates through the transport of sugars from the leaves to the root. In another way, potassium is necessary for the translocation of sugars and formation of carbohydrates. The results obtained in this study are in agreement with those of [36], who had also found in their work in Romania, that organic fertilizers, when applied alone, had significantly increased the total carbohydrate content in carrots compared to those grown with chemical fertilizer.

Reducing sugars: The fact that *Amazonia* carrots untreated gave higher reducing sugars contents could be due to by the sugars decreasing the effect of fertilization. [14] showed that the untreated carrots had the highest levels of reducing sugars (10.27%); these results showed that reducing sugars content decreases with fertilization. This reduction in reducing sugar content could be caused by the fact that fertilization favours storage of polysaccharides than the synthesis of reducing sugars. Indeed, according to [37], nitrogen and phosphorus contents in the soil have a negative effect on the synthesis of the sugars in the plant but a positive effect on the synthesis of proteins.

Mineral: The high calcium content obtained with the compost can be relatively attributed to the releasing of a large amount of calcium in the soil solution by this fertilizer. In fact, according to [38], organic manure can increase the mineral composition of soil and therefore, plant by absorbing soil nutrients, increase its components. The difference between the calcium contents of the varieties could also be due to a genotypic difference since they were grown in the same environment [39]. The high iron content may be due to the fact that organic carbon has acted as a source of energy for soil microorganisms, which on the effect of mineralization have released organic acids that have reduced soil pH and improved the availability of iron [38].

Carotenoids: Carotenoids are phytochemicals responsible for antioxidant activities and carrot colour [40].

They protect the human body against cardiovascular disease, arteriosclerosis and cancer [41]. According to [42], the total carotenoid content in carrots varies from six to 54 mg/100g. The results obtained in this study support the assertion of [42]. Because they fall within the early mentioned range (8.89 to 14.52 mg/100g DM). Nevertheless, these values obtained in this experiment are weak, and this could be explained by the fact that we determined solely six carotenoids and there are more than 650 naturally isolated and described carotenoids; however, only 60 of them are regularly present in the human diet, and only 20 of them can be detected in human plasma and tissues; 20 of which six are more abundant [43]. The observed differences in the carotenoid content in the *Madona* carrot variety analyzed could be explained by the increasing effect of fertilizers on the synthesis of carotenoids in the carrot roots. Indeed, according to [43], carotenoid levels in core samples vary with cropping conditions, including light as well as the presence of fertilizer.

Oxalate: Oxalate is an antinutritional, which present in the digestive tract can limit the nutritional availability of calcium and to a lesser extent, iron and magnesium [44]. The highest oxalate content (114.17 mg/100g DM) was obtained with the control of the *Amazonia* variety and the lowest oxalate content (23.10 mg/100g DM) with the *Madona* variety treated with compost. However, investigations of different forms of fertilization have shown that high calcium content in fertilizers contributes to the reduction of soluble oxalate levels in plants [45]. As a consequence, varieties with low oxalate content are mainly composed of soluble oxalates and those with high content, consisting the most part of insoluble oxalates. Indeed, carrot variety presenting the highest oxalate content did not receive an input which could have reduced its oxalates content (soluble oxalates). The content highest obtained with the control of the *Amazonia* variety suggests that the inputs have the capacity to reduce the oxalate content in the carrot roots.

Root carrot sweetness: Abiotic and biotic are the factors that affect carrots quality during the entire production chain, from seed to consumption. Fertilization is among the factors that affect the sensory quality of carrot by contributing plant uptake of constituents present in soil [46]. In this study, the fact that *New Kuroda* variety treated with chicken manure gave better sensory quality could be explained by its higher carbohydrate content as found in this experiment. Indeed, the quality of carrot roots is partially determined by the content of sugar that contributes to a pleasant taste [47]. Additionally, chicken manure as organic manure, organic carrots have been established to be more appreciated than conventional ones

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[12]. The difference observed between the varieties could be due to the genetic background, since the quality characteristics such as sugars and nutrients seem to be genetically determined [46]. Indeed the genetic factor gives the initial code for the level of important chemical compounds involved in sensory aspects of carrots.

Conclusion

This study showed that carrot best yield parameters were obtained with the chicken droppings and the dung combination + NPK fertilizer. The best organoleptic quality was obtained with the variety *New Kuroda* treated with chicken manure. The *New Kuroda* variety treated with NPK fertilizer, compost + NPK fertilizer and chicken manure gave a better nutritional and functional quality. Thus, to best preserve the nutritional quality in the carrot roots, *New Kuroda* variety should be fertilized with compost + NPK fertilizer. Moreover, good organoleptic qualities can be obtained if the variety of *New Kuroda* is fertilized with 'chicken manure'.

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