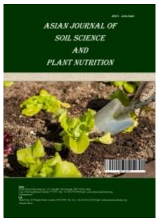

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Nutritional Quality Response of Carrot (*Daucus carota*) to Different Rates of Inorganic Fertilizer and Biochar

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Authors' contributions

This work was carried out in collaboration among all authors. Author KA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors JMA and MEE managed the analyses of the study. Author MEE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Nutritional quality of most high valued crops including carrot can be influenced by soil management practices. A field study to evaluate soil management improvement effect on nutritional quality of carrot was carried out in two contrasting cropping seasons of two rainfall regimes ranging from 600 mm to 800 mm in 2016 and 2017 at Mampong in the Forest-Savannah transition zone of Ghana. Three rates of soil amendments using biochar rates of 0, 5 and 10 tons/ha and five rates of inorganic fertilizers (NPK 15:15:15 at 200 kg/ha; P&K 50:50 at 50 kg/ha; P&K 50:100 at 50 kg/ha; Liquid Fertilizer at 1 L: 200 L Water/ha; and the control were applied using 3x5 factorial in RCBD. The combined analysis for the different treatments showed that NPK at 200 kg/ha+10 ton/ha biochar gave the highest protein content while Liquid fertilizer+5 ton/ha biochar gave the highest beta-carotene and total carotenoid contents in carrot root during the minor cropping season of 2016. However, during the major copping season of 2017, a combination of liquid fertilizer +10 ton/ha biochar gave the highest protein content whilst NPK at 200 kg/ha +5 ton/ha biochar gave the

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highest carotenoid content for the carrot. Nutritional contents such as carbohydrate, beta-carotene and total carotenoids were boosted by soil amendments. This indicates that both biochar and inorganic fertilizers have varying effects on the nutritional qualities of carrot.

Keywords: Nutrition quality; biochar; inorganic fertilizer; sustainable agriculture; carrot production.

1. INTRODUCTION

Carrot (*Daucus carota* L.) is an important vegetable among succulent vegetables consumed across the globe. Apart from its high potential for agricultural products import and export in continental trade, it is one of the exotic vegetables with high nutritive and economic value and of great demand in urban centers of the country [1]. The crop responds favorably to both organic and inorganic fertilizers [2]. However, excessive amount of inorganic fertilizer results in soil acidification, increased greenhouse gas (GHG) emissions, and increased eutrophication of water bodies [3]. These are detrimental to production and loss of nutritional qualities of most crops. Excessive amounts of soil organic matter also promote forking and reduce market acceptability and profitability [4].

As a way to mitigate the environmental pressure resulting from inorganic fertilizers and simultaneously improve carrot quality and yield, soil amendment using biochar has been recommended [5]. Poor soil and crop management practices have been observed among other things as the leading causes of poor production and its attendant low nutritional qualities of most crops in sub-Saharan Africa. Most farmers in these areas have limited access to good production information which often results in limited knowledge coupled with their inability to afford production inputs such as fertilizers and good seeds.

Carrot is an important vegetable grown and marketed by farmers in the study area. The crop provides substantial income which has helped to improve their livelihoods over the years. Most of the produce is transported to large urban centers where they are sold and used for food preparations. However, production has been on subsistence level due to several factors including poor soil management. In this study, biochar as soil conditioner was used because of its documented positive influence on soil physical and chemical properties. Biochar is a material created by pyrolysis of biomass for incorporation into soils to increase the amount of stable organic matter and consequently improve soil fertility [6]. The key idea behind biochar is the enrichment of soils with stable organic carbon compounds which have the potential to improve both the yield and quality of most crops [7].

In order to mitigate the negative environmental effects resulting from inorganic fertilizers and simultaneously improve the nutritional quality of carrots, a combination of biochar and inorganic fertilizers were used with a view to improve soil productivity, carbon sequestration and greenhouse gas adsorption among others [8].

2. MATERIALS AND METHODS

2.1 Experimental Site and Design

The study was carried out at Mampong located in the Forest-Savannah transition zone of Ghana (Lat. 07º, 04’N; Long. 01º, 24’W) [9].

During the minor cropping season of 2016, the maximum and minimum average temperatures were 29.06ºC and 22.82ºC respectively. Total rainfall was 681.6 mm whiles the average relative humidity was 79.6%. In the major cropping season of 2017 (March to July), the maximum average temperature was 32.14ºC and the minimum was 23.38ºC. Total rainfall for the same period was 791.4 mm and the average relative humidity was 79.6%.

A 5x3 factorial arranged in a randomized complete block design (RCBD) was used. The treatments, made up of five fertilizer rates and three biochar rates were assigned to the plots in each block. Each plot measured 2.0 m × 1.2 m. The treatment combinations are described in Table 1.

2.2 Land and Biochar Preparation and Application

The land was ploughed, harrowed, leveled and laid out to a pre-determined field size of 26 m x 10 m. Seeding beds measuring 2 m x 1.2 m were raised to a height of 25 cm and leveled again. There was a 1.0 m path left between each bed and 2.0 m interval between the block.

Table 1. Treatments for the experiment

Treatments	Inorganic Fertilizer	Biochar
T1	NPK 15:15:15@200 Kg/ha (Recommended)	5 ton/ha
T2	P&K 50:50 @ 50 kg/ha*	10 ton/ha
T3	P&K 50:100 @ 50 Kg/ha**	No Biochar (Control)
T4	Liquid Fertilizer	5 ton/ha
T5	No Fertilizer (Control)	10 ton/ha
T6	NPK 15:15:15@ 200 Kg/ha (Recommended)	No Biochar (Control)
T7	P&K 50:50 @ 50 kg/ha	5 ton/ha
T8	P&K 50:100 @ 50 Kg/ha	10 ton/ha
T9	Liquid Fertilizer	No Biochar (Control)
T10	No Fertilizer (Control)	5 ton/ha
T11	NPK 15:15:15@ 200 Kg/ha (Recommended)	10 ton/ha
T12	P&K 50:50 @ 50 kg/ha	No Biochar (Control)
T13	P&K 50:100 @ 50 Kg/ha	5 ton/ha
T14	Liquid Fertilizer	10 ton/ha
T15	No Fertilizer (Control)	No Biochar (Control)

** P&K 50:50= 50 kg/ha P and 50 kg/ha K or 50 parts P and 50 parts K*
*** P&K 50: 100 = 50 kg/ha P and 100 kg/ha K or 50 parts P and 100 parts K*

Biomass from woody branches of avocado was slowly pyrolyzed at about 500ºC in an anoxic heap reactor to constitute the biochar. The biochar was then crushed and milled to <2 mm-sized particles. The powdered biochar was applied a week after bed preparation by mixing with the soil at 10 cm deep for the different treatments as described in table 1 and left for two weeks before planting.

2.3 Soil Sampling and Biochar Analysis

Initial soil samples were randomly taken from 5 different spots at a depth of 0-15 cm from each plot and block. Soil samples from similar plots were bulked, air dried and sub-samples taken for analysis before planting. Soil samples treated with biochar were also taken at six weeks after biochar application and analyzed.

2.4 Planting, Fertilizer Preparation and Application

Carrot seeds of a popular variety (Chantenay) were sown by drilling to a depth of about 2 cm at 30 cm between rows on each bed. The beds were covered with grass straw to prevent desiccation from excessive heat and possible washing off of seeds during heavy rains. The grass straw was removed after seedling emergence. Emergence was observed six days after sowing. At 12 days after planting, seedlings were thinned to 10 cm within plants. Different rates of fertilizers as described in Table 1 were applied at 2 weeks after planting.

2.5 Cultural Practices

Watering was done once daily except when it rained. A fitted watering can measuring 15 liters per plot was applied up to 21 days after sowing (DAS) and was gradually increased to 30 liters per plot at establishment. Weeds were hand-picked. The paths between the blocks and plots were kept weed free throughout the period of the study.

Earthening-up was done every two weeks after weeding and watering to cover exposed roots. The intra-row spaces were stirred up with hand fork at two weekly intervals throughout the growing period to improve soil aeration and enhance growth and development of the crop.

2.6 Data Collection

2.6.1 Soil analysis

Data collected from soil analyses included, soil pH, soil organic carbon, organic matter, available phosphorus, potassium, sodium and cation exchange capacity.

Soil pH was measured using a glass electrode (pH meter). Soil organic matter was determined by the wet combustion method [10]; Percentage total nitrogen was determined by the micro Kjeldahl-technique [11]; the available phosphorus was extracted by the Bray method and determined calorimetrically [12]; Potassium was determined by flame emission photometry [13]; exchangeable cation, calcium, magnesium, potassium and sodium were also determined as recommended by using EDTA Titration after extraction with 0.1N Ammonium Acetate at pH 7 [14]. Effective Cation Exchange Capacity (ECEC) was calculated as the sum of the exchangeable bases and exchangeable acidity.

2.6.2 Plant tissue analysis

Plant tissue analysis was determined using proximate analysis procedures as described by [15]. Variables determined including moisture, ash, protein, fat, carbohydrate and crude fibre content. Crude Protein was determined by Kjeldahl Method [11].

Nitrogen-Free Extract (NFE) which represents the non-structural carbohydrates such as starches and sugars was determined by calculation after the determination of the various components of the proximate analysis using the formula:

$$\%NFE(ondrymatterbasis) = 100 - (\%CP + \%CF + \%Ash + \%EE)$$

Where, NFE = nitrogen free extract; EE = ether extract or crude lipid; CP = crude protein; CF = crude fiber

The determination of percentage total carbohydrate was carried out using the values obtained for NFE and crude fibre in the formula:

$$\%Carbohydrate = \%\,NFE + \%Fibre$$

2.6.3 Beta-Carotene and total carotenoid contents

Plant β- and total carotenoid analyses were determined using method described by [16].

2.7 Data Analyses

Data collected for all variables were analyzed by Analysis of Variance (ANOVA) using Version 11.1 of GenStats software package (2008) to determine the level of variability among the treatments. Means were separated using standard error of differences at 1% and 5% significance level.

3. RESULTS AND DISCUSSION

3.1 Biochar and Soil Chemical Properties at Experimental Site

Results of the initial soil analysis of the site (Table 2) showed that the pH was moderately acidic (5.72). However, acidity went up to 5.35 at the beginning of the second season which started in March, 2017. The organic matter content for the same period was moderate to low whiles nitrogen content remained moderate. The exchangeable cations (calcium, magnesium and potassium) were low. Effective cation exchange capacities for both growing seasons were also low. This phenomenon was as a result of excessive leaching and run-off caused by continuous cropping of the site. This observation is similar to the findings of [2], who assessed the response of farmyard manure and inorganic fertilizers for sustainable production of carrot in Northern Nigeria.

Analysis of the chemical composition of the biochar (Table 3) showed that the soil pH was slightly acidic (6.37) whiles the percentage organic carbon content was 34.5%. This contributed significantly to the total soil organic matter content. Biochar also contributed to increase the soil Nitrogen content, whiles phosphate, potassium and magnesium contents remained low.

3.2 Fertilizer and Biochar Effects on Soil Chemical Properties

There was significant (P<0.01) interaction between fertilizer and biochar (applied at 10 ton/ha and 5 ton/ha) on soil pH (Table 4) during the minor cropping season which resulted in changes in soil from pH 5.99 and 5.71 which was moderately acidic. Soils without biochar were acidic with pH of 5.47. These changes could be attributed to the regulatory effect of biochar on soil pH which made biochar-treated plots to produce less acidic media. This is similar to what [15] found. Plots treated with NPK fertilizer were also acidic with a pH of 5.37. P&K 50:50 gave a moderately acidic pH among the fertilizers due to the improved release of base cations into soil solution as similarly observed by [17,18].

The percentage organic carbon present in P&K 50:50 +5 ton/ha and 10 ton/ha biochar were the same (0.9) but a slight improvement over P&K 50:50 applied alone (0.71) (Table 4). Under P&K 50:100, biochar at 5 ton/ha gave the highest % organic carbon (0.94) with biochar at 10 ton/ha showing the least % organic carbon. Plots treated with liquid fertilizer showed higher % organic carbon in the presence of 5 ton/ha and 10 ton/ha biochar. This could be due to the enhanced contribution of biochar environments to organic carbon [19]. In the absence of fertilizer, biochar applied at 10 ton/ha showed the highest % organic carbon.

During the major cropping season, plots receiving 10 ton/ha biochar gave an average pH of 5.5 among biochar treatments (Table 5). Although, still within the acidic range, plots treated with 10 ton/ha biochar resulted in an increased pH as observed by [20]. Among fertilizer treatments, P&K 50:50 and liquid fertilizer also gave an acidic mean pH of 5.2. Treatments without fertilizer gave acidic mean pH of 5.5 similar to NPK 200 kg/ha which produced a PH of 5.4. Among individual treatments, 10 ton/ha biochar without fertilizer gave a moderately acidic pH of 6.1. This confirms the regulatory ability of biochar on soil pH [16]. These results had consequential reduction effect on the availability of macronutrients and an increment in micronutrient availability. It also corroborated in the findings of [21] which suggested that the significant increase in soil acidity was probably due to leaching of base cations. This implied that controlled use of biochar has a good potential for reducing soil acidity and reducing the application of lime to the soil. Hence, effective management of soil pH is critical for plant nutrition and sustainable agriculture.

3.3 Effect of Fertilizer and Biochar on Tissue Composition

The combined treatment of fertilizers and biochar had positive and significant interactive ($p<0.01$) effects on carrot tissue nutritional composition. In general, chemical compositions such as fat, fibre, ash and moisture of the carrot tissue were either high or low depending on the different combinations of fertilizers and biochar applied (Tables 6 and 7). For example, plots treated with liquid fertilizer+5 ton/ha biochar showed the highest fat composition while liquid fertilizer without biochar gave the least during the minor cropping season. Similar results were found for carbohydrate and protein contents in the carrots.

These observations may be due to enhanced release of Gibberellins (a stress hormone), to induce the root tubers to take up more soil nutrients in order to make up for insufficient nutrient arising from reduced precipitation and corresponding reduction in nutrient transport [22].

3.4 Effect of Fertilizer and Different Levels of Biochar on Carotenoid Composition

Beta carotene content was highest in carrots which received liquid fertilizer and least for plots which did not receive fertilizer and biochar in the minor cropping season (Table 8). The major cropping season, however, saw plots treated with NPK 200 kg/ha +5 ton/ha biochar showing the highest beta carotene content while plots receiving P&K 50:100 gave the least. Similarly, plots which received P&K 50:50 +5 ton/ha biochar produced the highest total carotenoids, while plots that received P&K 50:100+ 5 ton/ha biochar produced the least during the minor cropping season. During the major cropping season, NPK 200 kg/ha +5 ton/ha biochar produced the highest total carotenoid content while P&K 50:100 + 5 ton/ha biochar had the least. These observations are due largely to the fact that 10 ton/ha biochar, NPK and P&K 50:100 offer adequate nutrients for the formation of chloroplasts to house chlorophyll and carotenoids in source tissues for subsequent translocation into sink structures of the roots. Detailing the mechanism involved, [23] explains that, like chlorophylls, carotenoids of leaves are ubiquitous structural components of the photosynthetic apparatus of leaves.

It is further argued that in higher plants, chlorophylls and carotenoids are bound to specific proteins to form either reaction centre pigment–protein complexes or light-harvesting pigment– protein complexes (LHCs) of photosystem (PS) I and PSII (LHCII). The seasonal differences in the mean carotenoid composition is explained by [24] who argues that abiotic stresses arising from drought, extreme temperatures, salinity, or nutrient deficiency adversely affect the photosynthetic process in higher plants. They further explain that crop growth, development, yield and quality are influenced by abiotic stressors. It is further established that the photosynthetic machinery consists of various mechanisms, including gaseous exchange systems, photosynthetic pigments, photosystems, electron transport systems, carbon reduction pathways, and enzyme systems whose impairment to one or more of these processes would reduce the photosynthetic activity of the crop, their growth, their biomass production and nutrient composition [25].

Table 2. Soil chemical properties at experimental sites, 2016 and 2017

Year	pH, H_2O 1:2.5	Org.C %	Total N %	Org. M %	Exch. Cations (me/100 g)				T.E.B cmol/kg	Exch. A(Al+) cmol/kg	ECEC me/100 g	Base Sat %	Available		SO_4^{2-} (mg/kg)
					Ca	Mg	K	Na					P	K	
2016	5.72	0.94	0.11	1.61	2.14	2.40	0.21	0.05	4.80	0.50	5.30	90.56	5.46	9.28	16
2017	5.35	0.71	0.11	1.23	5.07	2.67	0.27	0.09	7.83	0.72	6.97	89.95	13.47	9.96	30

Org. C=organic carbon, N=Nitrogen; Org. M=Organic Matter: Exch. Cations=Exchangeable cations (Ca, Mg, K, Na); T.E.B=Total Exchangeable Bases; Exch. A=Exchangeable Acidity; Base Sat=Base Saturation

Table 3. Chemical properties of biochar used for the field studies

	pH 1:5	%Org. Carbon	Mg%	P%	K%	N%	*EcuS/cm 1:5
Biochar	6.37	34.50	0.10	0.11	0.11	0.50	946

**Ec=Soil Electrical Conductivity*

Table 4. Effects of fertilizer and biochar on soil chemical properties, 2016

Soil Data	Treatment	Biochar			Mean	S.E.D.		
Soil Chemical Properties 2016		0t/ha	5t/ha	10t/ha		Fertilizer	Biochar	Fertilizer X Biochar
Soil pH	NPK 200kg/ha	5.34	5.00	5.77	5.37			
	P&K 50:50	5.67	6.00	6.08	5.92			
	P&K 50:100	5.26	5.71	6.14	5.70	0.004**	0.003**	0.008**
	Liquid Fertilizer	5.37	5.84	6.01	5.74			
	No Fertilizer	5.72	6.01	5.93	5.89			
	Mean	5.47	5.71	5.99	5.72			
Organic Carbon (%)	NPK 200kg/ha	0.79	0.86	0.82	0.82			
	P&K 50:50	0.71	0.90	0.90	0.84			
	P&K 50:100	0.75	0.94	0.71	0.80			
	Liquid Fertilizer	0.82	0.98	0.90	0.90	0.00357**	0.00277**	0.00619**
	No Fertilizer	0.94	0.80	1.01	0.92			
	Mean	0.80	0.90	0.87	0.86			
Total Nitrogen (%)	NPK 200kg/ha	0.07	0.07	0.07	0.07			
	P&K 50:50	0.06	0.08	0.08	0.07			
	P&K 50:100	0.06	0.09	0.06	0.07			
	Liquid Fertilizer	0.07	0.10	0.09	0.09	0.002023**	0.001567**	0.003504**
	No Fertilizer	0.11	0.08	0.09	0.09			
	Mean	0.07	0.08	0.08	0.08			
Organic Matter (%)	NPK 200kg/ha	1.36	1.48	1.42	1.42			
	P&K 50:50	1.23	1.57	1.55	1.45			
	P&K 50:100	1.29	1.61	1.23	1.38			
	Liquid Fertilizer	1.42	1.68	1.55	1.55	0.00356**	0.00276**	0.00616**
	No Fertilizer	1.61	1.36	1.74	1.57			
	Mean	1.38	1.54	1.50	1.47			

*S.E.D. Standard Error of the Deferences of mean; **Mean significant at 1% probability level*

Table 5. Effects of fertilizer and biochar on soil chemical properties, 2017

Soil Data	Treatment	Biochar			Mean	S.E.D.		
Soil Chemical Properties 2017		0t/ha	5t/ha	10t/ha		Fertilizer	Biochar	Fertilizer X Biochar
Soil pH	NPK 200kg/ha	5.50	5.22	5.52	5.41			
	P&K 50:50	5.25	5.15	5.32	5.24			
	P&K 50:100	5.13	5.35	5.28	5.25	0.0020**	0.0016**	0.0035**
	Liquid Fertilizer	5.15	5.21	5.37	5.24			
	No Fertilizer	5.35	5.23	6.05	5.54			
	Mean	5.28	5.23	5.51	5.34			
Organic Carbon (%)	NPK 200kg/ha	0.80	0.55	0.91	0.75			
	P&K 50:50	0.64	0.77	0.72	0.71			
	P&K 50:100	0.62	0.82	0.81	0.75			
	Liquid Fertilizer	0.70	0.66	0.95	0.77	0.0029**	0.0022**	0.0050**
	No Fertilizer	0.72	0.82	0.55	0.70			
	Mean	0.69	0.72	0.79	0.74			
Total Nitrogen (%)	NPK 200kg/ha	0.14	0.13	0.12	0.13			
	P&K 50:50	0.14	0.13	0.11	0.13			
	P&K 50:100	0.13	0.12	0.11	0.12			
	Liquid Fertilizer	0.11	0.11	0.13	0.12	0.0010**	0.0007**	0.0017**
	No Fertilizer	0.11	0.12	0.13	0.12			
	Mean	0.13	0.12	0.12	0.12			
Organic Matter (%)	NPK 200kg/ha	1.38	0.94	1.57	1.30			
	P&K 50:50	1.10	1.32	1.23	1.22			
	P&K 50:100	1.07	1.42	1.38	1.29			
	Liquid Fertilizer	1.19	1.13	1.63	1.32	0.0016**	0.0012**	0.0028**
	No Fertilizer	1.23	1.41	0.94	1.19			
	Mean	1.19	1.24	1.35	1.26			

*S.E.D. Standard Error of the Deferences of mean; **Mean significant at 1 % probability level*

Table 6. Influence of fertilizer and biochar on proximate composition, minor cropping season, 2016

Proximate Analysis 2016 %Nutrient Composition	Treatment	Biochar			Mean	S.E.D.		
		0t/ha	5t/ha	10t/ha		Fertilizer	Biochar	Fertilizer X Biochar
Fat	NPK 200kg/ha	2.50	2.54	2.09	2.38	0.2376	0.1841**	0.4116*
	P&K 50:50	2.53	2.89	3.04	2.82			
	P&K 50:100	2.28	2.54	3.23	2.68			
	Liquid Fertilizer	1.85	3.66	3.26	2.92			
	No Fertilizer	2.47	2.95	3.31	2.91			
	Mean	2.33	2.92	2.99	2.74			
Fibre	NPK 200kg/ha	5.74	4.58	6.03	5.45			
	P&K 50:50	5.81	4.81	4.96	5.20			
	P&K 50:100	5.33	5.59	5.34	5.42			
	Liquid Fertilizer	6.43	5.58	6.37	6.13	0.2353**	0.1822	0.4075**
	No Fertilizer	5.38	6.11	4.50	5.33			
	Mean	5.74	5.34	5.44	5.50			
Ash	NPK 200kg/ha	26.32	26.34	26.30	26.32			
	P&K 50:50	26.04	25.61	26.01	25.89			
	P&K 50:100	25.69	29.19	25.74	26.87			
	Liquid Fertilizer	26.18	25.84	25.76	25.93	0.903	0.7	1.565
	No Fertilizer	26.58	28.53	25.08	26.73			
	Mean	26.16	27.10	25.78	26.35			
Moisture	NPK 200kg/ha	47.90	46.98	44.23	46.37			
	P&K 50:50	48.99	46.12	47.29	47.47			
	P&K 50:100	45.93	47.23	45.74	46.30			
	Liquid Fertilizer	45.59	50.11	46.15	47.28	0.927	0.718	1.605**
	No Fertilizer	46.48	45.16	51.76	47.80			
	Mean	46.98	47.12	47.04	47.04			
Protein	NPK 200kg/ha	10.47	9.65	11.89	10.67			
	P&K 50:50	9.33	10.17	11.85	10.45			
	P&K 50:100	11.72	10.10	10.79	10.87			
	Liquid Fertilizer	10.58	9.73	10.53	10.28	0.435	0.337**	0.753
	No Fertilizer	9.76	9.65	9.59	9.67			
	Mean	10.37	9.86	10.93	10.39			

Carbohydrates	NPK 200kg/ha	7.07	9.90	9.46	8.81			
	P&K 50:50	7.30	10.39	6.85	8.18			
	P&K 50:100	9.05	5.36	9.17	7.86			
	Liquid Fertilizer	9.38	5.07	7.92	7.46	0.851	0.659	1.474**
	No Fertilizer	9.33	7.60	5.75	7.56			
	Mean	8.43	7.66	7.83	7.97			

*S.E.D. Standard Error of the Deferences of mean *, **Mean significant at 5 % and 1 % probability levels respectively*

Table 7. Influence of fertilizer and biochar on proximate composition, major cropping season 2017

Proximate Analysis 2017	Treatment	Biochar			Mean	S.E.D.		
%Nutrient Composition		**0t/ha**	**5t/ha**	**10t/ha**		**Fertilizer**	**Biochar**	**Fertilizer X Biochar**
Fat	NPK 200kg/ha	1.75	1.07	0.34	1.05			
	P&K 50:50	1.77	1.48	0.88	1.38			
	P&K 50:100	1.75	2.51	1.94	2.07	0.02034**	0.01576**	0.03523**
	Liquid Fertilizer	1.53	1.07	1.49	1.36			
	No Fertilizer	0.94	1.13	2.01	1.36			
	Mean	1.55	1.45	1.33	1.44			
Fibre	NPK 200kg/ha	7.02	12.88	8.56	9.49			
	P&K 50:50	6.62	9.19	7.79	7.87			
	P&K 50:100	7.45	10.00	8.67	8.71			
	Liquid Fertilizer	7.13	15.64	10.03	10.93	0.0361**	0.0279**	0.0625**
	No Fertilizer	12.00	12.36	7.81	10.72			
	Mean	8.04	12.01	8.57	9.54			
Ash	NPK 200kg/ha	6.10	5.09	6.38	5.85			
	P&K 50:50	6.99	7.00	6.64	6.88			
	P&K 50:100	8.02	6.61	7.59	7.41			
	Liquid Fertilizer	8.22	7.61	8.13	7.99	0.02555**	0.01979**	0.04426**
	No Fertilizer	8.86	7.60	6.37	7.61			
	Mean	7.64	6.78	7.02	7.15			

Moisture	NPK 200kg/ha	66.75	69.57	68.45	68.26			
	P&K 50:50	68.60	67.39	69.49	68.49			
	P&K 50:100	67.74	66.78	68.99	67.84			
	Liquid Fertilizer	66.19	67.02	67.41	66.87	0.0534**	0.0413**	0.0924**
	No Fertilizer	67.41	68.77	67.78	67.99			
	Mean	67.34	67.91	68.42	67.89			
Protein	NPK 200kg/ha	7.01	7.88	8.54	7.81			
	P&K 50:50	7.44	10.51	4.38	7.44			
	P&K 50:100	9.19	6.61	8.32	8.04			
	Liquid Fertilizer	8.54	7.44	10.97	8.98	0.01001**	0.00775**	0.01734**
	No Fertilizer	7.88	7.88	8.54	8.10			
	Mean	8.01	8.07	8.15	8.08			
Carbohydrates	NPK 200kg/ha	11.38	3.51	7.75	7.55			
	P&K 50:50	8.59	4.42	10.82	7.94			
	P&K 50:100	5.85	7.48	4.49	5.94			
	Liquid Fertilizer	8.39	1.22	1.97	3.86	0.00808**	0.00626**	0.01400**
	No Fertilizer	2.91	2.26	7.49	4.22			
	Mean	7.42	3.78	6.51	5.90			

*S.E.D. Standard Error of the Deferences of mean; **Mean significant at 1 % probability level*

Table 8. Influence of fertilizer and biochar on carotenoid composition, minor cropping season, 2016

Soil Data	Treatment	Biochar			Mean	S.E.D.		
Carotenoid Content 2016		0t/ha	5t/ha	10t/ha		Fertilizer	Biochar	Fertilizer X Biochar
Beta Carotene Content mg/ml	NPK 200kg/ha	0.190	0.078	0.152	0.140			
	P&K 50:50	0.113	0.042	0.227	0.127			
	P&K 50:100	0.064	0.412	0.474	0.316			
	Liquid Fertilizer	0.089	0.599	0.059	0.249	0.00703**	0.00544**	0.01217**
	No Fertilizer	0.093	0.099	0.134	0.108			
	Mean	0.110	0.246	0.209	0.188			
Total carotenoids mg/ml	NPK 200kg/ha	0.380	0.156	0.304	0.280			
	P&K 50:50	0.226	0.084	0.383	0.231			
	P&K 50:100	0.127	0.823	0.948	0.633			
	Liquid Fertilizer	0.179	1.197	0.118	0.498	0.000703**	0.000544**	0.001217**
	No Fertilizer	0.185	0.197	0.267	0.217			
	Mean	0.219	0.492	0.404	0.372			

*S.E.D. Standard Error of the Deferences of mean; **Mean significant at 1 % probability level*

Table 9. Influence of fertilizer and biochar on carotenoid composition, major cropping season, 2017

Soil Data	Treatment	Biochar			Mean	S.E.D.		
Carotenoid Content 2017		0t/ha	5t/ha	10t/ha		Fertilizer	Biochar	Fertilizer X Biochar
Beta Carotene Content mg/ml	NPK 200kg/ha	0.350	0.570	0.226	0.382			
	P&K 50:50	0.118	0.097	0.415	0.21			
	P&K 50:100	0.595	0.064	0.414	0.358			
	Liquid Fertilizer	0.114	0.099	0.142	0.118	0.000706**	0.000547**	0.001223**
	No Fertilizer	0.190	0.152	0.402	0.248			
	Mean	0.274	0.196	0.320	0.263			
Total carotenoids mg/ml	NPK 200kg/ha	0.701	1.139	0.453	0.764			
	P&K 50:50	0.236	0.195	0.831	0.421			
	P&K 50:100	1.191	0.128	0.829	0.716			
	Liquid Fertilizer	0.227	0.197	0.283	0.236	0.0000721**	0.0000558**	0.0001248**
	No Fertilizer	0.381	0.297	0.804	0.494			
	Mean	0.547	0.391	0.640	0.526			

*S.E.D. Standard Error of the Deferences of mean; **Mean significant at 1 % probability level*

4. CONCLUSION

The results show that both inorganic fertilizer and biochar have different effects on the nutritional quality of carrots. This arises from amendment and climate-induced soil chemical changes on soil pH, Percent Organic Carbon, Total Nitrogen and Percent Organic matter. Consequently, it is demonstrated that soil amendment with different levels of biochar and fertilizer affect soil chemical properties and render rhizosphere environment either more or less conducive for the accumulation of certain nutrients in the crop. Nutritional parameters significantly affected by the soil amendment were fat, fibre, Ash, Moisture, Protein, Carbohydrates, β-carotene and total carotenoids.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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