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Research Article

Effect of Salinity on Plant Growth, Yield and Root Nutritional Value of Carrot (*Daucus carota* L.) in the Sahelian Area of Cameroon

Mathias Julien Hand[1]*, Kingsley Mbi Tabi[2], Chimène Fanta Abib[1], Ismael Ramza[1], Victor Désiré Taffouo[3] and Emmanuel Youmbi[4]

[1]Department of Biological Sciences, Faculty of Science, University of Maroua, P.O. Box 46, Maroua, Cameroon

[2]Department of Crop Production, College of Technology, University of Bamenda, P.O. Box 39, Bambili, Cameroon

[3]Department of Botany, Faculty of Science, University of Douala, P.O. Box 24157, Douala, Cameroon

[4]Department of Biology and Plant Physiology, Unit of Physiology and Plant Improvement, Laboratory of Biotechnology and Environment, Faculty of Science, University of Yaoundé I, P.O. Box 812, Yaoundé, Cameroon

Abstract

Context: Salinity is a permanent threat to the survival of plants. An improved understanding of the responses of species to salinity may aid the development of more tolerant cultivars and improved management practices.

Objective: This study aims to evaluate the effects of different levels of NaCl salinity on plant growth, nutritional value and root yield of three carrot varieties.

Methodology: Four levels of NaCl, 0, 60, 120 and 240 mM and three varieties of carrot (Pamela, New kuroda, Touchon) were used for this pot experiment. The two-factor experiment was laid out in randomized complete block design with four replications.

Results: The nutritional value, growth and yield components varied significantly between three carrot varieties and intensity of salt concentration. From 0 to 240 mM NaCl, root yield decrease (to 25.4%, 30.5% and 30.3% in New kuroda, Touchon and Pamela respectively), root beta-carotene reduced (to 11.4%, 13.5% and 15.8% in New kuroda, Touchon and Pamela respectively), pH of root (to 12.5%, 16.9% and 16.5% in New kuroda, Touchon and Pamela respectively) and accumulation of osmolytes, fiber content, total phenolic, Na content of root and root titrable acidity (to 35%, 27.8% and 36.8% in New kuroda, Touchon and Pamela respectively). The accumulation of Na+ content is very important in the root of sensitive variety Pamela and the lowest in the root of tolerant variety New Kuroda. Salinity stress at certain level remarkably enhances nutritional quality of the root of *Daucus carota*.

Conclusion: It can be summarized that New Kuroda and Touchon showed relatively salt tolerant ability as compared to Pamela. So, New Kuroda and Touchon can be recommended for cultivation in saline prone areas of Cameroon.

More Information

***Address for correspondence:**
Mathias Julien Hand, Department of Biological Sciences, Faculty of Science, University of Maroua, P.O. Box 46, Maroua, Cameroon,
Email: handmaty@gmail.com

https://orcid.org/0009-0006-7312-716X

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Keywords: Carrot; Growth; Nutritional quality; Root yield; Salinity; Tolerance

Abbreviations: Ca: Calcium; DAP: Days after Planting; DAS: Days after Sowing; DM: Diameter in the Middle; DC: Diameter to the Collar; DW: Dry Weight; EC: Electric Conductivity; FC: Fiber Content; FW: Fresh Weight; Fe: Iron; LR: Length of Root; Mg: Magnesium; N: Nitrogen; NL: Number of Leaves; C: Organic Carbon; PD: Peak Diameter; P: Phosphorus; PH: Plant Height; K: Potassium; RWC: Relative Water Content; RFW: Root Fresh Weight; RY: Root Yield; SDW: Shoot Dry Weight; SFW: Shoot Fresh Weight; Na: Sodium; SP: Soluble Proteins; TP: Total Phenolics; TSS: Total Soluble Sugars; WAS: Weeks After Sowing

Introduction

The carrot (*Daucus carota* L.) is for family of Apiacaea, or Ombelliferes [1]. It is a biennial plant, but it is grown and harvested each year for hypertrophic roots. Orange carrots are now the type that predominates worldwide markets, even though varieties of other colors are familiar to the population [2]. The carrot is an excellent source of beta-carotene (provitamine A), vitamine C, vitamine B6 and folic acid, proteins, sugars, not to mention potassium [3]. It is also used as dye, for example in dairy products like butter or some cheeses. The real methods of processing the carrot are

rather canned and freezing. Carrots can be consumed floods, cooked or in the form of juice [4]. The carrot is grown at once for the fresh produce market and for transformation, and it is a vegetable, consumption by housing of the habit [5]. From economic point of view, the carrot is part of the top ten the highest vegetables in the world, in terms of production area and market value [4].

Carrot is most cultivated in organic floors at temperature betwen 20 °C and 24 °C. Its consumption contributes to a healthy and balanced diet [6]. The carrot culture has developed in some tropical regions of Africa including Cameroon. The low yield of carrot in Cameroon depends on various factors and the irrigation and soil management are very vital factors in increasing the production of carrot. Salinity seriously damages young roots, slowed growth and reduces performances. It is a major abiotic environmental constraint to crop production throughout the arid and semi-arid regions of the world [7]. Salinity can affect growth and yield of plant by creating osmotic pressure that prevent water uptake and exert toxic effects of sodium and chloride ions [8]. High salinity causes ion imbalance, toxic levels of cytoplasmic sodium, and drought stress [9]. Carrot can tolerate low salinity condition, but the highest salinity condition reduces the plant growth and yield. Salt induces growth reduction of plant which poses major problem in crop productivity in the places where the lands are affected by salt [10,11]. Considering the above statements it is necessarily important to find out salt tolerant carrot variety for cultivation in saline prone areas of Cameroon.

Therefore, this study was conducted to evaluate the effects of differents levels of salinity stress on the growth, root nutritional value and yield of carrot (*Daucus carota* L.) cultivars.

Materials and methods

Description of locality site

This experiment was conducted during the period from 5th September 2023 to 19th December 2023 at Palar Harde, in the Maroua city, Department of Diamare, Region of Far Nord of Cameroon (latitude: 10°36'37,57''N, longitude: 14°17'34,41''E). The climate is tropical of a hot sudano-sahelian type, average annual rainfall is estimated at 700 mm. The rainy season lasts about 3 to 4 months from June to September. The temperatures range from 25 °C à 30 °C in the rainy season and culminate at 45 °C in the dry season. The soil of the experimental site is mainly of the sand like clay type. In these periods of heat are a consequence of precipitation related to an important evaporation thus promoting the accumulation of salt in the soil [12].

Treatment and experimental design

The two-factor experiment consisted of three varieties of carrot namely: Pamela (80 to 90 days cycle, heat resistant, conical shape and sweet taste), New kuruda (95 to 105 days, very good heat resistance, conical shape and very sweet taste), Touchon (105 to 115 days cycle, heat resistant, cylindrical shape and the taste is moderately sweet) and four levels of salinity stress: 0 mM (Control), 60 mM, 120 mM and 240 mM NaCl solution. Seeds were provided by the breeding program of the TECHNISEM (SEMAGRI, Maroua). The study was carried out following randomized complete block design with three replications. Ten kilograms of the sieved soil was weighed into pots, each with a seven-liter capacity, perforated at the bottom to allow proper drainage. The seeds were planted in cavity trays in the greenhouse into the prepared polythene bags containing 5 kg of soil on the 5th of September 2023. Dithane M-45 at 2 g/L of water was applied to the seedlings after three weeks of germination to keep them diseases free. On the 6th of October 2023, and before initiating treatments plants were watered with normal tap water using a hand sprinkler to full saturation for two weeks to improve root development [13]. After which 500 ml of water was applied to each pot and this was able to wet the soil to full saturation. All plants were fertilized daily with a modified nutrient solution (in g L^{-1}): 150 g $Ca(NO_3)_2$, 70 g KNO_3, 15 g Fe-EDTA, 0.14 g KH_2PO_4, 1.60 g K_2SO_4, 11 g $MgSO_4$, 2.5 g $CaSO_4$, 1.18 g $MnSO_4$, 0.16 g $ZnSO_4$, 3.10 g H_3BO_4, 0.17 g $CuSO_4$ and 0.08 g MoO_3 [14]. Different soil salinity treatments were applied at 35 Days after sowing (DAS). The pH of the nutrient solution was adjusted to pH - 7.0 by adding HNO_3 0.1 mM. In each case, amendment was applied at 7 WAS using 1.4 t ha^{-1} of organic fertilizer.

Soil moisture content determination, irrigation water and analysis

Soil samples were collected from representative spots on the experimental site from where soil was collected for potting using a soil auger to a depth of 20 cm, the samples were composited into a single sample. A sub-sample was taken, air-dried, crushed and sieved with a 2-mm mesh sieve after which physical and chemical analyses were carried out (Table 1). The following chemical analyses were done on the soil and tap water (Tables 1,2). Organic carbon (C), was determined by the wet oxidation procedure [15] and total Nitrogen (N) by the micro-Kjeldahl digestion method. Magnesium (Mg) was extracted using the Mehlich 3 method

Table 1: Physical and chemical characteristics of the soil used.

Physio-chemical properties	Quantity
Clay %	39.98 ± 2.81
Sand%	68.04 ± 2.87
Total carbon %	0.82 ± 0.11
Total nitrogen %	0.35 ± 0.27
Ratio C/N	3.77 ± 1.08
Phosphorus (%)	0,29 ± 0.12
Potassium (meq $100g^{-1}$)	2.25 ± 1.06
Sodium (meq $100g^{-1}$)	1.14 ± 0.66
Calcium (meq $100g^{-1}$)	11.27 ± 1.92
Magnésium (meq $100g^{-1}$)	2.65 ± 1.07
pH EC (dS/m)	5.73 ± 1.11 3.12 ± 0.79

Table 2: Chemical characteristics of irrigation water

Chemical characteristics									
Irrigation Water	Ca^{2+} (mg g^{-1})	Mg^{2+} (mg g^{-1})	K^{+} (mg g^{-1})	HCO_3^- (mg g^{-1})	Na^{+} (mg g^{-1})	SO_4^{2-} (mg g^{-1})	Cl^- (mg g^{-1})	pH	CE (dS m^{-1})
Tap water	230.9	117.1	22.9	63.8	442.5	515.7	27.9	7.31	1.96

and determined by Auto ANALYSER 5Technicon 2). The total and available soil phosphorus (P) were determined by the method of Okalebo, et al. [16]. Soil pH was measured potentiometrically in a 1:2.5 soil: water mixture. Calcium (Ca), potassium (K) and sodium (Na) were determined by aflame photometer (JENWAY) as described by Hand, et al. [17]. Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^-, SO_4^{2-}, NO_3, Cl^- content in the water tap was determined by using the colorimetric or amperometric titration method [18] (Table 2). Electric conductivity and pH were determined by a conductometer.

Collection of data on plant growth and yield parameters

Seedlings were harvested 105 DAS by carefully removing and washing the soil particles from the roots, after which the plants parts were separated into shoots and roots [19]. Leaves, stem and root of carrot cultivars were analysed. The tissues (leave and root) were dried at 105 C for 24 hours [20]. The dry and fresh samples were weighed using digital balance and expressed in grams (g). Plant samples were harvested after 14 weeks of culture and under two months of salt stress. Plant were collected to determine agro-morphological traits (plant height, longer of root, diameter to the collar, diameter in the middle, peak diameter, root weight, root yield) carrot cutivars.

The root relative water content (RWC) was recorded according to the formula as follows: RWC = (FFW - FDW)/ (TW - FDW) × 100, where FFW is fresh weight, FDW is dry weight, and TW is turgid weight [21].

Chemical and nutritional composition

TSS content in root was measured by the phenolsulphuric method according to Dubois, et al. [22]. For this purpose, root material (50 mg) was oven-dried until the constant dry mass was reached. Dried leaf material was powdered in a mortar and pestle and TSS was extracted by 70 % ethanol. After centrifugation of extract at 3,500 rpm for 20 min, a reaction mixture was prepared. This mixture consisted of 1,000 µL supernatant, 300 µL phenol, and 2,000 µL concentrated sulphuric acid. Absorbances of these mixtures were read at 470 nm and the TSC content of the fruit was calculated by a standard curve using sucrose.

Soluble protein content (SP) was determined by Bradford's method [23]. Briefly, an appropriate volume (from 0 - 100 µl) of sample was aliquoted into a tube and the total volume was adjusted to 100 µl with distilled water. A 1 mL of Bradford working solution was added to each sample well. Then the mixture was thoroughly mixed by a vortex mixer. After being left for 2 min, the absorbance was read at 595 nm. The standard curve was established by replacing the sample portions in the tubes with proper serial dilutions of bovine serum albumin.

The pH and titrable acidity were determinated by homogeneization of 10 g of extract in 90 mL of distilled water. The homogenate was filtered using Whatman filter paper No. 4 and the pH of this filtrate was measured using a pH-mètre (Hanna, Spain). As for the parameter of titrable acidity, it was assayed by a sodium solution at 0.1 N.

Total phenolic content of extracts from cultured sprouts of Garden cress exposed to different levels of PEG, Mannitol and NaCl was determined by the Folin-Ciocalteu micro method [24]. A 20 µl aliquot of extract solution was mixed with 1.16ml of distilled water and 100 µl of Folin-Ciocalteu reagent followed by 300 µL of 200 g L^{-1} Na_2CO_3 solution. The mixture was incubated in a shaking incubator at 40°C for 30 min and its absorbance at 760 nm was measured. Gallic acid was used as the standard for the calibration curve. Total phenolic contents were expressed as gallic acid (mg gallic acid g^{-1} dry weight).

For estimation of vitamin C, 1 g of frozen root tissues was homogenised in 5 mL of ice-cold 6% m-phosphoric acid (pH 2.8) containing 1 mM EDTA [25]. The homogenate was centrifuged at 20,000 × g for 15 min at 4°C. The supernatant was filtered through a 30-µm syringe filter, and 50 µL of the filtrate was analyzed using an HPLC system (PerkinElmer series 200 LC and UV/VIS detector 200 LC, USA) equipped with a 5-µm column (Spheri-5 RP-18; 220 × 4.6 mm; Brownlee) and UV detection at 245 nm with 1.0 mL/min water (pH 2.2) as the mobile phase, run isocratically (Gahler, et al. 2003).

Beta-carotene (BC) was extracted by grinding fruit tissues in a solution of 100% acetone containing $CaCO_3$ [26]. The extracts were centrifuged at 16,000 × g for 10 min, and 20 µL of the resulting supernatants were used for HPLC analysis, as described by (Gilmore and Yamamoto, 1991) using the previously mentioned HPLC system. Solvent A (acetonitrile, methanol, Tris-HCl buffer 0.1 M, pH 8.0, 72:8:3) was run isocratically from 0 to 4 min followed by a 2.5 min linear gradient to 100% solvent B (methanol, hexane, 4:1) at a flow rate of 2 mL/min. The detector was set at 440 nm for the integration of peak areas after calibration with the external standard.

Fiber content (FC) analysis have been realised by the method of Van Soest, 1963 [27].

Nutrient content

Ca, K, Na, Mg and Fe contents in the root tissue of the

plants were evaluated in dry, ground, and digested samples in a CEM microwave oven [28]. K was determined by flame photometry; calcium, sodium and magnesium by atomic absorption spectrometry [29]. Iron content were determined by the method reported in [30]. Root of carrot was dry ashed at 450 ˚C for 2 hours and digested on heat cave with 10 mL of 1 M. The solution was filtered and adjusted at 100 ml with HNO_3 at 1/100 and analyzed with an atomic absorption spectrophotometer (Rayleigh, WFX-100).

Statistical analysis

The experiment was conducted as a factorial completely randomized design with four NaCl treatments (0, 60, 120 and 240 mM NaCl) and three cultivars (Pamela, New kuruda, Touchon) in four replications. Data are presented in term of mean (± standard deviation). All data were statistically analysed using Statistica (version 9, Tulsa, OK, USA) and first subjected to analyses of variance (ANOVA). Statistical differences between treatment means were established using the Fisher LSD test at $p < 0.05$.

Results and discussion

Influence of salinity on plant growth, relative water content and root yield

The PH, RY, LR, DC, DM, PD, RFW and RWC of carrot have not significantly decreased with the increase of salinity dose (Table 3). The varieties of carrot responded différently to salt stress. Indeed, the Pamela variety is most affected by salt. PH, RY, LR, DC, DM, PD, RFW and RWC decreases observed betwen 0 and 240 mM NaCl were respectively to 29.8%, 30.3%, 12.4%, 21.6%, 29.4%, 11%, 41.9% and 12.3% for the Pamela variety; to 28.7%, 30.5%, 16%, 18%, 24.6%, 16.6%, 37.4% and 11.3% for the Touchon variety and to 24.3%, 25.4%, 10%, 13%, 15.5%, 7.4%, 23.8% and 8.4% for the New kuroda variety.

The results of present work reveal other adverse effects at morphological, biochemical and physiological levels occurring in the salt-stressed carrot plants. The tallest carrot plants were observed under control conditions. On the other hand, the shortest and thinnest plant was recorded in 240 mM NaCl level. The reduction in shoot length with increasing salinity levels [8]. The maximum LR, DC, DM and PD were obtained from control and minimum were obtained by maintaining salt concentration to 240 mM. Similar results in eggplant were reported by Unlukara, et al. [31]. The optimum moisture availability to plants lead to higher production of food material in the roots and ultimately resulted in the production of thicker roots of carrot [8]. The increased root length due to untreated control condition may be attributed to sufficient moisture availability which helped in rapid cell elongation leading to longer root formation. Ahmad, et al. [32] reported that root length of carrot was higher with higher amount of water level. The lowest root weight was produced by the application of salt concentration up to 240 mM. It was observed that treatment of control produced longest root having maximum diameter and that might have contributed to the maximum root weight of roots as stated by Hand, et al. [33]. Water uptake by plants growing in the saline soil is limited due to osmotic pressure leading to plant, especially leaf, dehydration. The root RWC decrease was however similar for the plants of tolerant and sensitive varieties. a significant decrease in RWC is usually observed in sensitive varieties while the accumulation of osmoprotectants is considered as an adaptive mechanism enhancing the succulence and securing maintenance of water balance [34].

Influence of salinity on chemical and nutritional composition

The TSS, SP, titrable acidity, FC and TP content increased significantly depending on the growing dose of NaCl while the

Table 3: Effects of salt stress rates on growth and root yield of three cultivars of carrot (14 WAS).

Cultivars	Salt stress mM NaCl	PH (cm)	RY (t ha^{-1})	LR (cm)	DC (cm)	DM (cm)	PD (cm)	RFW (g)
New kuroda	0	38.62 ± 3.24a	16.35 ± 1.55e	10.12 ± 0.79f	4.62 ± 1.57i	4.13 ± 1.11i	4.34 ± 0.99i	18.32 ± 1.77e
	60	35.35 ± 4.02a	15.86 ± 1.32e	9.64 ± 1.02g	4.46 ± 1.49i	3.92 ± 1.04i	4.21 ± 0.79i	16.16 ± 1.53e
	120	32.83 ± 3.58b	13.41 ± 1.42f	9.25 ± 1.11g	4.31 ± 1.64i	3.66 ± 0.88i	4.14 ± 1.03i	15.94 ± 1.42e
	240	29.24 ± 3.26b	12.19 ± 1.03f	9.11 ± 1.14g	4.02 ± 0.93i	3.49 ± 1.06j	4.02 ± 1.11i	13.95 ± 1.08f
Touchon	0	39.48 ± 3.71a	21.22 ± 1.53d	9.87 ± 1.08g	4.35 ± 1.01i	4.02 ± 1.19i	2.89 ± 0.66k	20.57 ± 2.01d
	60	35.25 ± 3.09a	19.17 ± 2.15d	9.32 ± 1.84g	4.09 ± 0.88i	3.76 ± 1.12i	2.76 ± 0.72k	17.81 ± 1.79e
	120	31.93 ± 3.28b	16.39 ± 1.91e	8.88 ± 1.01h	3.82 ± 0.94i	3.39 ± 1.17j	2.59 ± 0.60k	15.58 ± 1.74e
	240	28.16 ± 2.97c	14.74 ± 1.09e	8.29 ± 1.12h	3.57 ± 0.92j	3.03 ± 1.03j	2.41 ± 0.72l	12.88 ± 0.97f
Pamela	0	36.92 ± 2.92a	25.76 ± 2.17c	11.43 ± 1.03f	4.72 ± 1.09i	4.28 ± 0.77i	4.56 ± 1.25i	16.96 ± 0.99e
	60	32.76 ± 3.11b	22.83 ± 2.04d	11.08 ± 1.09f	4.37 ± 1.17i	3.83 ± 0.91i	4.35 ± 1.13i	12.63 ± 1.11f
	120	28.84 ± 3.05c	19.62 ± 1.55d	10.64 ± 0.92f	4.01 ± 0.99i	3.41 ± 0.84j	4.19 ± 0.88i	10.79 ± 1.20f
	240	25.93 ± 2.79c	17.96 ± 1.88e	10.01 ± 1.05f	3.70 ± 1.02i	3.02 ± 0.95j	4.06 ± 1.09i	9.85 ± 1.16g
Two-way ANOVA results								
Cultivars (C)		*	*	**	**	NS		NS
Salt stress (SS)		*	*	NS	*	*		*
Interaction C x SS		**	*	*	**	*		*

Values shown are means ($n = 5$) ± SD; within columns, means followed by different letter are significantly different ($p < 0.05$).
**, * significant at 1 and 5% probability levels, respectively, NS: Not Significant

BC, Vitamin C and pH levels were significantly reduced under salt stress in the roots of the three carrot varieties studied (Table 4). From control to 240 mM NaCl, SP, TSS, titrable acidity, FC and TP increased in Pamela by 91.5%, 33%, 36.8%, 39.3% and 292.6% respectively; in Touchon by 93.2%, 30%, 27.8%, 41.4% and 302.6% respectively and in New kuroda by 105.3%, 41.3%, 35%, 46.7% and 331.3% respectively. As for BC, Vitamin C and pH levels, they decreased between 0 and 240 mM NaCl for Pamela by 15.8%, 28.7% and 16.5% respectively; for Touchon by 13.5%, 25.7% and 16.9% respectively and in New kuroda by 11.4%, 25.1% and 12.5% respectively.

Salt stress increase titratable acidity. The values of titrable acidity were between 2.43 and 3.72 g L^{-1}. But, Abbas and Khoudi [35], having worked on carrot pure, reported that a titrable acidity, of the order of 0.2 g L^{-1}. Increased accumulation of osmolytes significantly prevent the salinity-induced inhibition of photosynthesis [36]. Osmolytes protect the structure and the osmotic balance of cells by maintaining the water influx [36]. Proteins that accumulate in plants under saline conditions may serve as nitrogen storage that is reused later and can play a role in osmotic adjustment and stabilization of membrane structures [37]. The accumulation of sugars is suggested as a salt stress resistance index [38]. Increased accumulation of phenolic compounds imparts greater radical scavenging activity reflecting in apparent growth improvement under stressed conditions [39]. Phenolic compounds possess antioxidant activity; thus they may protect cell structures against damage from excessive ROS generated under oxidative stress. They also play a role of signal molecules (salicylic acid), inducing the expression of genes associated with secondary metabolism. Moreover, due to the affinity to sugars, phenolics enable their transport facilitating the regulation of cell osmotic pressure [40]. The increment of fiber contents in root of carrot could be contributed to human diet in the communities of saline prone area compared to non-saline area. Fiber has a significant role in palatability, digestibility and remedy of constipation [41]. An important finding of the current study is that β-carotene, vitamin C and pH of root of carrot were significantly decreased by the salt stress. The pH of root of carrot decrease depending on the growing dose of NaCl varying of 6.62 to 5.31. Abbas and Khoudi [35] had indicated a pH value of 6.53 of carrot pure. However, the sudies of Arqha and Gavin [42] revealed that the average value of the pH of carrot is between 4.9 and 5.2. Sehrawat, et al. [43] showed that the β-carotene content decrease with increasing salinity levels in mung beans. In other vegetables such as amaranth species, Ratnakar and Rai [44] observed a decrease of vitamin C content with increase of salt concentration. Salinity decreased the vitamin C content of pepper fruits, and this effect was dependent on the maturity stage [20].

Influence of salinity on mineral composition of the root

The effet of salt stress on the Na, P, Fe, Ca, Mg and K content varied with varieties and salt doses. Root rates of K, Ca, Mg and Fe have decreased under the effect of salinity (from 0 to 240 mM NaCl) for the Pamela variety (to 32%, 34.6, 45 and 36% respectively), for the Touchon variety (to 29.8%, 34.4, 36.4 and 33% respectively) and for the New kuroda variety (to 21.1%, 20.7%, 33.3% and 28.1% respectively). In addition, salt stress has caused a significant increase in Na content in all varieties. This increase is proportional to all salt concentration. The lowest values were recorded in the root of New kuroda variety, where we note a significant effect only for the most stressed treatment 240 mM NaCl (3.24 g kg^{-1}) (Table 5). For Touchon, the Na content begins to increase significantly in the roots from 120 mM NaCl (1.92 g kg^{-1}). For Pamela, Na content accumulates rapidly in the roots under the effect of salinity from 60 mM NaCl (1.36 g kg^{-1} contrary 0.63 g kg^{-1} in the control).

Table 4: Effects of salt stress rates on root chemical and nutritional components and relative water content of three cultivars of carrot (14 WAS).

Cultivars	Salt stress (mM NaCl)	SP (mg g^{-1})	TSS (mg g^{-1})	RWC (%)	Vitamin C (mg kg^{-1})	BC (mg kg^{-1})	TP (g EAG kg^{-1})	FC (mg g^{-1})
New kuroda	0	9.42 ± 0.19q	97.55 ± 3.71c	91.26 ± 2.26d	40.25 ± 1.23k	83.47 ± 1.97f	1.98 ± 0.11s	26.93 ± 0.74n
	60	12.84 ± 0.75p	118.43 ± 3.19b	89.44 ± 2.19d	37.41 ± 1.05l	80.55 ± 0.98f	3.71 ± 0.19r	30.85 ± 0.66m
	120	15.63 ± 0.55o	129.91 ± 2.98a	86.53 ± 2.14e	33.76 ± 1.01m	77.43 ± 1.56g	5.83 ± 0.11q	35.52 ± 0.58l
	240	19.35 ± 1.02o	137.82 ± 3.77a	83.61 ± 1.98f	30.13 ± 1.04m	73.94 ± 1.14i	8.55 ± 0.14q	39.77 ± 1.05l
Touchon	0	8.86 ± 0.15q	98.47 ± 2.95c	93.41 ± 2.72d	43.54 ± 0.79k	82.64 ± 1.47f	1.95 ± 0.12s	28.53 ± 0.88m
	60	10.47 ± 0.49p	113.64 ± 2.86b	90.69 ± 2.07d	39.86 ± 0.94l	79.82 ± 1.18g	3.32 ± 0.17r	33.19 ± 0.76m
	120	14.15 ± 0.93p	119.72 ± 3.05b	86.17 ± 2.69e	36.53 ± 1.07l	75.35 ± 1.08h	5.01 ± 0.41q	37.86 ± 1.10l
	240	17.12 ± 0.81o	127.93 ± 4.08a	82.88 ± 1.84f	32.37 ± 0.63m	71.46 ± 1.11i	7.85 ± 0.72q	40.34 ± 1.41k
Pamela	0	9.28 ± 0.77q	96.91 ± 3.59c	90.76 ± 2.14d	39.61 ± 1.08l	79.51 ± 1.08g	2.17 ± 0.13r	27.47 ± 0.95n
	60	12.86 ± 0.35p	115.38 ± 3.88b	87.33 ± 2.06e	35.94 ± 1.06l	74.19 ± 1.25i	4.53 ± 0.15r	30.63 ± 1.04m
	120	15.25 ± 0.49o	121.58 ± 2.79a	83.51 ± 2.80f	32.18 ± 0.87m	70.67 ± 0.95i	6.35 ± 0.69q	34.74 ± 0.83m
	240	17.79 ± 0.38o	128.94 ± 3.07a	79.57 ± 2.07g	28.25 ± 0.68n	66.92 ± 1.52j	8.52 ± 1.02q	38.28 ± 0.96l
Two-way ANOVA results								
Cultivars (C)		NS	NS	NS	*	*	NS	NS
Salt stress (SS)		**	**	*	*	**	**	**
Interaction C x SS		*	*	*	*	*	*	*

Values shown are means (n = 5) ± SD; within columns, means followed by different letter are significantly different (p < 0.05).
**, * significant at 1 and 5% probability levels, respectively, NS: Not Significant

Table 5: Effects of salt stress rates on root titrate acidity, pH and mineral composition of three cultivars of carrot (14 WAS).

Cultivars	Salt stress (mM NaCl)	Na (g kg^{-1})	K (g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})	Iron (mg kg^{-1})	Acidity (mg kg^{-1})	pH
New kuroda	0	0.61 ± 0.10i	3.18 ± 0.55d	0.29 ± 0.11j	0.12 ± 0.12k	2.95 ± 0.23e	2.43 ± 0.28f	6.62 ± 1.09a
	60	1.18 ± 0.15h	3.02 ± 0.43d	0.26 ± 0.16j	0.10 ± 0.19k	2.61 ± 0.27e	2.65 ± 0.32e	6.55 ± 1.07a
	120	1.89 ± 0.19g	2.76 ± 0.38e	0.27 ± 0.10j	0.09 ± 0.15l	2.38 ± 0.33f	2.94 ± 0.25e	6.23 ± 1.11a
	240	3.04 ± 0.43d	2.51 ± 0.40e	0.23 ± 0.21j	0.08 ± 0.26l	2.12 ± 0.25f	3.28 ± 0.50d	5.79 ± 1.06a
Touchon	0	0.65 ± 0.11i	3.15 ± 0.36d	0.32 ± 0.14j	0.11 ± 0.12k	2.73 ± 0.27e	2.91 ± 0.21e	6.39 ± 0.91a
	60	1.19 ± 0.14h	2.95 ± 0.15e	0.29 ± 0.13j	0.09 ± 0.30l	2.39 ± 0.26f	3.29 ± 0.46d	5.91 ± 0.88a
	120	1.92 ± 0.17g	2.54 ± 0.18e	0.25 ± 0.19j	0.08 ± 0.23l	2.04 ± 0.18f	3.56 ± 0.55c	5.59 ± 0.85a
	240	3.67 ± 0.42c	2.21 ± 0.22f	0.21 ± 0.23j	0.07 ± 0.34l	1.83 ± 0.13g	3.72 ± 0.39c	5.31 ± 0.89a
Pamela	0	0.63 ± 0.13i	3.12 ± 0.47d	0.26 ± 0.14j	0.11 ± 1.01k	3.28 ± 0.45d	2.69 ± 0.18e	6.48 ± 1.01a
	60	1.36 ± 0.16h	2.91 ± 0.44e	0.26 ± 0.11j	0.08 ± 0.29l	2.81 ± 0.28e	2.91 ± 0.21e	6.16 ± 0.97a
	120	2.17 ± 0.29f	2.45 ± 0.23f	0.22 ± 0.13k	0.07 ± 0.25m	2.46 ± 0.19f	3.32 ± 0.22d	5.79 ± 0.79a
	240	3.89 ± 0.36c	2.12 ± 0.12f	0.17 ± 0.20k	0.06 ± 0.34m	2.10 ± 0.26f	3.68 ± 0.67c	5.41 ± 0.83b
Two-way ANOVA results								
Cultivars (C)		*	NS	NS	*	*	*	NS
Salt stress (SS)		**	*	*	*	*	*	*
Interaction C x SS		**	*	*	*	*	*	NS

Values shown are means (n = 5) ± SD; within columns, means followed by different letter are significantly different ($p < 0.05$).
**, * significant at 1 and 5% probability levels, respectively, NS: Not Significant

Salt tolerance in higher plants depends on how plants control the transport of salt accross organs [46]. In this study, New kuroda, presents the lowest Na content in its roots, while the Pamela variety indicate high accumulation of Na in its roots. Touchon variety holds the middle of intermediary between New kuroda and Pamela. According, Acosta-Motos, et al. [47], **the** tolerant species and in particular halophytes accumulate significant amounts of sodium in the airline, while the roots are less rich in Na+. On the contrary, in the glycophytes, a sigium migration limit to the leaves is present, where osmotic adjustment difficulties in the rich rod in salt level disorders at the roots. Almost all of the lowering of osmotic potential is due to the absorption of Na in halophytes and glycophytes [48]. For New kuroda, the most salt tolerant, the Ca, K, Mg and Fe content not significant affected by salt treatments contrary the Pamela and Touchon varieties most sensitive [20]. According, Almeida, et al. [49], the salt tolerance in the tomato is often associated with particular capacities to maintain the high content of K+.

Conclusion

The root nutritional quality, growth and yield contributing traits of carrot irrespective of variety were influenced by different levels of soil salinity. The findings of this study postulated that salinity stress significantly reduced pH, relative water content, and beta-carotene and all studied growth and yield parameters at 120 mM and 240 mM as compared to untreated control as well 60 mM NaCl. While the osmolytes, total phenolic, fiber, sodium content and titrable acidity of root carrot increased with soil salinity increased. Furthermore, *Daucus carota*, which is cultivated under salinity stress, could enhance the nutritional quality of the final product in terms of polyphenols, sugar, proteins and nutrient fiber. The differences between the tolerant new kuroda, Touchon and sensitive Pamela varieties can be recognized as those that are constitutive and those, which are induced by stress. Therefore, it can be concluded that the variety of New kuruda was found as relatively salt tolerant and it can be recommended for cultivation in saline prone areas (coastal and sahelian) of Cameroon.

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