Plant
2024, Vol. 12, No. 3, pp. 66-75
https://doi.org/10.11648/j.plant.20241203.13

Research Article

Influence of Different Rates of Salinity on Flowering, Yield and Fruit Nutritional Value of Three Okra [*Abelmoschus esculentus* (L.) Moench] Cultivars in far North Region of Cameroon

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Abstract

Context: Salinity is in coastal, arid and semi-arid regions a major constraint in the productivity and agricultural development around the world. *Objectifs:* The objective of this study is to evaluate the effect of salinity on the growth, the nutritional value of the fruits of three okra (*Abelmoschus esculentus* L.) cultivars including two local (Javia and Parkwa) and a hybrid variety (Hire). *Methodology:* This is how four solutions of different NaCl concentrations from 0, 60, 120 to 240 mM were used to water okra plants at the four-leaves stage and this for two months in completely randomized device with four repetitions. *Results:* The results have differneces and similarities between the three varities during saline treatments. Salinity causes a decrease in growth, performance yield (from 0 to 240 mM NaCl to 28%, 23.6% and 22% in Parkwa, Hire, Javia cultivars respectively), mineral elements, antioxidants components and accumulation of Na content (to 45% in Parkwa, 23% in Hire and 18.4% in Javia from 0 to 240 mM NaCl) and flowering period (from 0 to 240 mM NaCl to 27.5%, 23.1% et 21.9% in Parkwa, Hire, Javia respectively). The reductions generated by salt have been less strong in Javia and Hire cultivars while the reductions were stronger at Parkwa cultivar. In addition, NaCl, at high concentrations, advantage of osmoticum accumulation involved in the osmotic ajustement mechanisms and would also serve as osmoprotector. Accumulation of osmolytes is salinity tolerance index that explains the maintenance of good water status in okra. *Conclusion:* Cultivars Javia and Hire were the most salt tolerant while the Parkwa was the most sensitive. The good behaviour of Javia and Hire varieties in the face of salinity can be considered for their use to better enhance the sahelian and coastal areas.

Keywords

Growth, Nutritional Value, Okra, Salinity, Tolerance

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Received: 30 April 2024; **Accepted:** 27 May 2024; **Published:** 20 September 2024

1. Introduction

Okra is a vegetable-fruit containing many nutrients (calcium, iron, proteins and vitamins) that are food supplements. It is grown in tropical and subtropical regions of the world [1] and has great importance as well as social and economic. Indeed the okra is used in the kitchen as condiment or as binder in sauces (fruit and leaves), in medecine (roots) in crafts or industry (fiber of stem) [2]. The okra's culture remains facing the problems of climate change, the degradation of natural resources especially the ground, diseases and pests (natural enemies), but also to that of varietal selection that does not allow to make available to producers of the performance varieties. In several tropical countries, okra faces multiple constraints that negatively affect its production [3] with salinity and low availability of mineral elements in the soil.

In Cameroon, the okra is increasingly cultivated in coastal and sahelian region where salinity of ground and irrigation water is a reality.

Salin stress is known for its adverse effects on growth and development of the plant at all stages of development [4]. Plant production in saline areas depends largely on the success of germination, lifting, planting and the efficiency of the reproduction phase [5]. Salinity causes a significant change in the concentration of certain osmo-regulatory molecules in plants [6] and those of the bioactive compounds of the fruits of some vegetable [7] thus leading to a modification of their nutritional quality [8]. Thus salt stress reduces the size of fruits, the productivity and increases the flowering time, the rate of total soluble solids (organic acids, sugar, amino acids) [9]. Salt stress also influences vitamin and lycopene content, which has involvement of plant physiology [10]. Soil salinity affects plants through osmotic effects, ion-specific effects, and oxidative stress [11]. The effect of salinity stress in plants is mediated at least in part by an enhanced generation of active oxygen species, especially in chloroplasts and mitochondria which cause lipid peroxidation and membrane injury, protein degradation and enzyme inactivation. Plants have developed a complex antioxidant system which mitigates and repairs the damage initiated by reactive oxygen species, toward enzyme synthesis to protect the cellular and subcellular systems from the cytotoxic effects of these active oxy-free radicals.

If many physical factors affect the production of okra, including salinity and poverty in fertilizer elements, it is therefore necessary to conduct investigations to assess the impact of soil salinity on the production and fruit quality of okra hence the interest of this study. This article analyzes the effects of different levels of salinity on growth, performance and nutritional value of fruit of three okra cultivars in Far noth region in Cameroon. The purpose of this study is also to identify the most tolerant okra cultivars with saline stress that can give satisfactory yields in salt areas.

2. Materials and Methods

2.1. Site Description

The study was conducted from 22 March 2023 to 12 August 2023 at Palar harde, in the Maroua city, Department of Diamare, Region of Far nord of Cameroun (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 ℃ à 30 ℃ in rainy season and culminate at 45 ℃ in the dry season. The soil of the experimental site is mainly the sandy-clay type. In these periods of heaplers, it is a consequitus of precipitation related to an important evaporation thus promoting the accumulation of salt in the soil [12].

2.2. Plant Material and Experimental Device

Plant material was consisting of three okra cultivars of which two local cultivars from the department of Mayo Sava: Javia (its fruit is pyramidal, long and green color) and Parkwa (fruit is pyramidal, medium size and dark green color) and a hybride variety call Hire (characterized by a short shot) purchased from AGRISEP of Maroua. These three cultivars of okra were chosen for their socio-economic importance and the nutritional value of their fruit. The seeds were surface sterilized with 3% sodium hypochlorite for 20 min and washed four times with deionized water. The seeds were planted in cavity trays in the greenhouse of Maroua-Palar, Cameroon and transplanted when seedlings reached 10 cm in height into the prepared polythene bags containing 5 kg of sterilized soil. Each pots of seven litres capacity perforated at the bottom to allow unimpeded drainage. The pots were arranged in a split plot design with one plant per pot and three replicates per treatment with as factors three cultivars of okra, four level of salinity (0, 60, 120 and 240 mM NaCl). The seeds were planted at a spacing of 0.5m x 0.5m to give a total of 40 000 plants ha^{-1}.

The plants were watered immediately after transplanting to avoid drought stress. Before initiating treatments plants were irrigated with normal tap water using a hand sprinkler to full saturation for two weeks in order 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]. The pH of the nutrient solution was adjusted to 7.0 by adding HNO_3 0.1 mM. Plants were watered with deionized water every morning. The amendment in each case was applied 5 WAS with organic fertilization rates each of

compost and 150 kg h^{-1} of NPK (10 – 18 – 18).

2.3. 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 soil auger to a depth of 20 cm, the samples were made into a sample. A sub-sample was taken, air-dried, crushed and sieved with 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 and 2). Organic carbon (C), was determined by the wet oxidation procedure [15] and total Nitrogen (N) by micro-Kjeldahl digestion method. Magnesium (Mg) was extracted using the Mehlich 3 method and determined by auto ANALYSER 5Technicon 2). The total and available soil phosphorus (P) were determined by the method of [16]. Soil was measured potentionmetrically in 1:2.5 soil: water mixture. Calcium (Ca), potassium (K) and sodium (Na) were determined by aflame photometer (JENWAY) as described by [17]. Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, SO_4^{2-}, NO_3^{-}, Cl^{-} content in water tap was determined by using colorimetric amperometric titration method [18] (Table 2). Electric conductivity and pH were determined by conductometer.

Table 1. *Physical and chemical characteristics of soil used.*

Physio-chemical properties	Quantity
Clay %	38.98 ±2.59
Sand%	67.04 ±2.77
Total carbon %	0.77 ±0.09
Total nitrogen %	0.33 ±0.23
Ratio C/N	3.67 ±1.06
Phosphorus (%)	0,28 ±0.09
Potassium (meq $100g^{-1}$)	2.23 ±1.03
Sodium (meq $100g^{-1}$)	1.14 ±0.57
Calcium (meq $100g^{-1}$)	11.19 ±1.85
Magnésium (meq $100g^{-1}$)	2.65 ±1.01
pH	5.89 ±1.02
EC (dS/m)	3.15 ±1.49

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	238.2	118.3	25.4	63.1	441.4	515.9	26.8	7.34	2.11

2.4. Plant Measurements

Seedlings were harvested 16 WAS by carefully removing and washing the soil particles from the roots, after which the plants parts were separated into shoots and roots [19]. The tissues (fruit) were dried for 24 h at 105˚C [20]. The dry samples were weighted. Plant samples were harvested after 4 months culture and under 10 weeks of salt stress, plant were collected to determine plant height, flowering, number of fruit per plant, number of seed per fruit, fruit fresh weight, longer of fruit, width of fruit, fruit yield (measuring fresh weight of fruits from 10 plants per plot at 50 % flowering and 50 % maturity) in okra.

The relative water content (RWC) in fruit 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].

2.5. Organics Compounds in Fruit

For measurement of total soluble sugar (TSS), a modified phenolsulfuric assay was used [22]. Subsamples (100 mg) of dry fruit were placed in 50 mL centrifuge tubes. 20 mL of extracting solution (glacial acetic acid: methanol: water, 1:4:15 (v/v/v)) was added to the ground tissue and homogenized for 15 sec at 16000 rpm. The homogenate was centrifuged for 10 mn and the supernatant was decanted to a 125 ml Erlenmeyer flask. The residue was resuspended in 20 mL of extracting solution and centrifuged another 5 min. The supernatant was decanted, combined with the original extract, and made up to 100 mL with water. One mL of 5% (v/v) phenol solution and 5 mL of concentrated H_2SO_4 were added to 1 mL aliquots of SS (reconstituted with 1 mL water). The mixture was shaken, cooled to room temperature, and absorbance recorded at 490 nm wavelength with spectropho-

tometer (Pharmaspec UV-1700 model). The amount of TSS present in the extract was calculated using standard curve prepared from graded concentration of glucose.

Soluble protein content (SP) was determined by [23] method. Briefly, 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 vortex mixer. After 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.

Fiber content (FC) analysis have been realised by the method of [24].

2.6. Fruit Antioxidant Components

For estimation of ascorbic acid content (ASA), 1 g of frozen fruit 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 [26].

Beta-carotene (BC) was extracted by grinding fruit tissues in a solution of 100% acetone containing $CaCO_3$ (Jung, 2004) 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 [27] 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.

2.7. Fruit Minerals Contents

K, Ca, Na, Mg and P contents in the fruit tissue of the plants were evaluated in dry, ground, and digested samples in a CEM microwave oven [28]. P was determined by colorimetry; potassium by flame photometry; magnesium, sodium and calcium by atomic absorption spectrometry [29]. Iron content was determined by method reported in [30]. Fruit of okra was dry ashed at 450˚C for 2 hours and digested on heat cave with 10 ml HNO3 1 M. The solution was filtrated and adjusted at 100 ml with HNO_3 at 1/100 and analyzed with an atomic absorption spectrophotometer (Rayleigh, WFX-100).

2.8. Experimental Design and Statistical Analysis

The experiment was conducted as a factorial completely randomized design with four NaCl treatments and three cultivars 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 $p < 0.05$.

3. Results and Discussion

3.1. Effects of NaCl on Growth, FRWC and Yield Characteristics

The growth parameters, yield and fruit relative water decreased significantly with increasing NaCl salinity concentrations (Table 3); whereas, the period of flowering increased more in the presence of NaCl application. For Javia cultivar, PH, NF, NS, LF, WF, FFW, FY, FRWC decreased to 29.3%, 28.8%, 20.5%, 27.7%, 45.3%, 28.3%, 22% and 9.6%, and FLO increased to 21.9% from control (0 mM) to 240 mM respectively. For Hire cultivar, PH, NF, NS, LF, WF, FFW, FY, FRWC decreased to 33.7%, 43.5%, 19.8%, 31.4%, 50.5%, 39.7%, 23.6% and 9.8%, and FLO increased to 23.1% from control to 240 mM respectively. For Parkwa cultivar, PH, NF, NS, LF, WF, FFW, FY, FRWC decreased to 34.7%, 46.8%, 24%, 31.9%, 57.5%, 42.3%, 28% and 10.8%, and FLO increased to 27.5% from control to 240 mM respectively.

This results were agreed with [31] who observed that the fresh weight in four tomato cultivars decreased with salt stress. [32] found relative water content (RWC) decreased progressively with increasing of NaCl concentration in the leaves; [33] reported that salinity reduces plant productivity first by reducing plant growth during the phase of osmotic stress and subsequently by inducing leaf senescence during the phase of toxicity when excessive salt is accumulated in transpiring leaves. Increasing NaCl concentration tended to reduce the absorption of water leading to a drop in water content, the inhibitory effect of NaCl on growth parameters could be attributed to the osmotic effect of NaCl. The changes in water status under NaCl stress may cause a reduction in meristem activity as well as cell elongation [34].

3.2. Effects of NaCl on Osmolytes Compounds

The TSS, FC and SP in okra plant increased significantly with NaCl concentration compared to control as shown in Figure 1C, 1D and 1E. The highest values of TSS (30.74 mg g^{-1} for Javia, 36.22 mg g^{-1} for Hire and 36.19 mg g^{-1} for Parkwa), FC (32 mg g^{-1} for Javia, 36.31 mg g^{-1} for Hire and 30.62 mg g^{-1} for Parkwa) and SP (28.78 mg g^{-1} for Javia,

31.64 mg g^{-1} for Hire and 34.73 mg g^{-1} for Parkwa) were recorded with 240 mM NaCl. This accumulation varied from 0 to 240 mM NaCl for TSS (76.6% for Javia, 98.4% for Hire and 118.9% for Parkwa), for FC (40.2% for Javia, 47.9% for Hire and 41.6% for Parkwa) and SP (76.9% for Javia, 88.9% for Hire and 125.8% for Parkwa).

This study showed that increase of NaCl salinity caused high accumulation of fiber content, soluble protein and sugar [35, 10]. The increment of fiber contents in okra with NaCl could be contributed to human diet in the communities of saline prone area compared to non-saline area. The substantial increase in soluble sugars and proteins may be due to the activation of photosynthetic machinery, as a result of the stimulatory effects of the used plant growth bio stimulators on photosynthetic process. Soluble sugars and proteins play an important role of accelerating the cellular metabolism and maintaining homeostasis in the plant when it is under risk [36].

3.3. Effects of NaCl on Fruit Antioxidant Components

There was a significant reduction in the ASA and BC with the increase in the salinity levels from the control condition (Figure 1A and 1B). The highest ascorbic acid and beta-carotene content were observed in the control treatment for Javia (163.24 and 1.86 µg g^{-1} respectively) followed by Hire (161.29 and 1.81 µg g^{-1} respectively) and Parkwa (160.52 and 1.79 µg g^{-1} respectively). The lowest values of ASA and BC were obtained in 240 mM NaCl for Javia (109.34 and 1.09 µg g^{-1} respectively) followed by Hire (98.76 and 0.84 µg g^{-1} respectively) and Parkwa (91.57 and 0.82 µg g^{-1} respectively).

In the present study, salinity decreased β-carotene and Ascorbic acid content of all okra cultivars. Ascorbic acid helps in absorption of dietary iron by keeping it in the reduced form [37]. It is an important component of several fruits (tomato, pepper, and strawberry) that reacts with singlet oxygen and other free radicals and suppresses peroxidation [38]. [39] showed that the β-carotene content decrease with increasing salinity levels in mung beans.

3.4. Effects of NaCl on Fruit Minerals Contents

The effect of saline treatment Na, K, Ca, Mg, P and Iron concentrations varies according to the three cultivars (Table 4). Salinity stress caused an increase in Na content in the three varieties studied. On the other hand, K, Ca, Mg, P and Iron concentrations decrease significantly in the fruits of all cultivars of okra. The highest K^{+}, Ca^{++}, Mg^{++}, P and Iron content were obseved at 0 mM NaCl (1.34 mg g^{-1}, 762.49, 356.24, 318.64 and 2.95 µg g^{-1}) for Javia, (1.32 mg g^{-1}, 766.11, 335.35, 316.29 and 2.65 µg g^{-1}) for Hire and (1.36 mg g^{-1}, 758.54, 358.17, 312.65 and 2.78 µg g^{-1}) for Parkwa. And the lowest content were obtained at 240 mM (0.74 mg g^{-1}, 582.52, 231.26, 209.34 and 1.74 µg g^{-1}) for Javia, (0.78 mg g^{-1}, 405.43, 196.53, 194.55 and 1.47 µg g^{-1}) for Hire and (0.61 mg g^{-1}, 402.74, 199.12, 167.12 and 1.23 µg g^{-1}) for Parkwa. From 0 to 240 mM NaCl, the Na^{+} content increased to 18.4, 23 and 45% for Javia, Hire and Parkwa respectively.

Depending the growing salt doses, the sensitive cultivar Parkwa has higher Na^{+} content and the low P, K, Mg and Fe content; while the most tolerant cultivar Javia, has lowest Na^{+} content, which indicates that it is « excluder » type. It develops mechanisms to limit Na^{+} accumulation in its tissues [40, 41]. In saline condition, plants absorb of significant amounts of Na^{+} and of Cl^{-}, but the transport and accumulation of these elements often seek to depend on degree of tolerance of species considered [12]. Toxic effects of ions mainly Na^{+} and Cl^{-}, nutritional imbalance caused by reduced nutrient (P, K, Ca, Mg, Fe) uptake and/ortransport to the shoot [10, 42].

Table 3. *Effects of salinity rates on plant growth, fruit relative water content and yield characters of three okra cultivars (16 WAS).*

Growth and yield parameters										
Cultivars	**Treatment (mM NaCl)**	**PH (cm)**	**FLO (days)**	**NF per plant**	**NS per fruit**	**FFW (g)**	**LF (cm)**	**WF (g)**	**FY (t ha^{-1})**	**FRWC (%)**
Hire	0	31.56±1.13j	56.71±2.31f	11.86±1.26m	60.95±3.12e	6.85±1.11m	6.02±0.92n	2.06±0.78o	25.84±1.09k	89.94±3.53a
	60	28.95±1.02j	59.53±2.42f	9.91±2.33n	57.52±3.66f	6.15±1.21m	5.73±0.84n	1.79±0.59o	23.95±1.06k	87.32±4.07a
	120	25.67±1.13k	63.45±1.52e	7.88±2.12n	52.73±3.17g	5.01±0.88m	5.04±1.07n	1.36±1.01o	21.22±0.84k	84.10±3.55b
	240	20.93±1.09k	69.83±2.01d	6.72±3.01n	48.91±2.83h	4.13±0.92n	4.13±1.09o	1.02±1.08o	19.73±0.79l	81.13±4.01b
Parkwa	0	33.51±1.23j	53.91±1.88g	13.26±2.51m	55.95±3.28f	6.15±1.23m	9.57±0.92n	1.67±1.23o	25.22±1.22k	86.55±3.03a
	60	30.27±1.06j	57.27±1.73f	11.07±2.25m	51.76±2.55g	5.26±1.02m	8.25±1.11n	1.31±0.95o	23.31±1.05k	83.25±3.27b
	120	25.68±1.16k	62.68±2.86b	9.13±2.46n	47.29±2.43h	4.22±0.73n	7.79±0.86n	0.92±1.04p	21.53±0.94k	80.28±2.66b
	240	21.89±1.14k	68.76±1.93d	7.05±1.98n	42.54±3.01i	3.55±1.24n	6.52±1.03n	0.71±0.86p	18.18±1.31l	77.17±2.45c

Growth and yield parameters

Cultivars	Treatment (mM NaCl)	PH (cm)	FLO (days)	NF per plant	NS per fruit	FFW (g)	LF (cm)	WF (g)	FY (t ha^{-1})	FRWC (%)
Javia	0	29.96±1.07j	50.55±2.32g	14.43±1.17m	53.87±3.15g	8.12±2.17m	11.51±0.88m	1.61±0.84o	27.85±1.11j	85.16±2.27a
	60	27.82±2.12j	53.45±2.83g	13.15±2.88m	50.63±3.14g	7.55±1.15m	11.02±1.12m	1.30±0.92o	26.94±1.12k	83.52±2.19b
	120	25.63±1.07k	57.34±2.71f	11.73±3.22m	46.74±2.43h	6.81±1.18m	10.24±0.97m	1.08±0.76o	24.19±0.95k	79.64±2.38c
	240	21.19±2.13k	61.62±1.65e	10.27±3.02lm	42.83±3.52i	5.82±1.01m	8.32±0.77n	0.88±1.03p	21.71±1.03k	76.95±3.01c
Two way ANOVA results										
Salt stress (S)		*	*	*	*	*	*	*	*	*
Cultivar (C)		NS	NS	NS	*	NS	NS	NS	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

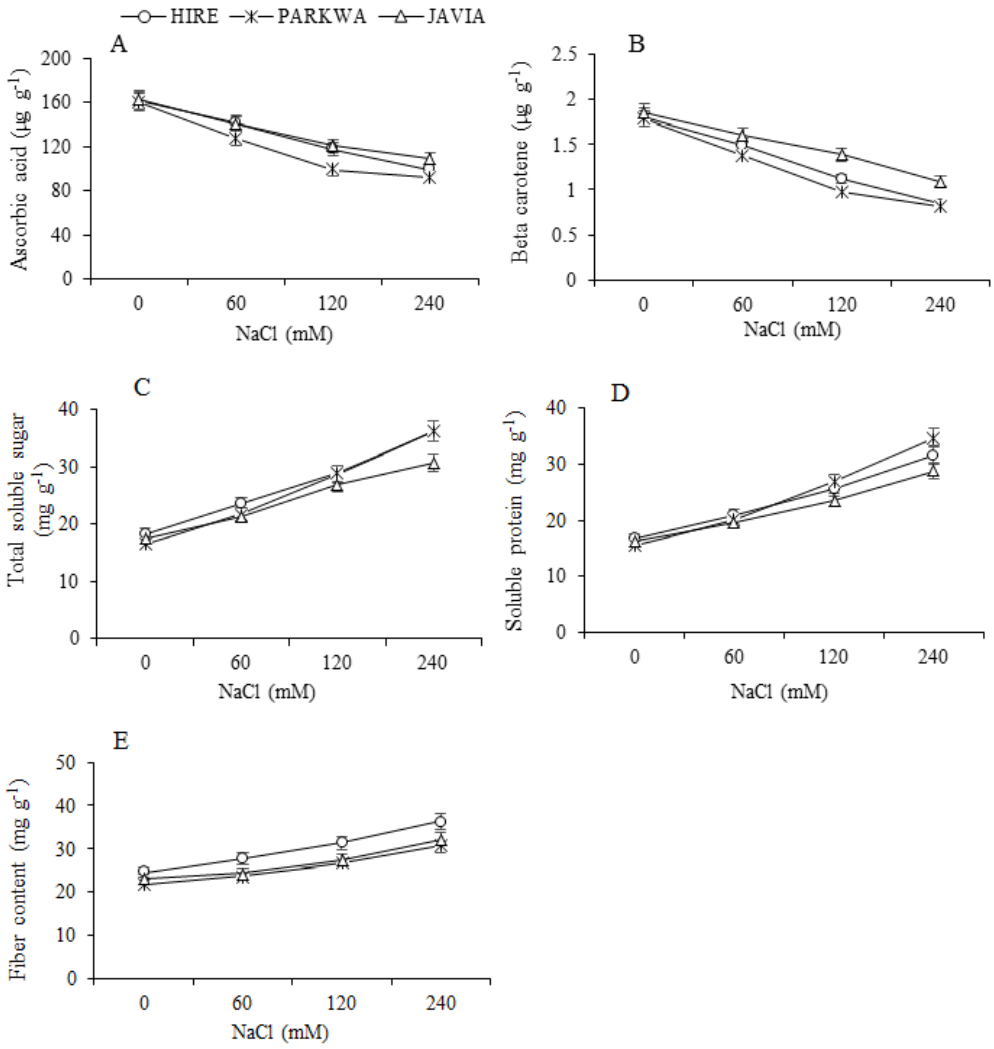

Figure 1. *Effects of salinity rates (60, 120 and 240 mM NaCl) on fruit osmolytes and antioxidant components of three okra cultivars (16 WAS). Ascorbic acid (A), Beta carotene (B), Total soluble sugar (C) Soluble protein (D) and Fiber content (E). Bars are means (n=5) ±SD. Means followed by different letter are significantly different ($p < 0.05$).*

Table 4. Effects of salinity rates on fruit mineral components of three Okra cultivars (16 WAS).

Fruit mineral components							
Cultivars	**Treatment (mM NaCl)**	**Ca (µg g^{-1})**	**P (µg g^{-1})**	**K (mg g^{-1})**	**Mg (µg g^{-1})**	**Iron (µg g^{-1})**	**Na (µg g^{-1})**
Hire	0	766.11 ±3.02a	316.29 ±1.33g	1.32 ±2.01m	355.35 ±2.33f	2.65 ±0.55m	59.33 ±2.22k
	60	694.90 ±3.14b	283.14 ±1.51g	1.05 ±2.22m	320.54 ±2.45f	2.37 ±0.62m	63.12 ±2.14k
	120	579.12 ±3.05c	240.72 ±2.02h	0.83 ±3.07n	242.26 ±2.81g	2.01 ±0.74m	67.50 ±2.44j
	240	405.43 ±3.07e	194.55 ±1.83i	0.68 ±2.12n	196.53 ±2.24h	1.47 ±0.88m	72.94 ±1.79i
Parkwa	0	758.54 ±3.11a	312.65 ±1.72g	1.36 ±2.11m	358.17 ±1.84f	2.78 ±0.85m	57.55 ±2.12l
	60	589.81 ±3.43c	259.22 ±1.73g	1.02 ±2.06m	301.79 ±2.21g	2.32 ±0.47m	65.95 ±1.99j
	120	456.36 ±2.96d	202.46 ±1.75h	0.78 ±2.64n	273.65 ±1.92g	1.93 ±0.91m	72.16 ±1.77j
	240	402.74 ±2.88e	167.12 ±0.97i	0.61 ±2.53n	199.12 ±1.89h	1.23 ±0.94m	83.47 ±3.14i
Javia	0	762.49 ±3.16a	318.64 ±1.99g	1.34 ±3.19m	356.24 ±1.93f	2.95 ±0.83m	58.61 ±3.11l
	60	701.83 ±3.22b	288.25 ±1.07g	1.09 ±3.27m	314.18 ±2.11f	2.61 ±0.78m	62.83 ±2.93k
	120	660.18 ±3.18b	241.43 ±2.05h	0.85 ±2.04n	288.54 ±2.05g	2.23 ±1.02m	65.92 ±3.07j
	240	582.52 ±3.06c	209.34 ±1.76i	0.74 ±2.77n	231.26 ±2.57h	1.74 ±1.09m	69.37 ±2.19i
Two way ANOVA results							
Salt stress (SS)		**	*	*	*	*	*
Cultivars (PP)		NS	NS	NS	NS	NS	NS
Interaction PP 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

4. Conclusion

This study found that salinity provoked a decrease in growth parameters, antioxidants compound (ascorbic acid, beta-carotene), mineral elements (P, K, Mg, Fe, Ca), yield and accumulation of osmoprotectors (proteins and solubles sugar), fiber content, period of flowering and Na content of all okra cultivars studied with difference of comportment between the cultivars and the level of NaCl. Of the three cultivars tested, Javia and Hire are the most resistants, while Parkwa is the most sensitive. Complementary studies are needed to determine physiological and molecular mechanisms involved in the behavior of cultivars. At this stage of the work, varieties Javia and Hire may be advised to producers of areas affected by salinity.

Abbreviations

ASA	Ascorbic Acid
BC	Beta Carotene
Ca	Calcium
DAP	Days After Planting
DAS	Days After Sowing
FC	Fiber Content
FLO	Flowering
FFW	Fruit Fresh Weight
FRWC	Fruit Relative Water Content
FY	Fruit Yield
LF	Longer of Fruit
Mg	Magnesium
N	Nitrogen
NF	Number of Fruit per Plant
C	Organic Carbon
PH	Plant Height
P	Phosphorus
K	Potassium
Na	Sodium
SP	Soluble Protein
S	Sulfate
TSS	Total Soluble Sugar
WAS	Week after Sowing
WF	Width of Fruit

Acknowledgments

We appreciate all who helped us to carry out this study.

Author Contributions

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Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

Table A1. *Effects of salinity rates on osmolytes and antioxidant content of three okra cultivars (16 WAS).*

Osmolytes, antioxidant components						
Cultivars	**Treatment (mM NaCl)**	**FC (mg g^{-1})**	**ASA (µg g^{-1})**	**BC (µg g^{-1})**	**TSS (mg g^{-1})**	**SP (mg g^{-1})**
Hire	0	24.55 ±0.93g	161.29 ±3.22a	1.81 ±1.19i	18.26 ±0.88h	16.75 ±0.97h
	60	27.77 ±1.01f	141.80 ±3.71b	1.49 ±1.21i	23.48 ±0.79g	20.92 ±0.89g
	120	31.36 ±1.04e	117.32 ±3.62c	1.12 ±1.03i	28.82 ±0.92f	25.53 ±0.68f
	240	36.31 ±1.07e	98.76 ±2.52b	0.84 ±1.09j	36.22 ±1.12e	31.64 ±0.61e
Parkwa	0	21.63 ±0.92g	160.52 ±2.88a	1.79 ±0.85i	16.53 ±0.98h	15.38 ±0.74h
	60	23.57 ±0.88g	127.66 ±3.77c	1.38 ±1.02i	21.74 ±0.73g	20.10 ±0.77g
	120	26.70 ±0.91f	98.85 ±3.33d	0.97 ±1.01j	28.68 ±0.85f	26.91 ±1.01f
	240	30.62 ±0.89e	91.57 ±2.64d	0.82 ±0.88j	36.19 ±1.14e	34.73 ±1.08e
Javia	0	22.94 ±0.76g	163.24 ±3.71a	1.86 ±1.11i	17.41 ±1.17h	16.24 ±1.17h
	60	24.26 ±1.22g	140.43 ±2.81b	1.61 ±1.03i	21.26 ±0.87g	19.69 ±0.83h
	120	27.53 ±1.09f	120.47 ±3.13c	1.39 ±0.68i	26.87 ±0.91f	23.55 ±0.95g
	240	32.17 ±1.12e	109.34 ±2.87d	1.09 ±1.01i	30.74 ±1.03e	28.73 ±0.87f
Two way ANOVA results						
Salt stress (SS)		**	*	*	**	**
Cultivars (C)		NS	NS	NS	NS	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

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