Asian Journal of Agricultural and Horticultural Research

Volume 10, Issue 3, Page 43-56, 2023; Article no.AJAHR.97250
ISSN: 2581-4478

Evaluation of Some Okra and Molokhia Landraces under Irrigation Water Salinity Stress

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJAHR/2023/v10i3230

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/97250

Original Research Article

Received: 05/01/2023
Accepted: 07/03/2023
Published: 10/03/2023

ABSTRACT

Aims: Evaluate eight landraces of okra and five landraces of molokhia, collected from different region of Egypt, under different levels of irrigation water salinity.
Study Design: The experimental design used was a split-plot in a randomized complete blocks design with three replicates, where the four irrigation water salinity concentrations were arranged in the main plots, whereas, landraces of okra or molokhia were arranged in the sub plots.
Place and Duration of Study: This investigation was carried out during the two successive summer seasons of 2021 and 2022 at Soil Salinity Laboratory Research, Alexandria Governorate, Agricultural Research Center.
Methodology: Four levels of saline irrigation water were applied having EC of 625 (tap water as a control), 2000, 4000 and 6000 ppm which was applied as necessary according to soil field capacity (27.85%).
Results: Generally, all the studied traits, of okra and molokhia, decreased as the salinity level increased except for the spines of edible pods which was in contrast, in both seasons**.** There were significant differences among the studied eight landraces of okra and the studied five landraces of

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molokhia for all the studied traits in both seasons. Edible pods yield/plant of Behera landrace was not significantly affect by irrigation at salinity levels up to 2000 ppm of salinity level in 2022 season. Moreover, Alexandria and Gharbya landraces were the least affected by increasing salinity levels comparing with the rest of landraces in both seasons. With respect to molokhia, Fresh leafy yield/plot of Alexandria landrace was not significantly affected by irrigation at salinity levels up to 2000 ppm of salinity level in the first seasons.

Conclusion: It can be recommended to cultivate Behera, Alexandria and Gharbya landraces of okra and Alexandria and Kafr Elsheikh landraces of molokhia when irrigation with relatively high levels of salinity, as these landraces were relatively less affected by increasing salinity concentration. These landraces can also be introduced into breeding programs to improve them or develop new varieties that are more salt-tolerant.

Keywords: Okra; molokhia; salinity levels; landraces.

1. INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) belongs to family Malvaceae. Okra is one of the most popular vegetable crops that grown throughout the tropics and subtropics of the world is mainly grown for its young immature pods and consumed as cooked. It is a very good source of dietary fiber, magnesium, manganese, potassium, vitamin K, vitamin C, folate, B1, and B6 [1,2].

Molokhia (*Corchorus Olitorius* L.) known as jews mallow is a leading leafy vegetable cultivated for its edible leaves. The genus *Corchorus* L. and most of the genera of the former family Tiliaceae transferred to the subfamily Grewioideae of the family Malvaceae [3]. The leaves are highly nutritious, rich in proteins, vitamins A, C and E, beta-carotene, iron, calcium, thiamin, riboflavin, niacin, and essential amino acids [4,5].

Salinity (whether in soil or irrigation water) is one of the obstacles to pant production, it causes multifarious drastic effects on leaf growth, photosynthesis, mineral nutrition, transpiration, water and ion transport and increases sugars, amino acids and different ions along with severe effects on yield and quality [6].

Thus, salinity stress is one of the most adverse factors that limiting or inhibiting plant growth and development. Since Egypt had been gifted a tremendous treasure of flora, one of the proposed solutions is to investigate local strains of different plant varieties that are characterized by genetic diversity to obtain local strains that contain salt-tolerant genetic structures and then introduce them into breeding programs to improve them or develop new varieties that are more salt-tolerant.

Therefore, this research investigated to find out the impact of different level of Salinity treatments on yield of some local landraces of okra and molokhia collected from different region of Egypt to know what extent of salinity level okra and molokhia can tolerate. The results could lead to improvements in agricultural production worldwide, especially on saline land.

2. MATERIALS AND METHODS

This investigation was carried out during the two successive summer seasons of 2021 and 2022 at Soil Salinity Laboratory Research, Alexandria Governorate, Agricultural Research Center.

2.1 Plant Materials

Plant materials of this study consist of eight landraces of okra and five landraces of molokhia, collected from different region of Egypt. The sources of okra and molokhia are shown in Table 1.

2.2 Agricultural Procedures

2.2.1 Okra

On the first week of May in both seasons, Seeds of the eight okra landraces were planted in a single row, 4m long, 0.7 m wide and hills 30 cm apart at the rate of 3 seeds per hill. Other cultivation practices have been performed as recommended okra planting. Harvesting took place from mid-June to mid-September.

2.2.2 Molokhia

On the first week of June in both seasons, Seeds of the five molokhia landraces were sown in 20 rows, 4 m long. Cultivation practices have been achieved as recommended for conventional planting.

Table 1. Sources of eight landraces of okra and five landraces of molokhia

Name	Source region of okra	Source region of molokhia
L1	Alexandria governorate	Alwadi Aljadid governorate
L2	Asiut governorate	Alexandria governorate
L3	Aswan governorate	Aswan governorate
L4	Behera governorate	Kafr Elsheikh governorate
L5	Gharbya governorate	Sohag governorate
L6	Kafr Elsheikh governorate	
L7	Menia governorate	
L8	Sohag governorate	

2.3 Soil of the Experimental Site

The physical and chemical properties of the soil are shown in Table 2. Soil analyses demonstrated that soil experiment was clay loam soil texture. For a saturation extract of the soil, electrical conductivity (EC) was measured by using a digital electrical conductivity meter and pH by electrical pH-meter (TWT, Germany). Soluble calcium and magnesium were determined by titration with versinate. Sodium and potassium were determined by using a flame photometer (Gallenkamp flame analyser, UK). Bicarbonate was determined using 0.01N HCl titration and Chloride by using titration of silver nitrate solution and potassium chromate as an indicator. Sulfate was calculated by difference between soluble cations minus anions. Soil organic matter content was determined by wet combustion with $K_2Cr_2O_7$. The calcium carbonate equivalent was measured by calcimeter. The particles size distribution of the initial soil was determined using the hydrometer method [7]. More details about the soil testing measures can also be found in [8].

2.4 Treatments

Treatments were initiated 30 days after plantation. Four levels of saline irrigation water were applied having EC of 625 (tap water as a control), 2000, 4000 and 6000 ppm which was applied as necessary according to soil field capacity (27.85%). The saline water was ready by mixing tap water (0.68 dS/m) with sea water (46 dS/m) at certain ratios.

2.5 Recorded Measurements

2.5.1 Okra

2.5.1.1 Vegetative growth

Plant height (cm) and number of branches / plant; average of 10 plant was measured at 90 days.

2.5.1.2 Yield, its components and quality

Edible pod weight (g) average of 50 edible pods was recorded. Number of edible pods / plant; total number of edible pods of five plants was counted at edible pod and average was worked out. Yield of edible pods / plant (g/plant); Weight of edible pods of five plants were counted and average weight was worked out. Pod net weight ratio (%); expressed as pod weight without neck / total pod weight x 100. Spines grade; was scored from 1 to 10 where 1 was the smoothest pod and 10 referred to the hard spiny one.

2.5.2 Molokhia

2.5.2.1 Vegetative growth

Plant height (cm) and number of branches / plant; average of 10 plant was measured at 90 days.

2.5.2.2 Yield and its components

Weight of ten plants (g), leaves weight of 10 plants (g) and Average fresh leafy yield/fed was calculated basis on the plot area. Net leaves weight percentage was calculated as: leaves weight of 20 plants / total weight of these plants × 100.

2.6 Experimental Design and Statistical Analysis

The experimental design used was a split-plot in a randomized complete blocks design (R.C.B.D) with three replicates, where the four irrigation water salinity concentrations were arranged in the main plots, whereas, landraces of okra or molokhia were arranged in the sub plots. The data collected in the experiments were analyzed statistically using the ANOVA method. The differences among the various means were tested, using Duncan's multiple range test. Data were analyzed using the COSTAT computer package (CoHort software, Berkeley, USA).

Table 2. Physical properties and chemical analyses of the experimental soil

Soil property	Year		Soluble cations ($meql^{-1}$)	Year	
	2021	2022		2021	2022
pH	7.87	8.18	Ca^{++}	5.51	5.43
EC (dS/m)	1.72	1.87	Mg^{++}	4.68	4.11
$CaCO_3$ (%)	2.35	2.37	Na^{+}	9.88	10.40
Organic matter (%)	2.17	2.51	K^{+}	0.25	0.28
Particles size distribution (%)			**Soluble anions ($meql^{-1}$)**		
Sand	38.5	38.71	HCO_3^{-}	8.41	8.46
Silt	21.1	21.77	Cl^{-}	3.74	5.66
Clay	40.7	39.52	SO_4^{--}	8.12	6.04
Soil texture	Clay Loam	Clay Loam			

The percentage decrease in the edible pods yield / plant of the eight landraces of okra as a result of the increase in the level of irrigation salinity relative to control (DS%) was calculated, as an average of both seasons, as follow.

DS% = Average yield of both seasons at control - Average yield of both seasons at certain salt level / Average yield of both seasons at control ×100

The dendrograms were built using the unweighted pairs method with arithmetic mean aggregation (UPGMA). Cluster analysis and dendrograms carried out using the computer program SPSS version 25.

3. RESULTS AND DISCUSSION

3.1 Okra Plant Growth and Yield

Results in Table 3 show the effect of irrigation by different levels of salinity on vegetative growth, yield and its components of okra overall the eight landraces during 2021 and 2022 summer seasons. Generally, all the studied traits decreased as the salinity level increased except for the spines of edible pods which was in contrast, in both seasons. Irrigate with 6000 ppm of salinity gave the worst results values compared with the control and the other two levels of salinity in both seasons. This deterioration in the studied traits is explained to three ways; reduced water potential in root zone causing water deficit, phytotoxicity of ions such as Na+ and Cl- and nutrient imbalance, and depressing uptake and transport of nutrients [9]. These results are in agreement with obtained by Ali Khan A et al. [10] Haq IU, et al. [11] Ibrahim EA, et al. [12] Yunusa IAM, et al. [13].

There were significant differences among the eight studied landraces of okra for all the studied traits overall salinity levels in both seasons (Table 4). The highest plant was obtained by Assiut (L2) landrace in both seasons, and there were no significant differences between this landrace and Behera (L4), Gharbya (L5), Kafr Elsheikh (L6), Menia (L7), Sohag (L8) (in 2021 season), Alexandria (L1), and Kafr Elsheikh landraces (in 2022 season). Concerning No. of branches/ plant, all okra landraces were statistically similar in 2021 season, but they were significantly differed in 2022 season, where Gharbya (L5) landraces gave the highest number of branches/plant (6.1), and there were no significant differences between this landrace and Aswan (L3) (5.8), Behera (L4) (5.9), Kafr Elsheikh (L6) (6.0), and Sohag (L8) (5.8) landraces. On the other hand, the highest number of edible pods/plant was obtained by Alexandria (L1) and Behera (L4) landraces compared with the other landraces in both seasons. Meanwhile, Alexandria (L1) landrace had the highest mean value of edible pod weight followed by Behera (L4) landrace in both seasons. However, the highest percentage of the pod net ratio was obtained by Asiut (L2) and Gharbya (L5) landraces in both seasons. Regarding edible pods yield/plant, Alexandria (L1) landrace surpassed the other landraces in both seasons (173.9 and 179.1 g/plant, in order), meanwhile, there were no significant differences between Alexandria (L1) and Behera (L4) landraces in the 2021 season, only. Edible pods of Alexandria (L1) and Behera (L4) landraces were the smoothest pods compared with the other landraces. These differences among genotypes helps to choose desirable genotypes for establishing new breeding populations as reported by many researchers [6,10,14].

Results in Tables (5a&b) showed that the interaction between the eight landraces of okra and salinity levels was highly significant for all the studied traits except for a number of branches /plant in both seasons. These results indicated that landraces differed in their ranking by differed salinity concentrations. The edible pods yield/plant of Behera (L4) landrace was not significantly affected by irrigation at salinity levels up to 2000 ppm in the 2022 season. Moreover, Alexandria (L1) and Gharbya (L5) landraces were the least affected by increasing salinity levels compared with the rest of landraces in both seasons. In this regard, [15,16] studied 13 okra varieties under different salt levels. They reported that all varieties were affected by salt level with a different variation in their stress response, demonstrating the presence of genetic variability. Similar results were obtained by Ali Khan A, et al. [10] Haq IU, et al. [11], Ibrahim EA, et al. [12].

The percentage decrease in the edible pods yield / plant of the eight landraces of okra as a result of the increase in the level of irrigation salinity relative to control are shown in Fig. 1. At irrigation with 2000 ppm of salinity, the lowest reduction percentage in the edible pods' yield / plant was obtained by Kafr Elsheikh (L6) and Gharbya (L5) landraces (9.5 and 9.9%, in order) followed by Alexandria (L1) landrace (11.6%). However, the highest reduction percentage was obtained by Aswan (L3) (46.6%) followed by Asiut (L2) landraces (37.5%) at the same salinity level. While, at irrigation with 4000 ppm of salinity, Kafr Elsheikh (L6) and Alexandria (L1) landraces had the fewest reduction percentage in the edible pods' yield / plant (27.6 and 28.4%, in order) relative their control treatment. Meanwhile, Aswan (L3) landrace was the highest reduction (66.2). At the highest concentration of salinity in irrigation (6000 ppm salinity), Alexandria (L1) landrace gave the lowest reduction percentage in the edible pods' yield / plant (36.7%) relative to its control treatment compared with the other landraces. Aswan (L3) and Menia (L7) landraces were the most affected by this level of salinity (69.7 and 66.6 %, in order). The reduction in edible pods yield / plant due to the deterioration in the studied traits (vegetative growth, yield and its components) as mentioned in Table 3 as a result of an increase in the concentration of salinity of irrigation water, has been explained by Gama PBS, et al. [9].

The constructed dendrogram by UPGMA classified the seven landraces into two main clusters Fig. 1. The first one contained the collected landraces from lower Egypt (Alexandria (L1), Behera (L4) and Gharbya (L5), while the second one contained Kafr Elsheikh (L6) landrace and all the collected landraces from Upper Egypt Kafr Menia (L7) , Aswan, Sohag (L8) and Asiut (L2) and divided into two sub-clusters, one of them contained, Kafr Elsheikh (L6) and Kafr Menia (L7) landraces, but the second one divided into two groups, one of them gathered both Aswan (L3) and Sohag (L8) landraces, but the second one contained only Asiut (L2). The built dendrogram could able to separate the landraces according to their geographical location.

3.2 Molokhia Plant Growth and Yield

Results in Table 6 show the effect of irrigation by different levels of salinity on vegetative growth, yield and its components of molokhia overall the five landraces during 2021 and 2022 summer seasons. Generally, all the studied traits decreased as salinity level increased. However, number of branches / plant and the percentage of net weight were not affected at the salinity level up to 2000 ppm salinity in both seasons. Irrigate with 6000 ppm of salinity level gave the worst values results in both seasons. Moreover, there was no significant difference between 4000 and 6000 ppm of salinity level regarding the number of branches / plant and the percentage of net weigh in both seasons. The deterioration in the studied traits could be explained by Apel K and Hirt H. [17]. They reported that salt stress can lead to elevated levels of reactive oxygen species such as superoxide anion and hydrogen peroxide that are toxic and can cause oxidative damage to proteins, DNA, and lipids in the cell membrane. Similar results were obtained by Yang Z, et al. [18].

There were significant differences among the five studied landraces of molokhia in all the studied traits overall salinity levels in both seasons (Table 7). In general, Alexandria (L2) landrace gave the best mean values for all the studied traits in both seasons. Moreover, Alwadi Aljadid (L1) landrace was statistically equal to Alexandria (L2) landrace regarding No. of branches/plant, weight of ten plants, leaves` weight of ten plants, and fresh leafy yield/plot in both seasons. In addition to Aswan (L3) landrace was similar to Alexandria (L2) and Alwadi Aljadid (L1) landraces with respect to weight of ten plants in both seasons and leaves weight of ten plants in first season, only. These differences among genotypes helps to choose desirable genotypes for establishing new breeding populations as reported by many researchers [19,20].

Results in Table 8 exhibited that the interaction between the five landraces of molokhia and salinity levels was highly significant for all the studied traits in both seasons. These results indicated that landraces differed in their ranking by differed salinity concentrations. Fresh leafy yield/plot of Alexandria (L2) landrace was not significantly affected by irrigation at salinity levels up to 2000 ppm of salinity level in the first seasons. Many researchers evaluated many genotypes under different salinity levels [4,18,21]. They found that all tested genotypes were affected by salinity level with a differential variation in their stress response.

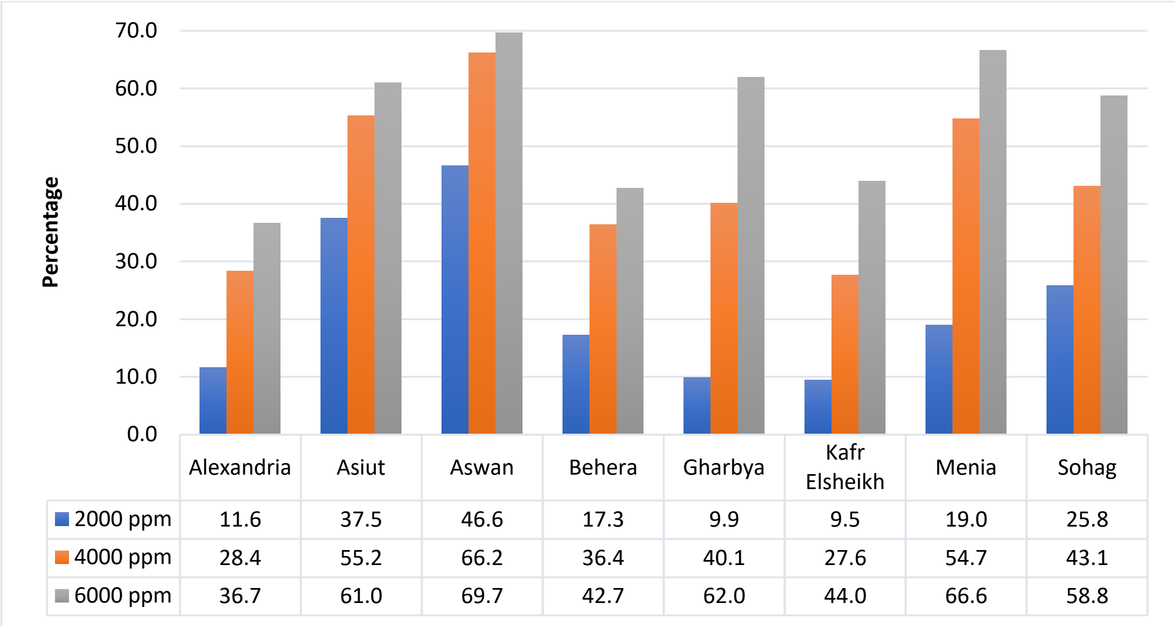


Fig. 1. The percentage decrease in the edible pods yield / plant of the eight landraces of okra as a result of the increase in the level of irrigation salinity relative to control, average of both seasons

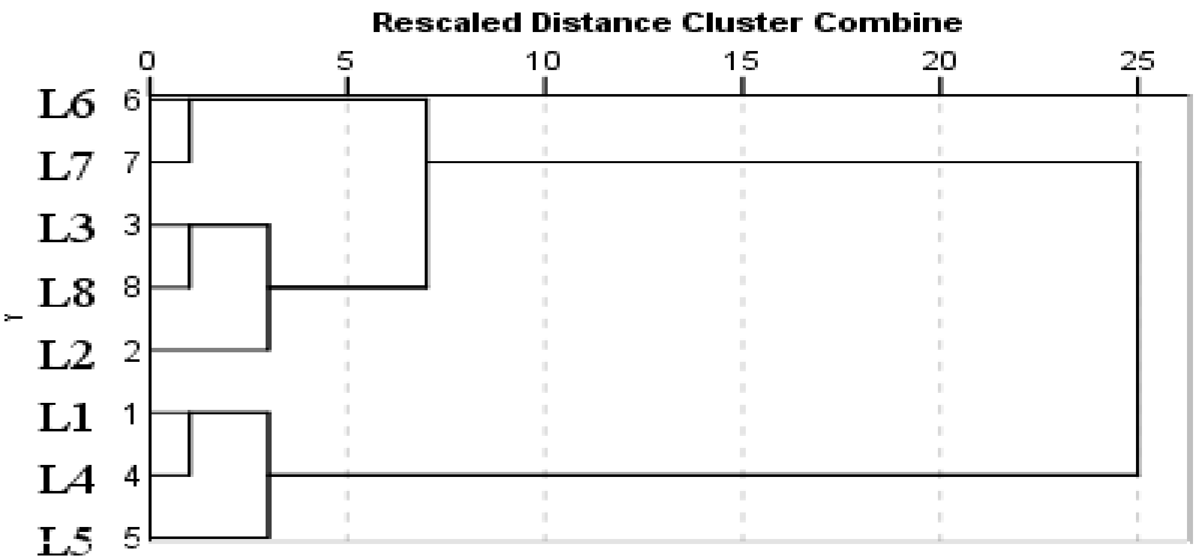


Fig. 2. Dendrogram using the average Linkage of the eight landraces of okra based on the studied traits, over both seasons, rescaled distance cluster combines

Table 3. Effect of irrigation by different levels of salinity on vegetative growth, yield, its components and quality of okra overall the eight landraces during 2021 and 2022 summer seasons

Salinity level	Vegetative growth				Yield, its components and quality									
	Plant height (cm)		No. of branches/plant		No. of edible pods/plant		Edible pod weight (g)		Pod net weight ratio (%)		Edible pods yield/ plant (g)		Spines of edible pods (1:10)	
	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season
625 ppm (Control)	163.2 a[#]	161.0 a	6.3 a	6.5 a	25.9 a	27.2 a	6.75 a	6.65 a	87.5 a	87.0 a	175.6 a	181.6 a	4.99 b	5.1 c
2000 ppm	147.3 b	143.6 b	5.7 b	5.8 b	22.9 b	24.5 b	6.06 b	6.01 b	84.7 b	85.4 ab	141.8 b	150.4 b	5.41 b	5.8 b
4000 ppm	134.1 b	123.0 c	5.4 bc	5.6 b	17.5 c	17.6 c	5.46 c	5.47 c	83.4 b	83.1 b	97.6 c	98.1 c	5.63 b	5.9 b
6000 ppm	118.9 c	115.6 c	5.2 c	5.3 c	14.9 d	15.1 d	4.89 d	4.99 d	81.1 c	80.8 c	74.1 d	76.3 d	6.55 a	6.6 a

[#]Values by the same alphabet letters do not significantly differ from one another, using Duncan's multiple range test at 0.05 level of probability

Table 4. Mean performances of vegetative growth, yield, its components and quality of the eight landraces of okra overall salinity levels during 2021 and 2022 summer seasons

Landraces	Vegetative growth				Yield, its components and quality									
	Plant height (cm)		No. of branches/plant		No. of edible pods/plant		Edible pod weight (g)		Pod net weight ratio (%)		Edible pods yield/ plant (g)		Spines of edible pods (1:10)	
	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season	2021 season	2022 season
L1	137.1 b#	140.1 ab	5.5 a	5.7 bc	25.6 a	26.6 a	6.73 a	6.69 a	84.6 abc	84.9 b	173.9 a	179.1 a	1.6 d	1.5 e
L2	150.8 a	145.8 a	5.7 a	5.5 c	16.3 d	17.3 e	5.44 c	5.33 d	87.7 a	86.9 a	90.8 d	94.6 e	8.9 a	9.4 a
L3	125.0 c	120.3 d	5.8 a	5.8 abc	13.5 e	14.1 g	5.23 c	5.39 d	81.0 cd	81.2 d	74.9 e	79.6 g	8.1 a	8.5 b
L4	142.0 ab	138.8 b	5.7 a	5.9 ab	26.4 a	26.4 a	6.33 ab	6.32 b	83.2 bcd	84.0 bc	165.0 a	170.4 b	1.3 d	1.2 e
L5	148.3 ab	139.1 b	5.8 a	6.1 a	23.2 b	24.4 b	6.11 b	6.15 b	87.1 ab	87.5 a	141.2 b	155.3 c	3.1 c	3.5 d
L6	141.4 ab	139.8 ab	5.7 a	6.0 ab	23.0 b	23.1 c	5.11 c	5.20 d	85.0 abc	84.5 bc	118.3 c	121.6 d	4.6 b	3.8 c
L7	141.1 ab	132.6 c	5.6 a	5.7 bc	20.9 c	21.7 d	5.44 c	5.43 d	79.9 d	80.3 d	113.6 c	122.4 d	8.4 a	9.1 a
L8	141.0 ab	129.9 c	5.4 a	5.8 abc	13.5 e	15.4 f	5.91 b	5.74 c	84.8 abc	83.2 c	78.6 e	89.8 f	9.1 a	9.3 a

[#]Values with the same alphabet letters do not significantly differ from one another, using Duncan's multiple range test at 0.05 level of probability

Table 5a. Effect of interaction between the eight landraces of okra and salinity levels on vegetative growth during 2021 and 2022 summer seasons

Salinity level	Landraces	Vegetative growth							
		Plant height (cm)				No. of branches/plant			
		2021 Season**		2022 Season**		2021 Season[ns]		2022 Season[ns]	
625 ppm (Control)	L1	145.0	Bcde[#]	152.7	bcd	6.0	abc	6.0	abc
	L2	210.0	a	211.3	a	6.3	ab	6.0	abc
	L3	146.7	bcde	146.3	bcdef	6.7	a	7.0	a
	L4	156.7	bc	152.3	bcd	6.3	ab	7.0	a
	L5	160.0	bc	151.7	bcd	6.3	ab	6.7	ab
	L6	158.7	bc	158.3	bc	6.3	ab	6.3	ab
	L7	155.0	bcd	159.3	b	6.3	ab	6.7	ab
	L8	173.3	b	156.0	bcd	5.7	abc	6.0	abc
2000 ppm	L1	142.7	bcde	143.3	def	5.7	abc	6.0	abc
	L2	141.7	bcde	134.0	fgh	6.0	abc	5.7	cde
	L3	125.0	cde	116.0	ijklm	6.0	abc	6.0	abc
	L4	150.3	bcd	144.0	cdef	5.7	abc	6.0	abc
	L5	160.0	bc	150.3	bcde	5.7	abc	6.0	abc
	L6	151.0	bcd	155.0	bcd	6.0	abc	6.0	abc
	L7	155.0	bcd	151.7	bcd	5.7	abc	5.7	cde
	L8	152.3	bcd	154.7	bcd	5.7	abc	6.0	abc
4000 ppm	L1	131.7	bcde	137.0	efg	5.3	bc	5.7	cde
	L2	131.7	bcde	120.3	hijkl	5.3	bc	5.3	de
	L3	118.3	cde	112.7	jklm	5.3	bc	5.3	de
	L4	136.7	bcde	135.7	fg	5.3	bc	5.7	cde
	L5	140.0	bcde	133.3	fgh	5.7	abc	6.0	abc
	L6	146.0	bcde	128.0	ghi	5.3	bc	6.0	abc
	L7	135.0	bcde	111.7	jklm	5.3	bc	5.3	de
	L8	133.3	bcde	105.0	m	5.3	bc	5.7	cde
6000 ppm	L1	129.0	bcde	127.3	ghi	5.0	c	5.0	e
	L2	120.0	cde	117.3	ijklm	5.0	c	5.0	e
	L3	110.0	de	106.3	lm	5.0	c	5.0	e
	L4	124.3	cde	123.3	hijk	5.3	bc	5.0	e
	L5	133.3	bcde	121.0	hijkl	5.3	bc	5.7	cde
	L6	110.0	de	118.0	ijklm	5.0	c	5.7	cde
	L7	119.3	cde	107.7	klm	5.0	c	5.0	e
	L8	105.0	e	104.0	m	5.0	c	5.3	de

The percentage decrease in the edible pods yield / plant of the five landraces of Molokhia as a result of the increase in the level of irrigation salinity relative to control are shown in Fig. 3. At irrigation with 2000 ppm of salinity level, the reduction percentage in the fresh leafy yield/plot ranged from 14.7 % in Alexandria (L2) landrace to 19.8 % in Kafr Elsheikh (L4) landrace. While, at irrigation with 4000 ppm of salinity level, the reduction percentage in the fresh leafy yield/plot ranged from 32.6 % in Alexandria (L2) landrace to 34.9 % in Kafr Elsheikh. relative their control treatment. Meanwhile, Aswan (L3) landrace was the highest reduction (66.2). At the highest concentration of salinity in irrigation (6000 ppm of salinity level), Alexandria (L2) landrace gave the lowest reduction percentage in the Fresh leafy yield/plot (44.2%) relative to its control treatment compared with the other landraces. Sohag (L5) landrace was the most affected by this level of salinity (71.2 %). The reduction in fresh leafy yield/plot due to the deterioration in the studied traits (vegetative growth, yield and its components) as mentioned in Table (6) as a result of an increase in the concentration of salinity of irrigation water, has been explained by [18].

The dendrogram obtained from the studied traits, over both seasons, grouped the five landraces of Molokhia into 2 main clusters (Fig. 4). The first cluster includes Sohag (L5) landrace and the second cluster divided to 2 groups. One of them includes Kafr Elsheikh (L4) landrace and the second one includes Alexandria (L2), Alwadi Aljadid (L1), and Aswan (L3) landraces.

Table 5b. Effect of interaction between the eight landraces of okra and salinity levels on yield, its components and quality during 2021 and 2022 summer seasons

Salinity level	Landraces	Yield, its components and quality									
		No. pods/plant		Edible pod weight (g)		Pod net weight ratio (%)		Edible pods yield/ plant (g)		Spines of edible pods (1:10)	
		2021 Season**	2022 Season**	2021 Season**	2022 Season**	2021 Season**	2022 Season**	2021 Season**	2022 Season**	2021 Season**	2022 Season**
625 ppm (Control)	L1	30.1 a	31.1 ab	7.11 abc	7.17 ab	87.5 abcde	88.1 bcde	213.6 a	223.1 a	1.0 g	1.0 j
	L2	23.7 ef	25.6 g	6.24 cdefg	6.00 de	88.5 abcd	88.4 abc	147.9 def	153.3 de	8.0 ab	8.7 abc
	L3	20.3 gh	19.8 ij	7.07 abcd	7.10 b	75.9 fg	78.5 bcdefgh	143.7 def	140.3 e	5.3 bcd	7.0 de
	L4	31.0 a	32.0 a	7.43 ab	7.03 b	90.7 ab	89.0 abc	216.8 a	224.9 a	1.0 g	1.0 j
	L5	28.5 abc	29.2 cde	7.58 a	7.67 a	89.6 abc	91.6 a	188.3 b	223.6 a	1.9 fg	1.7 ij
	L6	25.5 cdef	27.2 f	5.66 fghijk	5.77 ef	92.7 a	89.1 ab	144.1 def	156.9 de	3.0 cdefg	2.3 hij
	L7	29.4 ab	30.4 abcd	6.33 cdef	6.20 cde	84.6 abcdef	82.6 hij	174.7 bc	188.7 c	4.9 cde	6.3 ef
	L8	18.7 hi	22.6 h	6.55 bcdef	6.27 cde	90.1 abc	88.4 abcd	105.6 hij	141.8 e	8.0 ab	9.0 ab
2000 ppm	L1	26.7 bcde	28.2 ef	7.08 abcd	7.00 b	86.7 abcde	86.0 bcdefg	188.8 b	197.2 b	1.3 fg	1.0 j
	L2	16.4 ijk	19.1 ijk	5.29 ghijk	5.32 fgh	88.2 abcd	88.0 bcde	86.6 jk	101.5 g	8.5 a	9.3 a
	L3	15.1 jklm	16.4 lm	4.94 klm	4.93 ghi	79.6 defg	79.8 jkl	70.7 kl	81.1 h	8.0 ab	7.7 cd
	L4	29.7 ab	30.7 abc	7.00 abcd	7.00 b	82.1 bcdef	86.3 bcdef	150.3 de	215.1 ab	1.0 g	1.0 j
	L5	27.9 abcd	29.8 bcde	6.75 abcde	6.63 bc	86.9 abcde	88.4 abc	173.6 bc	197.5 b	2.2 efg	2.8 ghi
	L6	24.9 def	25.0 g	5.25 ghijk	5.67 ef	86.9 abcde	86.4 bcdef	130.7 defg	141.7 e	3.5 cdefg	3.0 gh
	L7	26.8 bcde	29.0 de	5.94 efghij	5.80 ef	81.1 cdefg	81.8 ijk	126.3 efgh	168.2 d	9.0 a	10.0 a
	L8	15.7 ijkl	17.6 kl	6.24 cdefg	5.75 ef	86.3 abcde	86.8 bcdef	82.2 jk	101.3 g	9.0 a	9.0 ab
4000 ppm	L1	23.6 ef	24.0 gh	6.51 bcdef	6.57 bcd	83.2 bcdef	82.8 ghij	155.1 cd	157.8 d	1.3 fg	1.0 j
	L2	13.0 lmn	13.9 n	5.20 ijkl	5.00 ghi	87.7 abcd	86.3 bcdef	65.3 klm	69.5 hi	9.0 a	9.7 a
	L3	9.8 opq	10.9 opq	4.66 klm	4.88 ghi	81.4 bcdefg	81.1 jklm	42.8 m	53.3 i	9.0 a	9.3 a
	L4	24.5 ef	22.9 h	5.98 efghij	5.88 ef	81.6 bcdefg	81.9 ijk	146.4 def	134.7 ef	1.4 fg	1.1 j
	L5	19.9 gh	20.3 i	6.08 defghi	6.07 cde	86.7 abcde	85.5 cdefgh	123.3 fgh	123.4 f	2.7 defg	3.7 g
	L6	23.6 ef	22.4 h	4.82 klm	4.73 hij	83.2 bcdef	84.9 efghi	111.5 ghi	106.2 g	4.0 cdef	3.3 gh
	L7	14.0 klmn	15.3 mn	4.75 klm	4.97 ghi	81.3 cdefg	81.7 ijk	88.5 jk	76.0 h	9.7 a	10.0 a
	L8	11.7 nop	11.3 op	5.64 fghijk	5.67 ef	81.9 bcdef	80.6 jkl	76.6 k	64.2 hi	9.3 a	9.3 a
6000 ppm	L1	22.2 fg	23.1 h	6.21 cdefgh	6.01 de	81.1 cdefg	82.6 hij	138.0 def	138.6 ef	2.6 defg	3.0 gh
	L2	12.2 mno	10.8 opq	5.02 jkl	5.00 ghi	86.6 abcde	84.9 defghi	63.6 klm	53.8 i	10.0 a	10.0 a
	L3	8.7 pq	9.4 pq	4.24 lm	4.65 ij	87.3 abcde	85.6 klm	42.6 m	43.6 i	10.0 a	10.0 a
	L4	20.3 gh	19.9 i	4.92 klm	5.37 fg	78.2 efg	78.8 klm	146.2 def	106.8 g	1.7 fg	1.7 ij
	L5	16.3 ijk	18.2 jk	4.03 m	4.23 j	85.1 abcdef	84.5 fghi	79.7 k	76.9 h	5.5 bc	5.7 f
	L6	18.0 hij	17.7 kl	4.73 klm	4.62 ij	77.0 fg	77.8 lmn	87.0 jk	81.7 h	7.8 bc	3.8 g
	L7	13.6 klmn	12.0 o	4.72 klm	4.73 hij	72.8 g	75.2 n	64.6 klm	56.8 i	10.0 a	10.0 a
	L8	8.0 q	9.9 pq	5.23 hijkl	5.28 fgh	81.0 cdefg	77.1 mn	50.0 lm	52.1 i	10.0 a	10.0 a

NS: Non-Significant

***, Interaction of such parameter is significant at level 1% of probability*

[#]Values with the same alphabet letters do not significantly differ from one another, using Duncan's multiple range test at 0.05 level of probability

Table 6. Effect of irrigation by different levels of salinity on vegetative growth, yield and its components of molokhia overall the five landraces during 2021 and 2022 summer seasons

Salinity level	Vegetative growth								Yield and its components															
	Plant height (cm)				No. of branches/plant				Weight of ten plants (g)				leaves weight of 10 plants (g)				Net weight ratio (%)				Fresh leafy yield (kg/m2)			
	2021 season		2022 season		2021 season		2022 season		2021 season		2022 season		2021 season		2022 season		2021 season		2022 season		2021 season		2022 season	
625 ppm (Control)	86.5	a[#]	88.9	a	7.8	a	7.3	a	336	a	301.5	a	127.9	a	114.3	a	38.19	a	37.95	a	3.097	a	3.261	a
2000 ppm	79.8	b	79.0	b	7.3	a	6.8	a	278	b	247.8	b	105.8	b	96.1	b	38.02	a	38.87	a	2.507	b	2.741	b
4000 ppm	74.1	c	67.9	c	6.1	b	6.0	b	225	c	208.6	c	86.5	b	76.6	c	38.69	a	36.77	b	2.017	c	2.181	c
6000 ppm	62.6	d	55.2	d	5.6	b	5.6	b	161	d	143.6	d	60.7	c	53.1	d	36.96	b	36.28	b	1.367	d	1.514	d

[#]*Values with the same alphabet letters do not significantly differ from one another, using Duncan's multiple range test at 0.05 level of probability*

Table 7. Mean performances of vegetative growth, yield and its components of the five landraces of molokhia overall salinity levels during 2021 and 2022 summer seasons

Landraces	Vegetative growth								Yield and its components															
	Plant height (cm)				No. of branches/plant				Weight of ten plants (g)				leaves weight of ten plants (g)				Net weight ratio (%)				Fresh leafy yield/plot (kg/m2)			
	2021 season		2022 season		2021 season		2022 season		2021 season		2022 season		2021 season		2022 season		2021 season		2022 season		2021 season		2022 season	
L1	70.0	c[#]	71.5	b	7.4	a	7.2	a	260.8	a	238.6	a	94.9	abc	88.6	ab	36.62	bc	37.17	b	2.413	ab	2.672	ab
L2	89.5	a	86.7	a	7.7	a	7.0	a	252.0	ab	225.1	ab	108.0	a	94.1	a	44.09	a	41.22	a	2.671	a	2.804	a
L3	66.3	d	65.7	c	5.7	c	6.2	b	249.2	ab	232.2	a	97.2	ab	86.5	bc	38.08	b	37.95	b	2.213	b	2.409	bc
L4	77.0	b	70.1	b	6.1	bc	6.1	b	256.3	ab	224.4	ab	93.0	bc	81.3	c	35.23	c	34.92	c	2.104	b	2.304	c
L5	75.9	b	69.7	b	6.5	b	5.8	b	230.6	b	206.7	b	83.0	c	74.7	d	35.80	bc	36.06	b	1.834	c	1.935	d

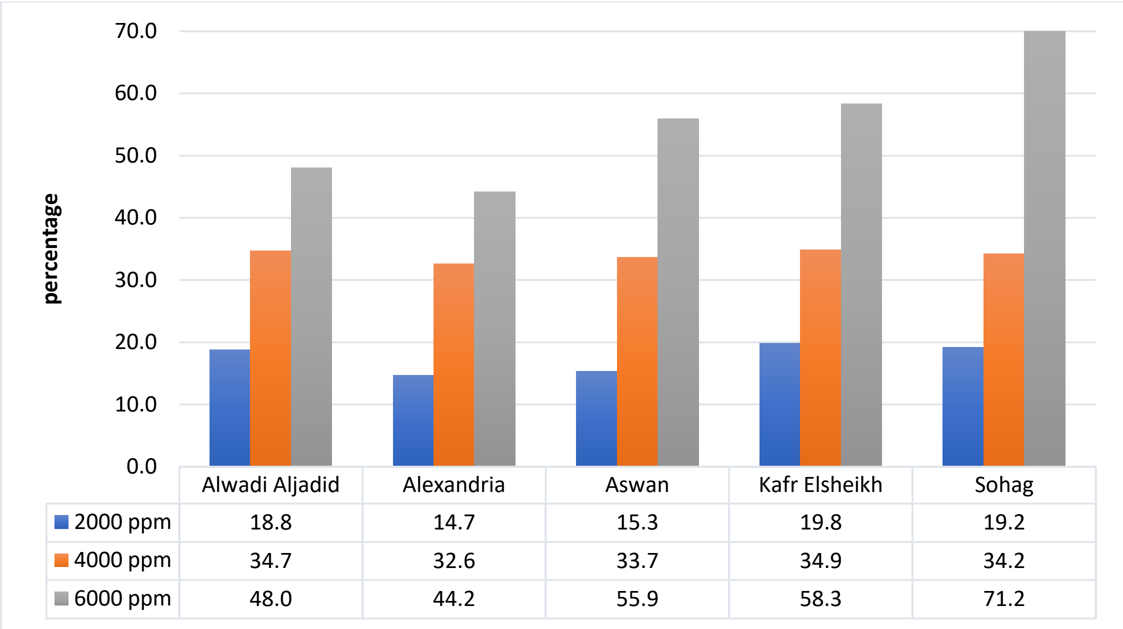
[#]*Values with the same alphabet letters do not significantly differ from one another, using Duncan's multiple range test at 0.05 level of probability*

Table 8. Effect of interaction between the five landraces of molokhia and salinity levels on vegetative growth, yield and its components during 2021 and 2022 summer seasons

Salinity level	Landraces	Vegetative growth				Yield and its components							
		Plant height (cm)		No. of branches/plant		Weight of ten plants (g)		leaves weight of 10 plants (g)		Net weight ratio (%)		Fresh leafy yield (kg/m2)	
		2021 season**	2022 season**	2021 season**	2022 season**	2021 season**	2022 season**	2021 season	2022 season	2021 season**	2022 season**	2021 season	2022 season
625 ppm (Control)	L1	79.6 e	83.4 c	8.8 a	8.5 a	350.5 b	315.5 ab	118.4 bcd	111.9 bc	33.77 d	35.47 cd	3.300 ab	3.513 ab
	L2	112.5 a	115.2 a	9.8 a	8.8 a	327.1 bc	294.3 abc	123.8 bc	112.0 bc	40.44 bc	37.67 bcd	3.467 a	3.630 a
	L3	71.3 ghi	75.6 d	6.2 cd	6.2 cde	306.2 bcde	297.4 abc	136.9 ab	123.1 ab	41.85 bc	41.83 b	3.067 abc	3.197 bc
	L4	83.7 d	87.0 c	6.5 c	6.3 bcd	400.8 a	339.1 a	152.6 a	127.2 a	38.08 c	37.50 bcd	2.950 bcd	3.193 bc
	L5	85.4 cd	83.2 c	7.7 b	6.8 bc	293.3 cdef	261.0 cde	108.1 cdef	97.3 de	36.84 cd	37.27 bcd	2.700 cde	2.773 de
2000 ppm	L1	68.2 ijk	76.6 d	7.3 b	7.3 b	255.6 efghi	225.4 ef	100.3 cdefg	100.0 cde	39.24 c	44.37 ab	2.567 def	2.967 cd
	L2	107.5 b	98.4 b	9.7 a	8.3 a	265.5 defg	235.3 def	123.1 bc	104.0 cd	40.83 bc	39.29 bc	3.067 abc	2.987 cd
	L3	69.9 hijk	71.7 de	5.8 cd	6.0 cde	301.5 bcdef	264.7 cde	102.7 cdefg	90.9 ef	38.70 c	38.65 bc	2.450 ef	2.853 cde
	L4	77.2 ef	72.8 d	6.2 cd	6.3 bcd	318.3 bcd	279.6 bcd	114.0 bcde	104.7 cd	35.81 cd	37.46 bcd	2.333 efgh	2.593 ef
	L5	76.4 ef	75.7 d	7.3 b	6.2 cde	250.0 fghi	234.2 def	88.8 efg	80.9 fg	35.52 cd	34.56 cd	2.117 fghi	2.307 fg
4000 ppm	L1	66.6 k	64.3 f	7.2 bc	6.3 bcd	224.1 ghij	220.3 ef	86.7 efg	76.7 ghi	38.69 c	34.82 de	2.117 fghi	2.333 fg
	L2	88.2 c	83.9 c	6.0 cd	6.0 cde	260.3 efgh	234.0 def	92.6 defg	82.1 fg	46.14 ab	41.02 b	2.417 efg	2.367 fg
	L3	66.9 ijk	62.4 fg	5.7 d	5.8 cde	200.7 ijk	200.1 fg	93.8 defg	83.0 fg	36.02 cd	35.47 cd	1.967 ghi	2.187 ghi
	L4	75.3 efg	62.5 fg	6.0 cd	6.2 cde	208.3 hij	187.5 fg	75.4 gh	66.7 hi	36.19 cd	35.58 cd	1.883 hi	2.117 ghi
	L5	73.6 fgh	66.3 ef	5.5 d	5.8 cde	230.7 ghij	201.2 fg	84.0 fg	74.3 ghi	36.42 cd	36.95 bcd	1.700 ij	1.903 hi
6000 ppm	L1	65.6 k	61.7 fg	6.2 cd	6.0 cde	213.2 ghij	193.0 fg	74.2 gh	65.7 i	34.80 d	34.01 d	1.667 ijk	1.873 i
	L2	50.0 m	49.4 i	5.3 d	5.7 cde	155.0 k	136.8 h	92.3 defg	78.2 gh	48.95 a	46.92 a	1.733 ij	2.230 gh
	L3	57.1 i	53.3 hi	5.2 d	5.0 e	188.7 jk	166.6 gh	55.4 hi	49.1 j	35.76 cd	35.86 cd	1.367 jk	1.397 j
	L4	71.8 ghi	58.3 gh	5.8 cd	6.0 cde	97.5 i	91.4 i	30.1 i	26.6 k	30.86 e	29.15 e	1.250 k	1.313 j
	L5	68.3 ijk	53.5 hi	5.3 d	5.5 de	148.5 k	130.3 hi	51.1 hi	46.2 j	34.42 d	35.44 cd	0.817 i	0.757 k

***, Interaction of such parameter is significant at level 1% of probability*

#Values with the same alphabet letters do not significantly differ from one another, using Duncan's multiple range test at 0.05 level of probability



	Alwadi Aljadid	Alexandria	Aswan	Kafr Elsheikh	Sohag
2000 ppm	18.8	14.7	15.3	19.8	19.2
4000 ppm	34.7	32.6	33.7	34.9	34.2
6000 ppm	48.0	44.2	55.9	58.3	71.2

Fig. 3. The percentage decrease in the fresh leafy yield/plot of the five landraces of molokhia as a result of the increase in the level of irrigation salinity relative to control, average of both seasons

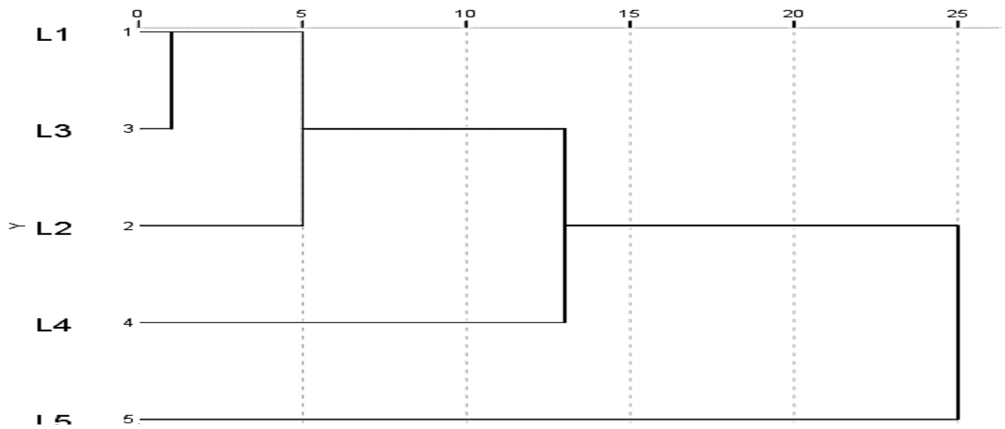


Fig. 4. Dendrogram using average Linkage of the five landraces of molokhia based on the studied traits, rescaled distance cluster combine

4. CONCLUSIONS

Although most of the studied traits were negatively affected by increasing salinity level in irrigation, it can be recommended to cultivate Behera (L4), Alexandria (L2) and Gharbya (L5) landraces of okra and Alexandria (L2) and Kafr Elsheikh (L4) landraces of molokhia when irrigation with relatively high levels of salinity, as these landraces were relatively less affected by increasing salinity concentration. These landraces can also be introduced into breeding programs to improve them or develop new varieties that are more salt-tolerant.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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The peer review history for this paper can be accessed here:
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