J. of Plant Production, Mansoura Univ., Vol. 15 (7): 357 - 365 , 2024

Journal of Plant Production

Journal homepage & Available online at: www.jpp.journals.ekb.eg

Performance of Cassava Plant (*Manihot esculenta* Crantz) under Salinity Stress Conditions

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ABSTRACT

A field experiment was conducted during the 2022/2023 and 2023/2024 growing seasons at the experimental farm of the Vegetables Research Department, Horticulture Research Institute, Dokki, Giza Governorate, Egypt. The experiment investigated the effects of different irrigation salinity levels on the growth potential of cassava plants (Indonesian cultivar) grown in sandy loam soil. Cassava plants were subjected to six irrigation water salinity levels: 0.44 (control), 0.98, 2.04, 3.33, 8.82 and 13.50 dS/m. Four replications of a randomized complete block design were carried out. The data indicated that cassava vegetative growth characteristics were decreased with increasing salinity in irrigation water. At harvest time, no cassava plants were stayed in plastic bags that received high concentration of saline water treatments (3.33, 8.82 and 13.50 dS/m) in both seasons. The saline concentricity (0.98 and 2.04 dS/m) not only contribute accumulation of sodium, chloride and hydrocyanic acid in cassava leaves at five months from planting and in tuber roots at harvest but also led to significant reduction in potassium and tuber roots starch percentage compared to control in the two seasons. The concentration of salts in irrigation water has a great impact on some soil characteristics which (EC, pH, CEC, Ca^2 and CO_3). The Productivity Index (PI) distribution for soil productivity classes was medium, based on the computed values that were obtained.

***Keywords**:* Cassava, saline water irrigation, cassava growth, initiative tuber root, starch and Hydrocyanic acid.

INTRODUCTION

The River Nile provides irrigation water (55.5 one billion m^3/year) for the majority of Egypt's agricultural needs (Kotb, 2011). Farmers are compelled to utilize all available water sources in order to improve food production, which requires more acreage. Thus, for the growth of irrigated agriculture and agricultural development, the use of low quality water such as ground, drainage, reclaimed waste, and even diluted sea water should be viewed as complementary sources. Generally, salinity is a significant indicator of poor soil quality, which lowers agricultural yield and progressively reduces the area under cultivation. If appropriate management techniques are not used, irrigated agriculture employing saline water in arid and semi-arid regions may result in salt buildup in the soil profile, a decrease in crops yield, and degradation of the soil resource (Ould *et al.*, 2007). The usage of irrigation has expanded by almost 300% over the previous three to four decades as a result of the rising demand for food. The lack of surface water resources, particularly in arid and semi-arid regions where agricultural lands relies on irrigation, compels farmers to use low-quality water, which has forced an additional rise in soil salinization (Poustini and Siosemardeh, 2004). In dry and semi-arid areas, controlling water supplies, growing salt-tolerant plants must taking into consideration. A saline water resource is one that has a high proportion of dissolved salt, specifically sodium chloride (NaCl). "ppm" stands for parts per million, which is the unit of salt concentration (by weight). Electrical conductivity (EC), which is measured in deciSiemen per meter (dS/m), is the indicator of salinity (Water Science School, 2018).

Cassava plant, *Manihot esculenta* Crantz, is a vital source of nutrition of many people in subtropical and tropical countries. Its starchy tuber roots are rich in digestible carbohydrates and vitamin C. It is a rural plant and best favorable to poor soils such as low fertilized soil and soil affected by salinity. Osmotic stresses as salinity is a specific factor for its agriculture. Cassava needs new land to grow for nutrition, but some of this land is saline (Carretero *et al.*, 2008). Besides, there is an increase in modern land reclamation in Egypt with an increase in the rate of population, especially the desert area, which is characterized by high concentrations of salinity due to scarcity of rain. The Nile River in Egypt is an essential source for irrigation cultivated plants for nutrition. Nowadays, with the increase in population, we suffer from insufficient irrigation, so the farmer began to resort to another source of irrigation without changing the soil and field crops.

Salinity is one of the main factors influencing plant de velopment and yield (Dasgupta *et al.*, 2013 and Gupta and H uang, 2014). As an active property of soil, salinity is a primary determinant of economic yield. It promotes osmotic and poisonous effects leading to physiological, morphological and biochemical changes. Salinity reduces respiration, growth size, crop production, protein synthesis and it results in insufficient nutrients in cassava (Burns *et al.*, 2010). These effects have been observed in agricultural and horticultural crops including

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DOI: 10.21608/jpp.2024.289963.1342

cassava**.** When using different concentrations of salinity on potato, it was found that a higher concentration led to a significant decrease in shoot biomass, root length and volume, tuber yield (Abdelal, 2010 and Akhtar *et at.*, 2015).

In many studies, it has been found that irrigation with saline water results in fewer tuber roots in salinity zone (Shani and Dudley, 2001). Other research emphasizes the importance of selecting proper irrigation systems practices that provide adequate water into the root zone for good evaporative and reduced salt accumulation in the root zone (Munns, 2002). Some researchers suggest that crops planted in saline should be chosen for their salt tolerance (Feitosa *et al.*, 2005). Additionally, when the salt content of the water is lower, irrigation with saline water generally reduces soil salinity. This study aims to investigate how saline irrigation affects cassava plant growth in sandy loam soils.

MATERIALS AND METHODS

This study evaluated how the six salt concentrations of irrigation water affected cassava tuber roots in sandy loam soil and their initial growth. Over two seasons, 2022/2023 and 2023/2024, the experiment was conducted out on cassava plants in plastic bags using soil samples were taken from the top 30 cm layer of the Ali Mobarek farm, located on the Cairo-Alexandria Desert Road (76 km to Alex). The farm is owned by the Vegetables Research Departments of the Horticulture Research Institute, Dokki, Giza Governorate. In Table (1) these soil samples was air dried, ground, and analyzed to determine the following physical and chemical parameters.

Table 1. The soil's physical and chemical characteristics at the experiment site

Soil size distribution (%)			
Sand (%)	**Silt (%)**	**Clay (%)**	**Texture**
69.1	28.8	2 .1	Sandy loam

Chemical analysis										
$CaCO_3$ (%)	OM%	pH	EC dS/m	Soluble cations (meq/l)				Soluble anions (meq/l)		
				Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	So_4^-
5.7	0.15	7.5	1.52	4.00	1.76	8.32	0.61	1.56	4.41	8.71

Plastic bags with a 50 cm diameter and 100 cm length were used for sowing. They were perforated at the bottom to allow excess irrigation water drain out, and then filled with approximately 50 kg of sandy soil. After that, the sand culture was cleaned with tap water and kept for a week.

During the third week of April in both seasons, stem cuttings were placed in the plastic bags. The cuttings, which were approximately 2.5 – 3 cm in diameter, were divided into 25 – 30 cm long stalks. Two thirds of the cuttings were placed inside the soil and the remaining third above soil culture. The cuttings were then planted vertically. Irrigation was completed to the water field's capacity after cassava plants were grown.

Sea water from the Mediterranean Sea at Alexandria Governorate was diluted to the necessary concentrations with fresh water before being used for irrigation. Throughout the nine month long trial, irrigation with the diluted sea water was conducted. Watering the plant with saline water depends on its age. Attention was given to irrigation at the beginning of growing plants, with watering every two weeks, then it decreases in middle grow to become every month, and at the end of the plants, one month before to harvesting, irrigation is not allowed toward. Sea water was used as a source of salinity. Sea water was diluted with tap water to achieve five levels of salinity: 0.98, 2.04, 3.33, 8.82 and 13.50 dS/m at 25ºC are corresponding to the irrigation treatments of 627, 1306., 2131, 7056 and 10800 ppm, respectively, beside the control which tap water (0.44 dS/m = 282 ppm). Thus, the experiment includes six levels of saline water: C_0= 0.44 (tap water), C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m. Four replications of each treatment were conducted using a completely randomized block design. Table (2) revealed the tap water and salinity concentrations in addition to the sea water (58 dS/m) analysis.

Table 2. The chemical composition of irrigation water (tap water, irrigation treatments and sea water).

Treatments	**EC (dS/m)**	**pH**	**Soluble cations (meq/l)**				**Soluble anions (meq/l)**			**SAR**
			Ca^{2+}	Mg^{2+}	Na^+	K^+	HCO_3^-	Cl^-	So_4^-	
C_0	0.44	8.1	1.00	0.92	1.74	0.13	1.56	0.49	1.74	1.42
C_1	0.98	8.4	1.6	1.66	5.48	0.19	1.04	2.09	5.80	3.61
C_2	2.04	8.6	1.8	3.00	15.01	0.35	1.13	5.64	13.39	5.20
C_3	3.33	8.6	1.8	5.30	27.91	0.53	1.13	10.27	24.14	6.65
C_4	8.82	8.6	3.2	12.54	81.61	1.20	1.13	30.73	66.69	10.82
C_5	13.5	7.7	10.3	18.71	117.39	1.69	1.42	43.13	103.54	12.88
sea water	58	7.6	17.0	110.6	620.00	9.12	0.94	272.7	483.13	27.74

SAR = Sodium adsorption ratio - C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m.

In the experiment, fertilization followed recommended doses consisting of ammonium nitrate (33.5 % N) at 77 kg/ fed., phosphoric acid (38% P) at 50 kg per fed. and potassium sulfate (48 % K) at 96 kg / fed. These fertilizers were divided to be added 6 times to the plants and the first time was after one month of planting then the remaining amount added with upcoming irrigation. All other agricultural procedure followed traditional guidelines for planting cassava.

$$\text{Applied irrigation water (AIW)} = \frac{\text{Water consumption use (CU)}}{\text{Ea}} + \text{LR}$$

AIW = applied irrigation water depth (liters/day).
CU = sum of depletion soil moisture in each soil layer (60 cm)
Ea = irrigation efficiency
LR = leaching requirements

Water consumption use (CU): it was determined as accumulated amounts of added water to the seedlings or plants at irrigation to attain field capacity point during the entire growing season under the assessed irrigation intervals.

Water consumptive use (CU), values were determined by Time Domain Reflectometry (TDR) sensor which measured the volumetric soil moisture contents in the surface 60 cm depth of soil before and after each irrigation. The TDR is widely used to measure soil water content according to (Cataldo *et al.*, 2011). The CU values were calculated according to Israelsen and Hansen (1963) using the following equation:

$$CU = \sum_{i=1}^{i=4} \frac{(\theta_2 - \theta_1)}{100} \times d$$

Where:

CU= water consumption used or actual evapotranspiration, ETa (mm).
i = number of soil layer.
θ2 = soil moisture content after irrigation, (%, by volume).
θ1 = soil moisture content just before irrigation, (%, by volume).
d = depth of soil layer, (150 mm).

Methods of analysis:

Soil analysis: Data were randomly taken from each treatment at the end experiment (nine months) and subjected to chemical and physical properties analysis of the soil using the following determinations; mechanical analysis was done using sodium hexameta-phosphate as a dispersing agent, following the international pipette method according to Piper (1950). Total salinity and soluble ions in the saturated paste extract were determined according to Richards (1954). pH was determined in a soil: water suspension (1:2.5) using a pH meter. Organic matter % was determined according to the modified method of Walkley and Black (1934). Available P, K were determined by extracting them from the soil with Ammonium-Bicarbonate- DTPA, (AB+DTPA according to Soltanpour (1985). Phosphorus was measured colormetrically; K was measured by Flam Photometer. Total nitrogen was determined by micerokjeldahl method as described by Chapman and pratt (1961).

Crop characteristics

A- Parameter of vegetative growth

After two, three, four, five, and six months from planting, data were randomly selected from each treatment to determine the average of the subsequent data:

1.Height of plant (cm).
2.Number of leaves/ plants.
3.Plant survival percentage %.
4.Branch diameter (cm).
5.Number of branches /plants

B- Initiative tuber roots constituents

Nine months after planting at harvest time, all the tuber roots in each plot were gathered, and the following data was noted:

1.Initiative tuber roots length/ plant (cm).
2.Initiative tuber roots diameter/ plant (cm).
3.Initiative tuber roots weight/ plant (gm).
4.Initiative tuber roots number/ plant.

C- Chemical analysis

1.Potassium and sodium (meq/l) were determined in cassava leaves at the fifth month from planting and in tuber roots after harvesting based on the procedures defined by Brown and Lilleland (1946).
2.Chloride percentage was determined in cassava leaves at the fifth month from planting and in tuber roots after harvesting using the method suggested by Helmkamp *et al.* (1954).
3.Starch percentage was determined in tuber roots after harvesting using the method described by AOAC (2016).
4.Hydrocyanic acid concentration was determined according to AOAC (2016) and Foda (1987) in tuber roots after harvesting.

Process of Hydrocyanic acid extraction and clarification

To release all bound hydrocyanic acid, 10 gm of crushed cassava tuber roots were put in a 500 ml volumetric flask then 200 ml of distilled water was added and the mixture was then boiled for four hours. 150 to 200 ml of the distillate was collected in a sodium hydroxide solution (0.5 gram/ 20 ml water) following the completion of steam distillation. Eight milliliters of 5% potassium iodide were added to every 100 milliliters of distillate, which was then diluted to 250 milliliters. The standard 0.02 N silver nitrate solution was then titrated using a microburet. A slight but persistent turbidity, which was particularly noticeable against a black background, served as an indicator of the end point.

The calculation: 1.08 mg of hydrocyanic acid is equivalent to 1 milliliter of 0.02 N silver nitrate.

Data analysis using statistics

The analysis of variance method, as described by Snedecor and Cochran (1980), was used to the data. The Duncan Multiple Range Test (Duncan, 1955) was used to compare the means. The STATISTIX version 8.0 program was used for all data analysis.

RESULTS AND DISCUSSION

Some soil chemical properties

Many soil scientists have established limitations for salt content based on it affects on soil quality and plant growth. These limitations are categorized as follows: non-saline (<2), very slightly saline (2-4), slightly saline (4-8), moderately saline (8-16) and Saline(>16 dS/ m). The findings show that the salinity, measured by electric conductivity (EC), ranged from 2.04 to 27.5 dS/ m. Only afew salt tolerant plants exhibited satisfactorily yield. Plants with moderate salt tolerance can be grown in most instances without special salinity control measures.

Data presented in Table (3) illustrate how irrigation water salinity affects soil EC, cations, and anions. Higher soil salinity levels were observed in treatments where irrigation water with high salt concentrations was used, while lower soil salinity levels were associated with the use of low-salinity irrigation water.The exchangeable sodium percent values (ESP) increased by increasing concentration saline water used for irrigation, range from 8.95 to 33.88.

Table 3. Chemical analysis of soil at the end experiment.

Treatments	Chimecal analysis									
Saline water	EC (dS/m)	pH	Soluble cations (meq/l)				Soluble anions (meq/l)			ESP
			Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	So_4^-	
C_0	2.04	7.3	5.47	3.78	11.30	0.24	0.68	18.91	1.20	8.95
C_1	3.34	7.5	8.79	6.07	18.14	0.39	1.10	30.36	1.93	11.48
C_2	3.80	7.3	10.00	6.91	20.64	0.45	1.25	34.55	2.20	12.82
C_3	3.87	7.4	10.18	7.16	21.02	0.46	1.27	35.18	2.37	12.40
C_4	8.21	7.4	21.61	14.93	44.60	0.97	2.70	74.64	4.77	18.28
C_5	27.5	7.1	72.37	50.00	149.4	3.24	9.05	250.0	15.96	33.88

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

Data illustrated in Table 4 show some chemical and physical properties including Electrical conductivity (EC) in saturated extract, organic matter (OM) and soil cation-exchange capacity (CEC) as influenced by different irrigation water salinity. The results indicate that EC ranged from 2.04 to 27.50, $CaCO_3$ ranged from 5.55 to 10.75%, CEC ranged from 1.88 to 3.3 meq 100 g^{-1} soil and OM % ranged from 0.19 to 0.90.

Table 4. Changes of electrical conductivity (EC), $CaCO_3$% and organic matter (OM) in soil after cassava plants cultivation as affected by salinity in irrigation water (Average of two seasons).

EC of water irrigation (dS/ m)	EC dSm^{-1SOIL}	Ca CO_3 %	CEC 5 meq $100g^{-1}$soil	OM %
C_0	2.04	6.11	1.92	0.77
C_1	3.34	5.55	3.3	1.60
C_2	3.87	7.11	2.1	1.97
C_3	3.80	6.80	3.0	0.87
C_4	8.21	5.77	2.5	1.00
C_5	27.50	10.57	1.88	1.67

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

Following cassava cultivation, the amount of accessible nitrogen in the soil was indicated by the data in Table 5. The rates of mineral fertilizers in soil enhanced the values of accessible N by 140 to 183 mg/kg. The amount of accessible nitrogen in salt-affected soils increased dramatically, according to the results. In comparison to normal soils, saline soils exhibited much lower levels of ammonification and nitrification. Additionally, available P and K rates are 10.8 - 14.0 mg/ kg soil and 177–199 mg/ kg soil, respectively. The availability of specific nutrients in the soil is a key factor influencing their content in cassava tissue. The tissues, especially the leaves, would exhibit higher nutrient levels in the soil as a result of fertilization. However, there is a maximum concentration of each nutrient in the leaf, beyond which more application could damage the plant, have no effect on yield, or even contaminate the surrounding area. A system of classification for the nutrients in soil that cassava requires is presented by Howeler (2002).

Table 5. Available N, P and K (mg/kg soil) in soil after cassava plants cultivation as affected by salinity in irrigation water (Average of two seasons)

EC of water irrigation (dS/m)	EC dSm^{-1SOIL}	N (mg/kg)	P (mg/kg)	K (mg/kg)
C_0 tap water	2.04	140	14.0	177
C_1 0.98	3.34	144	11.3	180
C_2 2.04	3.87	166	13.0	198
C_3 3.33	3.80	171	10.8	199
C_4 8.82	8.21	170	12.8	177
C_5 13.50	27.50	183	11.9	187

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

Productivity Index (PI): Productivity Index (PI) was estimated by calculation as:

T.P.K. is the productivity index (PI). T represents the soil texture rating, where 100 indicates a fine loamy texture that is appropriate for growing a variety of crops, 80 indicates a medium loamy texture and 60 indicates a coarse grained and/ or stratified soil. P stands for rating, which represents the fraction of accessible phosphorus (high P soils = 1, medium P soils = 0.8 and low P soils = 0.6). K is the productivity class rating for available potassium (as a proportion of 1) for each soil unit. For high K soils, this is 1, for medium K soils, it is 0.8 and for low K soils, it is 0.6. (Raj *et al.*, 2012). The zones with PI values < 40 were classified as low production class, 41–60 as medium, 61–80 as high, and >80 as extremely high.

Parameters and criteria of Productivity Index.

Parameters	Low	Medium	High
	Criteria		
Available P	<12.5	12.5-22.5	>22.5
Available K	<135	135-335	>335

Table 6 exhibited that the distribution of the Productivity Index (PI) for all productivity classes at the different levels these soils were rated as medium productive.

Table 6. Productivity index of soil after cassava plants cultivation as affected by salinity in irrigation water (Average of two seasons)

EC of water irrigation(dS/m)	Texture classes	Rating	available P	available K	Productivity Index (PI)
C_0	Sandy lomy	80	0.8	0.8	medium
C_1	Sandy lomy	80	0.8	0.8	medium
C_2	Sandy lomy	80	0.8	0.8	medium
C_3	Sandy lomy	80	0.8	0.8	medium
C_4	Sandy lomy	80	0.8	0.8	medium
C_5	Sandy lomy	80	0.8	0.8	medium

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

Exhibited the water samples were analyzed for cations and anions (Table 7). The major cations are Na^+, K^+, Ca^{2+} and Mg^{2+} and the anions Cl^-, So_4^-, NO_3 and HCO_3^- and pH value are 8.1 to 7.7. The results indicated high salinity of the C_5. Data illustrated in Table 7 showed some properties of irrigation water the SAR = Sodium adsorption ratio (1.42 to 12.88). FAO (2002) reposing parameters to evaluate irrigation water quality usual range in irrigation water electrical conductivity (ECi 0 - 3 dS/ m) total dissolved salts (TDS 0 - 2000 mg/ L) calcium (Ca^{2+} 0 - 20 meq/ L) magnesium (Mg^{2+} 0 - 20 meq / l) sodium (Na^+ 0 - 5 meq / L) chloride (Cl^- 0 - 10 meq/ L) adj. sodium adsorption ratio (SAR 0 – 15) acidity/ basicity (pH 5 - 8.5). Water stress during the early stage of cassava growth (initiated two months after planting and lasting for four months) greatly, reduces shoot and root yields. However, alleviation of this stress improves growth and yield (El-Sharkawy and Cadavid, 2002). The response of cassava to salinity has been described as hydric in the early stages of soil water stress, maintaining relatively constant leaf water potential even when the stomata are closed (Alves, 2002).

Crop characteristics

***A*- Parameter of vegetative growth**

The vegetative development parameters data shown in Table (8), showed that the saline water irrigation treatments significantly reduced the cassava plants height, leaf number per plant and branch diameter at two months age, except for branches number per plant and plant survival percent, which recorded non-significant decreases during the two growing seasons. Irrigation with saline water concentrations of 0.98 (C1) and 2.04 (C2) dS/m, as well as control (C0) resulted in the greatest plant growth parameters values for both seasons when compared to other treatments. In general, it is possible to observe a negative correlation between saline water concentrations and the measured parameters where the highest concentrations of saline water irrigation recorded the least values of data and *vice versa*. This is due to the hurtful effects of irrigation with salt water. The increase of Na and Cl (as a result of saline water irrigation) in leaves inhibits the production of chlorophyll and carotene within the leaves (El-Zohiri, 2009). Carretero *et al.* (2008) found that the growth rate of cassava plants decreased as NaCl concentrations increased. The same pattern of results was seen with Abdelal (2010) on potatoes.

Table 7. Some properties of irrigation water

EC of water irrigation (dS/m)	pH	Soluble cations (meq/l)				Soluble anions (meq/l)			SAR
		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^-	Cl^-	So_4^-	
C_0 tap water	8.1	1.00	0.92	1.74	0.13	1.56	0.49	1.73	1.42
C_1 0.98	8.4	1.6	1.66	5.48	0.19	1.04	2.09	5.81	3.61
C_2 2.04	8.6	1.8	3.00	15.01	0.35	1.13	5.64	13.39	5.20
C_3 3.33	8.6	1.8	5.30	27.91	0.53	1.13	10.27	24.14	6.65
C_4 8.82	8.6	3.2	12.54	81.61	1.20	1.13	30.73	66.69	10.82
C_5 13.50	7.7	10.3	18.71	117.39	1.69	1.42	43.13	103.54	12.88

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

Table 8. Impact of different irrigation water salinity on vegetative traits of cassava plants at two months age during 2022/2023 (S_1) and 2023/2024 (S_2)

Treatments saline water (dS/ m)	Plant height (cm)		Leaves number / plant		Branches diameter (cm)		Branches number/plant		Plant survival %	
Seasons	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
C_0	61.3a	66.0a	23.3a	25.0a	0.61a	0.78a	2.3a	2.3a	100a	100a
C_1	60.3a	64.3ab	21.3a	21.0ab	0.57a	0.73ab	2.3a	2.0a	100a	100a
C_2	58.0a	63.3ab	19.0a	20.3ab	0.56a	0.71ab	2.3a	2.0a	100a	100a
C_3	51.6b	58.6bc	14.0b	16.6bc	0.46b	0.60b	2.0a	2.0a	100a	100a
C_4	48.3bc	56.3c	6.6c	13.6c	0.46b	0.58b	2.0a	1.6a	100a	100a
C_5	44.3c	54.3c	1.3d	1.6d	0.41b	0.58b	1.6a	1.3a	100a	100a

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

The multiple range tests used by Duncan show no significant difference ($p \leq 0.05$) between mean values within columns with the same letter(s).

Table (9) revealed that after irrigation with low concentrations of saline water [0.98 (C1) and 2.04 (C2) dS/ m] the plant height, number of leaves and branch diameter of cassava plants at three months of age recorded high values also watered with tap water (C0). Furthermore, low values were obtained in both seasons from the plants that were irrigated with high salinity of 3.33 (C3) and 8.82 (C4) dS/ m. Regarding the impact of salinized water on the number of branches and plant survival percentage of cassava plants, no discernible declines occurred in either season. Nevertheless, this percentage was decreased with high irrigation levels of 8.82 (C5) dS/ m.

Table 9. Impact of different irrigation water salinity on vegetative traits of cassava plants at three months age during 2022/2023 (S_1) and 2023/2024 (S_2)

Treatments saline water	Plant height (cm)		Leaves number / plant		Branches diameter (cm)		Branches number/plant		Plant survival %	
Seasons	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
C_0	72.3a	80.0a	27.0a	26.3a	0.72a	0.0.81a	2.3a	2.6a	100a	100a
C_1	67.3a	72.6ab	26.3a	25.6a	0.63ab	0.78ab	2.0a	2.6a	100a	100a
C_2	67.3ab	67.0bc	17.6ab	21.3ab	0.61ab	0.63bc	2.0a	2.3a	100a	100a
C_3	54.6bc	60.6cd	7.3bc	10.6bc	0.55ab	0.51c	2.0a	2.0a	100a	100a
C_4	41.6c	50.3d	2.6c	3.3c	0.48b	0.46c	1.6a	1.6a	88b	88b
C_5	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0	0

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

The multiple range tests used by Duncan show no significant difference ($p \leq 0.05$) between mean values within columns with the same letter(s).

The findings revealed that the irrigation with saline water at 13.50 (C_5) dS/ m caused plant death at three months age, which show burning of the apical leaves then it died. This result is consistent with Hawker and Smith (1982), they found that for cassava irrigated with 50 and 75 mM NaCl experienced some burning of the apical leaves.

Plant height, number of leaves, branch diameter, and plant survival percentage significantly decreased when cassava plants were irrigated with saline water at a concentration of 2.04 (C2) dS/ m at four and five months, according to the results from both seasons. In contrast, the highest values of these assessed plant growth criteria were obtained using 0.98 (C1) and control (C0) dS/ m saline water (Tables 10 and 11).

Table 10. Impact of different irrigation water salinity on vegetative traits of cassava plants at four months age during 2022/2023 (S_1) and 2023/2024 (S_2)

Treatments saline water	Plant height (cm)		Leaves number / plant		Branches diameter (cm)		Branches number/plant		Plant survival %	
Seasons	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
C_0	89.6a	100.0a	25.0a	35.3a	0.81a	0.87ab	2.3a	2.3a	100a	100a
C_1	84.6a	89.3a	20.3ab	14.0ab	0.70a	0.82a	2.0a	2.3a	100a	100a
C_2	56.3b	66.3b	7.6ab	4.3b	0.46b	0.66bc	1.6a	2.0a	66b	66b
C_3	41.6c	55.0b	5.0b	2.3b	0.46b	0.55c	1.6a	1.6a	36c	36c
C_4	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0	0
C_5	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0	0

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

The multiple range tests used by Duncan show no significant difference ($p \leq 0.05$) between mean values within columns with the same letter(s).

Table 11. Impact of different irrigation water salinity on vegetative traits of cassava plants at five months age during 2022/2023 (S_1) and 2023/2024 (S_2).

Treatments saline water (dS/ m)	Plant height (cm)		Average leaves number/plant		Average branchs diameter (cm)		Average branchs number/plant		Plant survival %	
Seasons	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
C_0	106.3a	123.6a	31.6a	49.6a	0.94a	1.06a	2.0a	2.3a	100a	100a
C_1	102.3a	108.0a	24.6a	21.3b	0.86a	1.03a	2.0a	2.0a	88b	88b
C_2	49.3b	59.6b	1.6b	2.3c	0.50b	0.45b	1.3a	1.6a	66c	66c
C_3	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0	0
C_4	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0	0
C_5	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0	0

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

The multiple range tests used by Duncan show no significant difference ($p \leq 0.05$) between mean values within columns with the same letter(s).

Plant death was observed when cassava plants were irrigated with saline water at 8.82 (C4) dS/ m at four months of age. This was followed by irrigation with saline water at 3.33 (C3) dS/ m when the plants were five months old.

Moreover, no significant differences among the saline water irrigation levels were observed in case of branches number of cassava plants at four and five months age. Reduced vegetative growth is associated with increased salinity, which causes reduced loss of photosynthetic in leaf tissues (i.e., increased necrotic tissue).

When compared to saline water at 2.04 (C2) dS/ m with tap water (C0) and saline water at 0.98 (C1) dS/ m produced the highest ratings for plant height, leaves per plant, branch diameter and the highest survival percentage for six month old cassava plants in both seasons.

The data suggests it is evident that the number of branches in both seasons was unaffected by any saline water treatment. Furthermore, the findings showed that irrigated plants with 3.33 (C3), 8.82 (C4), and 13.50 (C5) dS/ m experienced reductions in all the examined parameters, including plant height, number of leaves, the number and diameter of branches, and cassava plant survival percentage, when compared to the control.

Table 12. Impact of different irrigation water salinity on vegetative characteristics of cassava plants at six months age, during 2022/2023 (S_1) and 2023/2024 (S_2).

Treatments saline water (dS/m)	Plant height (cm)		Leaves number / plant		Branches diameter (cm)		Branches number/ Plant		Plant survival %	
Seasons	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
C_0	119.6a	123.6a	33.3a	27.3a	0.96a	1.10a	2.0a	1.3a	100a	100a
C_1	115.0a	133.6a	21.ab	22.3ab	1.20a	1.23a	1.3a	1.0a	88a	88b
C_2	84.0b	91.0b	9.3b	20.3b	0.58b	0.81b	2.0a	2.0a	33b	66c
C_3	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0	0
C_4	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0	0
C_5	0.0	0.0	0.0	0.0	0.00	0.00	0.0	0.0	0	0

C_0= tap water, C_1=0.98, C_2=2.04, C_3=3.33, C_4=8.82 and C_5=13.50 dS/m

The multiple range tests used by Duncan show no significant difference ($p \leq 0.05$) between mean values within columns with the same letter(s).

The adverse impacts of salt stress on plant growth could be attributed to how salts affect the availability of water and uptake, which lowers the water content in plant tissues and changes internal metabolic functions. Moreover, higher salinity in irrigation water can affect closure of stomata and leaf water relationships, which in turn affect CO_2 transfer and photosynthesis rate, both directly and indirectly. Furthermore, plants may be directly harmed by elevated salt concentration in irrigation water, resulting in reduced plant accumulation of carbohydrates (Morales *et al.,* 2008 and Cruz *et al.,* 2017).

B-Initiative tuber roots components

At harvest time, no cassava plants remained on plastic bags that received high saline water treatments, except those irrigated with 0.98 (C_1) and 2.04 (C_2) dS/ m and control (C_0) treatments in both tested seasons. Therefore, the data in Table 13 demonstrate that salinity reduced every component of initiative tuber roots (as initiative tuber roots length, number, diameter and fresh weight per plant) compared with control (C_0) irrigation through both seasons. No significant decrease in the percentage of dry matter was observed during either season as a result of the presence of saline water.

When cassava tubers were irrigated with 40–60 mM NaCl, the weight of the tubers was reduced by half. (Cruz *et al.,* 2017). The similar results found by Abdelal (2010) on potato.

Concerning, the initiative tuber roots fresh weight an increase in saline water levels (0.98 and 2.04) resulted in a reduction in initiative tuber roots fresh weight by (12.9 and 36.4 %) and (18.7 and 40.6 %) in the first and second seasons, respectively, compared to the tap water.

Table 13. Impact of different irrigation water salinity on initiative tuber roots components of cassava plants, during 2022/2023 (S_1) and 2023/2024 (S_2)

Treatments saline water (dS/ m)	Initiative tuber roots length /plant (cm)		Initiative tuber roots number/plant		Initiative tuber roots diameter /plant (cm)		Initiative tuber roots fresh weight /plant (gm)		Dry matter %	
Seasons	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**	**S_1**	**S_2**
C_0	16.0a	14.6a	4.0a	5.6a	1.9a	1.5a	21.7a	19.2a	34.9a	34.2a
C_1	13.3b	12.0b	3.3ab	4.3ab	1.6ab	1.3b	18.9a	15.6b	33.2a	32.7a
C_2	11.6c	11.0b	3.0b	3.0b	1.3b	1.2b	13.8b	11.4c	31.8a	31.5a

C_0= tap water, C_1=0.98, C_2=2.04.

The multiple range tests used by Duncan show no significant difference ($p \leq 0.05$) between mean values within columns with the same letter(s).

In this study, the negative impact of increasing saline water levels on total yield can be attributed to the adverse effect of saline water irrigation on leaf area, total chlorophyll content, NPK proportions in leaves, branch numbers and tuber root setting that may result in decreased total yield.

C- **Chemical analysis of plants**

1. Chloride, potassium and sodium in cassava leaves

Data shown in Fig. (1) demonstrated that after five months of planting over the tested of two seasons, saline irrigation increased the amounts of sodium and chloride in cassava leaves.

In this concern, the highest saline level 2.04 dS/m not only contributes in accumulation of sodium and chloride in leaves but also leads to a significant reduction in potassium content. On the other hand, tap water and saline water at 0.98 dS/ m irrigation gave the lowest values in case of sodium and chloride leaves content compared to the 2.04 dS/ m treatment.

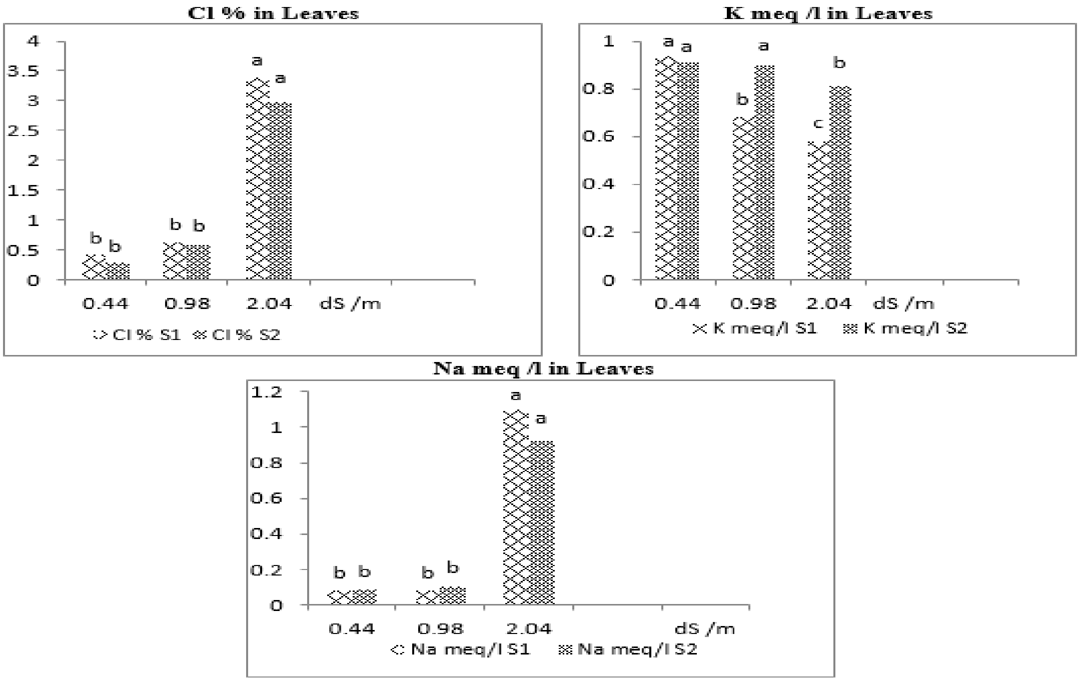


Fig. 1. Impact of different irrigation water salinity on chemical analysis of cassava leaves after five months from planting during 2022/2023 (S_1) and 2023/2024 (S_2).

The multiple range tests used by Duncan show no significant difference ($p \leq 0.05$) between mean values within columns with the same letter(s).

2. Chloride, potassium, and sodium in cassava initiative tuber roots

The effect of different water irrigation salinity on Cl and Na of cassava initiative tuber roots at harvest is shown in fig 2. In this regard, saline water at 2.04 dS/m increased the Cl and Na content of the tuber roots compared to other treatments in the first and second seasons. On the contrary, employing saline water at 2.04 dS/ m resulted in the lowest value of potassium concentration when compared to the other treatments across both seasons (Fig 2).

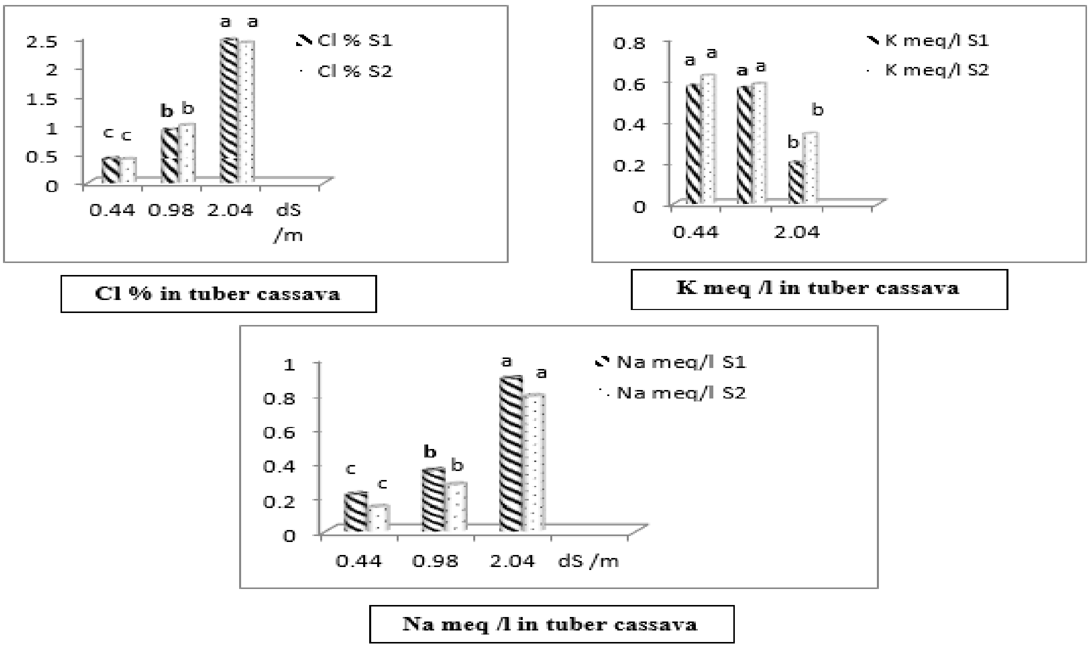


Fig. 2. Impact of different irrigation water salinity on chemical analysis of cassava initiative tuber root at harvest, during 2022/2023 (S_1) and 2023/2024 (S_2)

The multiple range tests used by Duncan show no significant difference ($p \leq 0.05$) between mean values within columns with the same letter(s).

Carretero *et al.* (2008) who worked on cassava found that salinity negatively affected mineral composition (mainly by accumulation of Cl and Na).

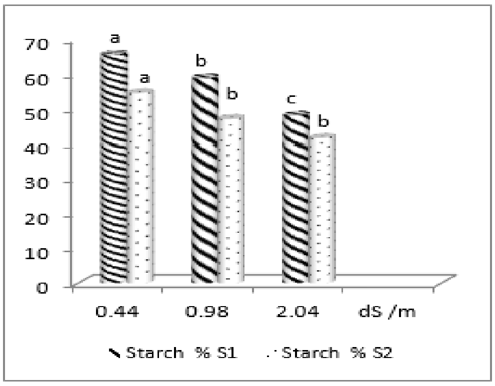
The rise in pH levels in the root zone caused by salinity may be the cause of the increase in Na+ percentage in vegetable leaves that results from increased saline water irrigation. This causes the plant to become less able to obtain K^+ and Ca^+, which in turn causes an accumulation of Na^+ inside the leaves (Mahdi and El-Katony, 2001).

Starch and Hydrocyanic acid in cassava initiative tuber roots

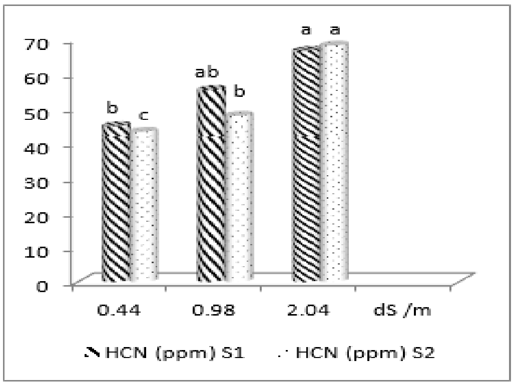
Result in Fig. 3 showed that using saline water at 2.04 dS/ m significantly gave the lowest value of starch percentage and the highest hydrocyanic acid concentration in cassava initiative tuber roots, during both seasons. In contrast, using tap water (0.44 dS/m) gave the highest value of starch percentage and recorded a lower value of hydrocyanic acid concentration in cassava initiative tuber roots in contrast to the other treatments during the two seasons.

Gleadow *et al.* (2016) stated that the HCN content in the cassava tubers increased with highest salt treatments (at 50 and 100 mM NaCl).

The reduction of starch accumulation in initiative tuber roots treated with the highest salinities may due to decrease in fermentable sugar percentage. Additionally, there is an increase in hydrocyanic acid concentration accumulation in initiative tuber roots at the highest salinities, which is attributed to new synthesis rather than breakdown of photosynthetic compounds. Form the data, this cultivar of cassava (Indonesian) showed an increase in hydrocyanic acid concentration with moderately salinity, but it does not reach toxic levels. So, it is classified as a sweet cultivar, because the value of hydrocyanic acid when estimated in plant falls within the permissible limit which is less than 100 ppm in dry matter (Hasan, 2018).



Starch %



HCN (ppm)

Fig. 3. Impact of different irrigation water salinity on Starch and Hydrocyanic acid of cassava initiative tuber root at harvest, during 2022/2023 (S_1) and 2023/2024 (S_2)

The multiple range tests used by Duncan show no significant difference ($p \leq 0.05$) between mean values within columns with the same letter(s).

CONCLUSION

From the findings of the experiment, it can be concluded that irrigation cassava plants with saline water is feasible up to a concentration of 2.04 dS/m, It is also possible to classify this cultivar of cassava as moderately tolerant to salinity and as a sweet cultivar.

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سلوك نمو نبات الكاسافا تحت ظروف الإجهاد الملحى

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الملخص

تم أجراء التجربة الحقلية بمزرعة شعبة بحوث الخضر – معهد بحوث البساتين – دقى - محافظة الجيزة – مصر خلال موسمى الزراعة 2023/2022 و 2024/2023 م فى تربة رملية تحت ظروف الإجهاد الملحى. الهدف من هذه الدراسة هو تحديد تأثير تركيزات مختلفة من الرى بالماء المالح على نمو نبات الكاسافا الصنف الأندونيسى، يشمل الرى بالماء الملحى (تخفيفات من مياة البحر) على خمس مستويات ملوحة (0.98 – 2.04 – 3.33 – 8.82 – 13.50 ديسمنز/م) بالاضافة الى معاملة الكنترول [ماء الصنبور(0.44 ديسمنز/ م)]، و كان تصميم التجربة فى قطاعات كاملة العشوائية لأربع مكررات. أشارت البيانات أن خصائص النمو الخضرى لنبات الكاسافا أنخفض مع زيادة الملوحة فى مياة الرى، لوحظ فى وقت الحصاد أنه لم يتبقى أى نبات كاسافا فى الأكياس البلاستيك التى رويت بالتركيزات العالية من الماء المالح ما عدا التى رويت بالماء المالح بالتركيزات المنخفضة وهى 0.98 و 2.04 ديسمنز/م و معاملة الكنترول فى الموسمين. أيضا لم تؤدى فقط المستويات العالية من الرى بالماء المالح تركيز 0.98 و2.04 ديسمتر/ م لتراكم عنصرى الصوديوم والكلور و حمض الهيدروسيانيك فى الأوراق الكاسافا عمر خمس شهور من الزراعة وفى درنات الحصاد ولكن أدت أيضا الى أنخفاض محتوى عنصر البوتاسيوم و نسبة النشا مقارنة بالكنترول فى الموسمين . إن تركيز الأملاح في مياه الري له تأثير كبير في بعض خصائص التربة وكان توزيع مؤشر الإنتاجية (PI) لفئات إنتاجية التربة متوسطًا، بناءً على القيم المحسوبة التي تم الحصول عليها.

الكلمات الداله: كاسافا – الرى بالمياه المالحية – نمو الكاسافا – بدائيات الجذور المتدرنه – النشا و حمض الهيدروسيانيك.