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ORIGINAL ARTICLE

Assessment of Cytotoxic Ions Sequestration as salt tolerant indicators in Tomato (*Solanum lycopersicum* L.)

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Abstract

This study determines the genetic diversity of 20landraces and released cultivars of tomato collected from Market places and research institutes in Nigeria. Ion homeostasis and cytotoxic sequestration significantly (P>0.05) affected by concentration of salt in a concentration dependent manner. Accumulation of Na+, Cl-, K+ and Ca2+ ions increased in salt treated groups (30 and 60 mg/L of NaCl) as compared to controls. Potassium ion uptake was salt concentration dependent in all cultivars; the magnitude of Na+/K+ levels is lower in released cultivars than in landraces cultivars. It can be concluded from these findings that Na+ was compartmentalized both in tomato by membrane transporters and that low level was a good indicator of salt tolerant in tomato genotype studied.

Keywords: Solanum lycopersicum, sequestration, genetic diversity, cytotoxics

1. Introduction

Tomato (*Solanum lycopersicum* L.) originated from South America, is nowadays one of the most economically important and widely grown plants in *Solanaceae* family. Soil salinity is one of the major factors of soil degradation and is recorded 19.5% of the irrigated land and 2.1% of the dry land agriculture existing on the globe (Jamil and Rha, 2006). Salinity is conspicuous in arid and semi-arid areas where 25% of the irrigated land is affected by salt (Lira *et al.*, 2014). Salinity inhibition of plant growth is the result of osmotic and ionic effect, and different plant species have developed different mechanisms to cope with those effects (Munns, 2002). Excess amount of salt in the soil adversely affects plant growth and development (Zhu, 2001). Several factors may contribute to reduction in growth exhibited by plant under salinity stress. Processes such as seed germination, seedling growth and vigour, vegetative growth, flowering and fruit set are adversely affected by high salt concentration ultimately causing diminishing economic yield and also quality of production (Sairam and Tygyi, 2004). Salinity also affects the diffusion both at stomata and the mesophyll (Dudly, 1992).

Morphology, anatomy, ultra-structure and metabolism of plant species are also deeply affected by salt (Prat, and Fathi- Ettai, 2013). Salinity impairs seed germination reduce nodules formation, retard plant development and reduce crop yield. These concentrations fluctuate because of change in water sources, drainage, evapotranspiration and solute availability (Shininger, 1997). Salinity affects plant through hyper osmotic effect, ion disequilibrium and oxidative stress. The homeostasis of intra cellular

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ion concentration is fundamental to the physiology of living cells. Proper regulation of ion flux is necessary for cell to keep the concentration of toxic ions low and to accumulate essential ions (Zhu, 2001). Plant cell employ primary active transport, mediated by H+ -ATPases, and secondary transport, mediated by channels and co transporters, to maintain characteristically high concentration of K+ and low concentration of Na+ in the cytosol.

2. Materials and methods

This study was conducted in the Biological Garden of Department of Biological Science Usmanu Danfodiyo University, Sokoto. Nigeria. The seeds of the selected landraces tomato cultivars were obtained from local markets around Sokoto and Zamfara metropolis and the released cultivars seeds were obtained from Zamfara State Agricultural Development Project, Gusau. A total of 20 genotypes of tomato grouped into landraces and released were used for the diversity analysis. The collection locality, type and common name of each cultivar are summarized in Table 1.

Tab. 1 Different tomato cultivars used and place of collection.

S/N	Accessions	Type	Collection locality
1.	Dan gainakawa	Landrace	Market
2.	Bahaushe	Landrace	Market
3.	Dandino	Landrace	Market
4.	Dan eka	Landrace	Market
5.	Dan Gombe	Landrace	Market
6.	Dan Mazari	Landrace	Market
7.	Dan Dubu kamiya	Landrace	Market
8.	Dan Kwandawa	Landrace	Market
9.	Ganwon Falke	Landrace	Market
10.	Dan Dogarawa	Landrace	Market
11.	Roma	Released	ZADP
12.	UTC	Released	ZADP
13.	Rio Grande	Released	ZADP
14.	Gianfranco F.	Released	ZADP
15.	UC 82B	Released	ZADP
16.	Indian Tomato	Released	ZADP
17.	Tomato Peto 86	Released	ZADP
18.	Tropimech	Released	ZADP
19.	Cherry	Released	ZADP
20.	Heiloom Tomato	Released	ZADP

Preparation of Plants Materials

The seeds of the twenty cultivars were surface sterilized by soaking in 5% sodium hypochlorite and then rinsed three times with distilled water. The seeds were first sown in nursery beds and uniformly germinated seedlings (2 weeks old) were selected and transferred to poly bags containing a mixture of river sand and organic manure in 3:1 ratio. NaCl was dissolve in irrigated water to make variant concentration of 30 and 60 mg/L of salt concentrations which was used to water the plants. The solutions were stored in air tight cans to prevent evaporation which can increase solution concentrations.

Elemental Analysis

For determination of sodium, potassium, calcium and chloride in leaf tissue, 1g of the plant leaves were prepared by grinding with distilled water (about 10 mL) at 25^0C for 10 min. The homogenate was centrifuged at 3000×g for 15 min, and the supernatant filtered through qualitative filter paper. An aliquot of filtrate was used for Na^+,$Ca^{2+}$and K^+ determination using flame photometry and Cl^- by precipitation titration with silver nitrate by Mohr's method .

3. Results and discussions

Elemental Analysis

Tab. 3 summarized the accumulation of ions (both cytotoxic and non cytotoxic) by different cultivars of tomato. The sodium ion (Na^+) of the 20 cultivars increased with the increasing concentration of NaCl. Controls recorded the least level of Na^+ and the highest levels were recorded in plants treated with 60 mg/L of NaCl. However, Dan Gainakawa and Dan dubukamiya recorded the highest level of Na^+ with 3200.0 respectively. The least level of Na^+ on plant treated with 60 mg/L of NaCl was recorded in Tropemech tomato and UC82B with 1323.67 and 1500.00 Na^+ respectively (Table 2). The result differ significantly ($P<0.05$). UC82B and UTC recorded the highest levels of K^+ with 8,700.00 followed by Roma with 8814.67. The least K^+ levels were recorded at plant treated with the highest concentration of NaCl (Table 2). Mean comparisons in some cultivars shows that differ ($P<0.05$) from the treated plant while in some did not differ significantly ($P> 0.05$).

Calcium (Ca^{2+}) and chlorine (Cl^-) content differs significantly ($P< 0.05$). The lowest content of Ca^{2+} was recorded in UC 82B with 0.56 at control. Highest value of 1.56 was observed at plants treated with 60 mg/L of NaCl (Table 2). The least chlorine content was observed at control and the levels increases with increase in the concentration of salt (Table 3).

4. Discussion

The amount of inorganic ions such as Na^+, K^+, Ca^{2+} and Cl^- increased with increasing salt concentrations except in K^+ increased at one time and decreased at higher salt concentration in order to sustain the osmotic potential and maintain water influx in the plant. High level of Na^+, Cl^-, and Ca^{2+} was recorded in all the plant treated with 60mg/L of NaCl and the low level of these ions was significantly ($P<0.05$) recorded in the controls of the entire plants respectively. In contrast, the highest concentration of K^+ content in all the plants was recorded at control followed by plants treated with 30mg/L of NaCl and the lowest is recoded in those treated with 60mg/L of NaCl. However, in some of the cultivars the lowest content of K^+ was recorded at plants treated with 30mg/L of NaCl. Under salt stress, Na^+ competes with K^+ for uptake in roots through common transport system effectively, since the Na^+ in saline environments is usually is usually considerably greater than K^+ (Rains, 1989; Maathius *et al*., 1992). These findings can be attributed to the competitive interactions between K^+ and Na^+ and the inhibition of K^+ uptake by high concentration of Na^+ as reported by Berntein, (1995). The maintenance of cytosolic of Na^+ concentration and Na^+/K^+ homeostasis is an important aspect of salinity tolerance and that salt tolerant lines shows lower Na^+/K^+ ratio levels (Chattopadhyay *et al*., 2002). Based on the Na^+/K^+ ratio observed in this study, the tomato cultivars studied could be classified as salt tolerant line.

Tab. 2 Effects of different salt concentration on ionic content ($mgKg^{-1}$) of 20 cultivars of tomato.

Accessions	Treatment (mg\L)	Na^+	K^+	Ca^{2+}	Cl^-
D. Gainakawa	0	233.64^a	$6,340.00^a$	0.65^a	32.96^a
	30	$2,400.00^b$	$6,200.00^a$	1.08^b	43.67^b
	60	$3,200.00^c$	6000.00^b	1.34^b	56.65^c
	LSD (0.05)	**122.45**	**149.75**	**0.26**	**3.00**
Bahaushe	0	242.00^a	$5,300.00^a$	0.76^a	25.56^a
	30	$1,500.43^b$	5000.97^b	1.26^a	43.85^b
	60	$2,600.00^c$	$6,700.00^c$	1.21^a	56.34^c
	LSD (0.05)	**150.00**	**229.74**	**0.59**	**4.65**
Dandino	0	300.45^a	$7,300.00^a$	1.20^a	27.53^a
	30	1400.00^b	$6,700.00^b$	1.30^{ab}	37.97^b
	60	2500.00^b	6500.00^b	1.56^b	54.43^c
	LSD (0.05)	**122.57**	**219.56**	**0.34**	**3.06**
Dan Eka	0	330.00^a	6500.00^a	0.98^a	28.76^a
	30	1300.00^b	6000.00^b	1.56^b	37.09^b
	60	2350.00^c	4900.00^c	1.59^b	39.07^b
	LSD (0.05)	**145.00**	**356.34**	**0.12**	**2.97**
Dan Gombe	0	300.00^a	$7,600.00^a$	0.65^a	23.98^a
	30	1450.00^b	$6,800.00^b$	1.26^b	45.54^b
	60	2000.00^c	$6,510.00^c$	1.25^b	47.56^b
	LSD (0.05)	**141.00**	**149.74**	**0.43**	**3.45**
Dan Mazari	0	304.80^a	$6,100.00^a$	0.68^a	6.94^a
	30	1480.07^b	$5,877.33^b$	0.98^a	48.02^b
	60	2713.67^c	$5,578.00^c$	1.19^b	49.24^c
	LSD (0.05)	**34.93**	**149.72**	**0.09**	**0.20**
Dan Dubu	0	310.60^a	$6,500.00^a$	0.78^a	34.00^a
	30	1587.98^b	$5,951.00^b$	1.23^a	47.00^b
	60	3200.00^c	$5,400.00^c$	1.34^b	56.35^c
	LSD (0.05)	**46.56**	**156.00**	**1.10**	**3.54**
D. Kwandawa	0	303.33^a	567.00^a	0.99^a	35.00^a
	30	1280.00^b	6678.00^b	1.05^a	48.00^b
	60	3100.00^c	4871.00^c	1.19^a	56.58^c
	LSD (0.05)	**49.00**	**149.45**	**1.27**	**1.34**
Ganwon Falke	0	350.81^a	367.00^a	0.89^a	27.00^a
	30	1310.00^b	345.56^a	0.99^a	37.75^b
	60	2600.00^c	320.00^a	1.03^a	42.85^c
	LSD (0.05)	**23.54**	**120.00**	**0.05**	**2.02**
Dogarawa	0	230.32^a	567.00^a	0.54^a	25.87^a
	30	1290.89^b	566.00^a	0.78^b	53.65^b
	60	2560.00^c	521.00^a	0.98^c	56.25^b
	LSD (0.05)	**37.43**	**249.74**	**0.10**	**3.05**
Roma	0	43.13^a	8814.67^a	0.68^a	32.30^a
	30	1389.30^b	6935.00^b	0.98^b	38.23^a
	60	1532.10^c	5184.33^c	1.19^c	55.27^a
	LSD (0.05)	**14.19**	**314.67**	**0.09**	**24.23**
UTC	0	37.32^a	$8,700.00^a$	1.04^a	32.00^a
	30	1230.00^b	$8,300.00^b$	1.30^a	36.00^a
	60	1321.00^c	$6,700.00^c$	1.26^a	38.00^a
	LSD (0.05)	**12.34**	**220.00**	**0.98**	**4.04**

Rio Grande	0	276.00^{a}	6500.00^{a}	0.65^{a}	34.98^{a}
	30	1600.00^{b}	6300.00^{a}	0.97^{a}	43.45^{b}
	60	2500.00^{c}	6100.00^{a}	1.43^{a}	54.23^{c}
	LSD (0.05)	**132.49**	**219.00**	**0.98**	**4.00**
Giofranco F.	0	213.00^{a}	5500.00^{a}	0.60^{a}	32.00^{a}
	30	1399.00^{b}	5100.00^{b}	0.98^{a}	42.00^{b}
	60	2520.00^{c}	4900.00^{c}	1.20^{a}	54.00^{c}
	LSD (0.05)	**159.00**	**236.00**	**0.76**	**2.45**
UC82B	0	220.00^{a}	$8,700.00^{a}$	0.56^{a}	31.00^{a}
	30	$1,340.00^{b}$	$7,400.00^{b}$	0.98^{b}	36.00^{b}
	60	1500.00^{c}	$7,300.00^{b}$	1.20^{c}	39.56^{b}
	LSD (0.05)	**122.49**	**256.67**	**0.12**	**3.01**
Indian tomato	0	209.00^{a}	6210.00^{a}	0.98^{a}	32.33^{a}
	30	1370.07^{b}	5138.00^{a}	1.05^{b}	54.24^{b}
	60	2413.34^{c}	4871.00^{b}	1.23^{c}	69.36^{c}
	LSD (0.05)	**39.13**	**149.72**	**0.10**	**0.30**
Tomato Peto	0	303.45^{a}	5120.00^{a}	0.64^{a}	37.00^{a}
	30	1230.45^{b}	4214.00^{b}	0.90^{a}	39.00^{a}
	60	1278.23^{b}	4012.00^{c}	0.98^{a}	43.12^{b}
	LSD (0.05)	**251.00**	**89.00**	**0.00**	**2.06**
Tropimech	0	300.67^{a}	6120.34^{a}	0.76^{a}	39.00^{a}
	30	1323.67^{b}	5670.00^{b}	1.05^{a}	43.00^{a}
	60	1453.65^{b}	5987.00^{c}	1.20^{a}	47.00^{b}
	LSD (0.05)	**271.98**	**123.98**	**0.50**	**4.98**
Cherry	0	45.00^{a}	7814.00^{a}	0.76^{a}	38.00^{a}
	30	1289.00^{b}	5234.00^{b}	0.45^{b}	39.89^{b}
	60	2004.56^{c}	4513.98^{c}	0.98^{c}	43.00^{c}
	LSD (0.05)	**14.68**	**143.56**	**0.04**	**1.06**
Heirloom	0	233.00^{a}	$6,750.00^{a}$	1.00^{a}	34.00^{a}
	30	1854.00^{b}	6000.00^{b}	0.98^{a}	37.00^{b}
	60	2456.00^{c}	5900.00^{b}	1.23^{a}	39.65^{b}
	LSD (0.05)	**155.32**	**275.00**	**0.50**	**2.07**

Values represent means of elemental analysis. Mean in a column with the same superscript are not significantly different at ($P<0.05$).

5. Conclusion

In conclusion, Na^{+} was sequestered plant tissue by active antiporters to minimize cytosolic toxicity and that the ratio of Na^{+} to K^{+} is a good indication of salt tolerant property due to competitive interactions of these ions.

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