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Effect of Soil Salinity on Physiological Traits of two Butternut Squash (*Cucurbita Moschata L. Mellonia*) Varieties in Mwea, Kenya

Nyambura M[1*], Gathaara M[1], Menge D[2], Wanjogu R[3]

Abstract

Kenyan soils are greatly affected by high salt levels which has caused a decline in crop yields. Eighty percent of Kenya's land is in ACZ V and VI that are prone to salinity. Farmers in these arid and semi-arid areas are adopting growth of non-staple food with butternut squash being one of them. Despite its economic potential, little research has been carried out on butternut squash and information on its physiological response to salinity is scarce. This study was therefore carried out to investigate the physiological response of Waltham butternut (Waltham) and Jupiter F1 hybrid (Jupiter) to salinity. The two butternut varieties were subjected to five NaCl concentrations i.e. 0, 25, 50, 75 and 100 mM resulting in ten treatments. These were arranged in a randomized complete block design with three replicates. A net plot was established from which the following data were recorded; transpiration rate, photosynthetic rate, stomatal conductance and chlorophyll concentration. The data were subjected to Analysis of variance (ANOVA) and means were separated using least significant difference (LSD) at 5 percent level. Transpiration rate, photosynthetic rate, stomatal conductance and chlorophyll concentration significantly decreased with an increase in salinity in Waltham and Jupiter. Adverse effects of salt were noted more on salinity level above 75 mMNaCl. However, the effects were low on Jupiter compared to Waltham implying it is more salt tolerant. Farmers in areas whose soils are saline are therefore recommended to adopt growing Jupiter F1 hybrid which showed tolerance to higher levels of salts and also maintain salinity levels below 75 mMNaCl to ensure maximum performance of the plants hence yield.

Keywords: Physiological parameters (Stomatal conductance; Chlorophyll concentration; Transpiration rates; Photosynthetic rates); Salinity; Butternut squash (Waltham, Jupiter)

Introduction

Soil salinity in ACZ V, and VI is a common problem globally among many other stresses [1]. Potential yield losses are estimated to be, 20% by salinity, 15% and 40% by low and high temperature respectively, 17% by drought and other factors by 8% [2]. Irrigated soils are prone to salinization [3]. Approximately 60 million ha are under over irrigation which causes solute salts to be transported to the top layers of the soil by the raised water table [4]. ACZ V, and VI cover 80% of Kenya's land where the problem of salinity is on the rise due to insufficient rainfall. Unless salinization is controlled, productive land area that is already becoming exhausted will be lost [4].

Several physiological processes in plants are disrupted by salinity resulting in a decrease in growth and yield. Minimal essential mineral nutrient uptake

Affiliation:

[1]Department of Plant Sciences, Kenyatta University, Nairobi, Kenya

[2]Kenya Agricultural and Livestock Research Organisation (KALRO), Kimbimbi, Kerugoya, Kenya

[3]National Irrigation Authority,Nairobi, Kenya

***Corresponding author:**
Mary Nyambura, Department of Plant Sciences, Kenyatta University, Nairobi, Kenya.

Email: marynyambura23@gmail.com

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and maximum absorption of soluble salts are characteristics of saline soils [5]. Salt limits nutrient uptake and water quality of plants and the normal plant metabolism. Stoeva et al. 2008 also noted that salinity causes stomatal closure hence reduction of intercellular carbon (iv) oxide concentration. Salt stress causes reduction in total leaf area due to decreased leaf turgor, degradation of the cell wall and photosynthetic rates [6].

Salinization often causes soil infertility thus identification of cultivars that can survive in these conditions is worth investigating [7]. Oba et al. [8] stated that in order to rehabilitate regions with salinity problems, cultivation of salt tolerant species especially species that can fix nitrogen would be advantageous. As there is no technological means that is economically viable to facilitate crop production under salinity stress, cultivation of species that are salt tolerant is a promising approach [7]. As such, alternative crops and plants that do well in moderate conditions of salinity need to be grown. Due to the growing importance of butternut squash farming in Kenya, this study was to examine the physiological response of two butternut squash (*Cucurbita moschata*) varieties namely, Waltham Butternut (Waltham) and Jupiter F1 hybrid (Jupiter) to salinity.

Materials and Methods

This field study was carried out at the Kenya Agricultural and Livestock Research Organization (KALRO) Centre, Kimbimbi (latitudes 00 1ʺ and 00 40ʺ South and longitudes 370 and 380 East (www.kpda.or.ke)) in Mwea East Sub County, Kirinyaga County which is in Agro Climatic Zone (ACZ) V. Two butternut varieties (Waltham butternut and Jupiter F1 hybrid) were subjected to 0, 25, 50, 75 and 100 mM NaCl. The experimental design was Randomized Complete Block Design (RCBD) with 3 replications resulting in 30 plots. Field work was carried out over two seasons, the dry seasons so as to avoid leaching out of the NaCl added in the soils during experimentation.

On clear sunny days, during the seedling stage, vegetative and reproductive stage, stomatal conductance, transpiration rate and photosynthetic rate measurements were taken on the surfaces of the uppermost leaves that were fully expanded. This was done using a steady-state porometer (LI-1600Lico Inc. Lincoln, NE, USA). To determine chlorophyll concentration, Leaf samples of the fifth leaf from shoot apex were obtained from which 0.4 g was weighed using an electronic weighing balance (Shimadzu TX4202L). 80% acetone (6ml) was used for soaking the leaves overnight. In the morning, a uv-spectrophotometer (Shimadzu UV 1800) was used to read the resulting extract at 664 nm and 647 nm. Total chlorophyll was calculated following Adelusi et al. equation: Total chlorophyll = 7.93 A664 +19.53 A647 (mg g-1 fresh weight) where A664= absorbence at 664 nm and A647= absorbence at 647 nm.

The data collected were subjected to Analysis of variance (ANOVA) whereby Statistical Analysis Software (SAS) was used. Means from ANOVA tests that were statistically significant were separated using least significant difference (LSD) at 5 percent level.

Results

Effect of soil salinity on stomatal conductance

The stomatal conductance of Waltham and Jupiter decreased significantly ($p \leq 0.05$) with an increase in NaCl concentration in all the growth stages in season one and two. However, there were no significant differences during the seedling stage for both Waltham and Jupiter and during the reproductive stage for Jupiter. Stomatal conductance was higher during the reproductive stage than during the seedling and the vegetative stage in both seasons (Table 1).

Table 1: Effect of different concentration of NaCl on Stomatal Conductance of Waltham and Jupiter.

Stomatal Conductance (mol/m²/s)							
		Seedling stage		Vegetative stage		Reproductive Stage	
Variety (a)	**NaCl Concentration (b)**	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
Waltham	0	46887.0a	10671.0a	66092.0a	35363.0a	90190.0a	68167.0a
	25	40770.0a	7485.7b	49009.0ab	2890.4b	81842.0ab	61087.0b
	50	32500.0a	6399.6c	39972.0ab	22379.0c	63005.0ab	53333.0c
	75	30503.0a	4948.4d	32793.0ab	16691.0d	53480.0bc	46610.0d
	100	29308.0a	4289.6d	28454.0b	8083.8e	31974.0c	36120.0e
Jupiter	0	79960.0a	32887.0a	80142.0a	81353.0a	100376.0a	75307.0a
	25	70173.0a	23779.0b	73505.0a	61414.0b	88323.0a	62493.0b
	50	56373.0a	19553.0c	61918.0ab	43513.0c	69386.0a	44803.0c
	75	53427.0a	12275.0d	39921.0b	38829.0d	63221.0a	37197.0d
	100	51110.0a	2775.1e	37263.0b	25357.0e	52250.0a	26830.0e
NaCl Concentration (b)		0.2014	<.0001	0.6674	<.0001	0.7973	<.0001
variety (a)		0.307	<.0001	0.5499	<.0001	0.7125	0.0019
a × b		0.3262	<.0001	0.3041	<.0001	0.7973	<.0001

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Effect of soil salinity on total chlorophyll, transpiration rates and photosynthetic rates

As the soil salinity increased, there were significant ($p \leq 0.05$) decreases in total chlorophyll, transpiration rates and photosynthetic rates among the NaCl treatments in season one and two (Table 2).

Table 2: NaCl treatments in season one and two.

Total chlorophyll (mg/g fresh weight)				Transpiration rate (mol/m²/s)		Photosynthetic rate (μmol/m²/s)	
Variety (a)	NaCl Concentration (b)	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Waltham	0	2237.1a	16667.0a	1581.1a	1959.5a	3249.7a	3641.6a
	25	1514.2b	7955.6ab	1344.7ab	1688.9b	2016.3b	2835.1b
	50	825.8c	1248.1b	839.6b	1235.7c	1685.5bc	1909.6c
	75	572.5cd	1011.2b	813.8b	842.4d	1415.9bc	1626.8d
	100	435.7d	701.9b	780.7b	613.8d	1205.7c	1385.1e
Jupiter	0	4031.4a	4509.4a	2470.5a	2549.4a	3384.2a	3759.6a
	25	3513.9b	3994.6b	1845.3b	1894.6b	2388.3b	3119.6b
	50	2908.6c	3043.6c	1518.2b	1589.1c	1922.1b	2373.6c
	75	1772.5d	2407.0d	1309.2b	1430.2d	1283.5c	1988.8d
	100	1539.3d	1767.5e	1035.6b	1040.3e	976.1c	1388.9e
NaCl Concentration (b)		0.5827	0.0264	0.5236	<.0001	<.0001	<.0001
variety (a)		0.4184	0.2242	0.8827	<.0001	0.3411	<.0001
a × b		0.3942	0.1386	0.9764	0.0216	0.1251	0.015

Discussion

Impact of salinity on stomatal conductance

Reduction in stomatal conductance of Waltham and Jupiter butternut varieties observed can be associated with stomatal closure due to reduced root mass which may have resulted in low water uptake. This collaborated with Steduto et al. [9] who noted that low water uptake results in reduced leaf turgor hence stomatal closure which greatly affects the transpiration and photosynthetic rates. The observed decline on stomatal conductance could be a responsive mechanism to counteract the high salts levels by accumulating less toxic ions via the transpiration stream as a result of low water uptake. Decreased stomatal conductance is a response mechanism to counteract high salts levels. Similar responses were reported by Dadkhah [10] who observed substantially lower rates of stomatal conductance in two sugar beet cultivars with high salt levels. Amirul et al. [11] did a study using purslane accessions and noted a significant decline in stomatal conductance in high salt levels.

Impact of salinity on total chlorophyll

The observed decrease in total chlorophyll concentration as sodium chloride levels rose can be attributed to reduction in minerals uptake like magnesium needed for chlorophyll biosynthesis as a result of reduced osmotic potential and reduced root mass. Reduced mineral uptake leads to slow synthesis of chlorophyll hence a decrease in total chlorophyll concentration [12]. High NaCl concentration may lead to fast breakdown of chlorophyll or its slow synthesis resulting in a decrease in chlorophyll concentration [12]. Reduced chlorophyll concentration under high salt levels can be due to destruction of chlorophyll pigments by sodium and chloride ions. Under salinity stress, decrease in chlorophyll concentration is common in salt- sensitive plants due to salt toxicity which leads to scorching of leaves and other succulent parts [12]. The higher total chlorophyll concentration observed in Jupiter compared to Waltham implies it is more tolerant to high salt levels. These results corresponded to Taffouo et al. [13] who noted a decline in chlorophyll concentration among tropical cucurbit species (*C. lanatus, C. moschata and L. siceraria*) under salt stress. A significant decline in total chlorophyll in *Pistacia vera L.* rootstocks by moderate and high salinity treatments was also noted by Zahra et al. [14].

Impact of salinity on transpiration rates of Waltham and Jupiter

The low transpiration rates observed in Waltham and Jupiter butternut varieties could be caused by low osmotic potential due to high NaCl concentration making water to be less available. The decrease can also be due to the reduction in root mass as salinity level increased, reducing the uptake of water and therefore reduced transpiration rates. The decline may also be as a result of decreased number of leaves and the leaf area as salinity level increased. This could be associated

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with reduction of the leaf surface area exposure hence low transpiration. Decreased transpiration rates under salinity stress may be due to low absorption of water [15].

Lower root hydraulic conductivity causes the leaf water content to decrease leading to the closure of the stomata hence a decrease in transpiration [15]. Similarly, Hatamnia et al. [16] noted low transpiration rates on tobacco (Nicotiana tabacum) cultivars under 200 mMNaCl. Jamil and Rha [17] also reported decreased transpiration rates in mustard (Brassica) under high salt levels.

Impact of salinity on photosynthetic rates of Waltham and Jupiter

Both Waltham and Jupiter butternut varieties recorded a decline in photosynthetic rate which could be attributed to stomatal and non-stomatal factors. At high salt levels, Waltham and Jupiter exhibited reduction in chlorophyll and stomatal conductance which in turn may have reduced the photosynthetic rates. Decreased stomatal conductance leads to stomatal closure reducing carbon (iv) oxide uptake which is a raw material for photosynthesis [10]. The observed decrease in photosynthetic rate in Waltham and Jupiter could also be due to less water uptake caused by high salt levels as a result of reduced osmotic potential and root mass. Water is a raw material of photosynthesis. Therefore, if it is inadequate, the rate of photosynthesis decreases. The results obtained in this study correspond with those of Dadkhah [10] who reported low rates of net photosynthesis in two Sugar beet (*Beta vulgaris L.*) varieties with increasing salt levels. Amirul et al. [11] also noted a decrease photosynthetic activities in Purslane (*Portulaca oleracea L.*) accessions under high salinity levels.

Conclusions

From the results obtained in this study, Salinity level above 75 mMNaCl had adverse effects on selected physiological parameters of the two butternut varieties. The effect of salt was however less adverse on selected physiological parameters of Jupiter hence it is more salt tolerant compared to Waltham. Farmers in areas whose soils are saline are therefore recommended to adopt growing Jupiter F1 hybrid which showed tolerance at higher levels of salts and also maintain salinity levels below 75 mM NaCl to ensure maximum performance of the plants hence yield.

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