Research Article

Impact of Soil Salinity on Growth of two Butternut Squash (*Cucurbita Moschata l. Mellonia*) Varieties in Mwea, Kenya

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Abstract

Eighty percent of Kenya is covered by the Arid and Semi-Arid Lands (ASAL) which is prone to salinity as aridity exacerbates salinity. Farmers in these semi-arid areas have adopted growth of non-staple food. Butternut squash is widely cultivated as it requires minimal rainfall and very little labor. Despite its potential, little research has been carried out specifically on growth response to salinity. This study was carried out to determine the effects of salinity on growth of Waltham butternut (Waltham) and Jupiter F1 hybrid (Jupiter) which are among the common varieties grown by farmers in Kenya. The two 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; germination percentage, plant height, leaf number, leaf area and plant girth. The data were subjected to Analysis of variance (ANOVA) and means were separated using Least Significant Difference (LSD) at 5 percent level. Salinity significantly reduced germination percentage, leaf number, leaf area, plant height/length and plant girth of Waltham and Jupiter. The depressive effect of salt was less marked on growth parameters of Jupiter implying it is more salt tolerant compared to Waltham. Jupiter is therefore recommended for cultivation in environments where salinity is endemic. Further studies should be done on this variety as a source of genes for salt tolerance that could be exploited in future breeding programs.

Keywords: Randomized complete block design; Salinity; ANOVA; Butternut squash (Waltham, Jupiter)

1. Introduction

Soil salinity is a major global concern owing to its adverse impacts on agricultural productivity and sustainability [1]. Under all climatic conditions, salinity occurs as a result of both natural and anthropogenic actions [1]. In arid and semi-arid regions, saline soils occur as rainfall is insufficient to leach mineral salts from the soil profile [2]. Kenya occupies a total land area of 582,646 sq. km, an approximate of 60 million ha, in which 80% is covered by the Arid and Semi-Arid Lands (ASAL) [3]. ASAL occur in Agro-Climatic Zones (ACZ) V, described as semi-arid, VI described as arid and VII described as very arid [3]. Nearly half of the country is covered by the ACZ VII [3]. Several physiological processes in plants are perturbed by high salt concentrations leading to a reduction in plant growth and development [4]. A higher concentration of salts in the soil makes it hard for plants to absorb water leading to ion toxicity and nutrient imbalances and deficiencies [5]. The use of mineral fertilizers like Diammonium Phosphate (DAP) and Calcium Ammonium Nitrate (CAN) has been proposed by some agronomists like Taffouo et al. [4] with an aim of overcoming the adverse effects of salinity on yield. The degree of salinity of soils however, largely influences the success of the use of mineral fertilizers [5]. One of the possible ways to address this constraint is to identify plant species which are capable of growing and developing in saline medium [5]. *Cucurbita moschata L. Mellonia* belongs to Curcubitaceae family [5]. It originated from Mexico [6] and is now widely cultivated in the world. It is rich in vitamins A, C and E, minerals including K, Mn and Mg and sugars (https://www.selinawamucii.com).

Butternut squash has a ready market and a high nutritional value. It is drought tolerant and requires little care and labor. Although studies on salinity in plants have long been carried out, little research on the effects of salinity on growth of butternut has been reported. This study therefore aimed at evaluating the effects of salinity on the growth of two butternut squash (*Cucurbita moschata*) varieties namely, Waltham butternut (Waltham) and Jupiter F1 hybrid (Jupiter).

2. Materials and Methods

This field study was carried out at the Kenya Agricultural and Livestock Research Organization (KALRO) Centre, Kimbimbi (latitudes 0°1‟ and 00

4°0‘‘ South and longitudes 37° and 38° 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. August to October 2020 (Season one) and mid-January to mid-March 2021 (Season two). The two seasons were chosen because they are the dry seasons so as to avoid leaching out of the NaCl added in the soils during experimentation.

The number of seedlings that germinated per plot was counted and recorded after which germination percentage was calculated. Leaves on the stem and the branches were counted immediately the first foliage leaf appeared until the end of the experiment so as to account for all leaves. Leaf area was calculated following Otusanya et al. [7] formula: $LA=0.5(L1 \times W1)$, where LA is the leaf area, L1 the length of the leaf and W1 the maximum width of the leaf. Plant height at seedling stage (plants were erect) and plant length (plants were decumbent) at vegetative stage and after harvesting was measured using a meter rule from the base of the stem, just above the soil surface, to its apex. Plant girth was measured with a vernier caliper and recorded in millimeters.

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.

3. Results

A comparison of the germination response to lower levels (0, 25, 50 mM NaCl) and higher levels (75, 100 mM NaCl) of NaCl concentration in the soil indicated a significant ($p \leq 0.05$) decrease in germination percentage in Waltham and Jupiter with increasing NaCl concentration in the two seasons (Table 1).

Germination Percentage			
Variety (a)	**NaCl Concentration (b)**	**Season 1**	**Season 2**
Waltham	0	83.3a	89.6a
	25	79.2a	83.4ab
	50	77.1a	81.3ab
	75	66.7ab	75.5bc
		54.2b	64.6c
Jupiter	0	100.0a	100.0a
	25	95.9ab	97.4ab
	50	91.7b	95.8ab
	75	89.6bc	87.5ab

	100	83.4c	85.4b
NaCl concentration (b)		0.1121	0.0022
variety (a)		<.0001	<.0001
a × b		0.187	0.7967

Table 1: Effect of different concentration of NaCl on germination percentage of Waltham and Jupiter.

3.1. Effect of soil salinity on the number of leaves per plant

In season one, the number of leaves decreased significantly ($p \leq 0.05$) with an increase in NaCl concentration during the seedling and vegetative stages and after harvesting for Waltham, however, there were no significant differences during the reproductive stage (Table 2). In season two, there were significant differences in leaf number among NaCl concentrations in all the growth stages for both Waltham and Jupiter. The significant ($p \leq 0.05$) decrease in the number of leaves was observed with an increase in NaCl concentration (Table 2).

Number of leaves									
		Seedling stage		**Vegetative stage**		**Reproductive stage**		**After Harvesting**	
Variety (a)	**NaCl Concentration (b)**	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
Waltham	0	4.3a	4.0a	23.7a	7.0a	36.0a	23.3a	31.7a	38.0a
	25	4.0ab	3.7ab	21.7ab	6.7ab	35.3a	20.0ab	28.0ab	33.3b
	50	3.7ab	3.3abc	14.0ab	5.7ab	27.3a	17.3b	15.7ab	30.7b
	75	3.3ab	3.0bc	11.7ab	5.0bc	22.0a	12.0c	13.3ab	26.0c
	100	3.0b	2.7c	10.7b	4.7c	17.7a	11.3c	12.3b	20.0d
Jupiter	0	5.0a	5.3a	33.0a	12.8a	40.0a	34.3a	40.3a	40.0a
	25	4.7a	4.7ab	32.3a	11.0ab	37.3ab	32.3a	33.3a	37.7ab
	50	4.0a	4.3ab	26.7ab	8.8bc	31.3bc	26.7b	25.6a	35.3b
	75	4.0a	4.0ab	24.3ab	7.0c	29.3c	22.3c	20.7a	32.0c
	100	3.3a	3.7b	19.3b	6.3c	25.7c	19.0c	17.7a	28.0d
NaCl concentration (b)		0.3437	0.0043	0.0283	<.0001	<.0001	<.0001	0.0437	<.0001
variety (a)		0.0041	0.0001	<.0001	<.0001	<.0001	<.0001	0.0242	<.0001
a × b		0.5663	0.9841	0.1426	0.0903	0.6431	0.3604	0.3108	0.1638

Table 2: Effects of different NaCl concentrations on the number of leaves of Waltham and Jupiter.

3.2. Effect of soil salinity on the leaf area

In season one, a comparison of the lower levels (0, 25 mM NaCl) and the higher levels (50, 75,100 mM NaCl) of response to salinity indicated a significant ($p \leq 0.05$) decrease in the area of the leaf during the vegetative stage, reproductive stage and after harvesting for both Waltham and Jupiter. However, there were no significant differences during the seedling stage (Table 3). In season two, there was a significant ($p \leq 0.05$) decrease in the leaf area with increasing NaCl concentration during the seedling, vegetative and reproductive stages and after harvesting for both Waltham and Jupiter (Table 3).

Leaf Area									
		Seedling stage		Vegetative stage		Reproductive stage		After harvesting	
Variety (a)	NaCl Concentration (b)	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Waltham	0	17.8a	20.8a	61.1a	94.1a	197.0a	203.0a	175.7a	192.0a
	25	15.1a	12.9b	52.2ab	76.3b	188.2a	194.2b	157.8a	166.1b
	50	12.4a	10.2c	48.0ab	57.8c	116.6b	169.1c	104.1b	129.6c
	75	8.0a	9.3c	18.3b	42.7d	81.3b	115.1d	89.4b	99.2d
	100	7.2a	5.6d	15.6b	27.1e	73.6b	98.4e	75.5b	84.6d
Jupiter	0	52.5a	62.5a	145.8a	172.4a	265.4a	257.8a	228.9a	250.9a
	25	50.3a	51.1b	132.5a	158.4a	231.4a	233.3b	196.7ab	206.1b
	50	38.7a	42.4c	93.0ab	127.5b	177.0bc	194.7c	143.7bc	184.6b
	75	35.5a	32.9d	74.2ab	103.6b	167.2bc	161.4d	127.1bc	156.5c
	100	22.7a	19.6e	42.7b	64.1c	143.7c	124.8e	101.0c	129.0d
NaCl concentration (b)		0.0241	<.0001	0.0785	<.0001	<.0001	<.0001	0.0003	<.0001
variety (a)		<.0001	<.0001	0.0009	<.0001	<.0001	<.0001	0.0005	<.0001
a × b		0.3263	<.0001	0.9203	0.0155	0.6251	0.0052	0.8578	0.5897

Table 3: Effects of different NaCl concentrations on the area of the leaf (cm^2) of Waltham and Jupiter.

3.3. Effect of soil salinity on plant height/length

There were significant ($p \leq 0.05$) decreases in plant height at seedling stage and length at vegetative stage and after harvesting among the NaCl treatments compared to the control. However, plant height and length reductions were not significantly different during the seedling and the vegetative stage for Waltham and the seedling stage for Jupiter in season one (Table 4). Significant decreases ($p \leq 0.05$) in plant height and length in Waltham and Jupiter were observed during the seedling and vegetative stages and after harvesting in season two. The reductions were observed with increasing NaCl concentrations (Table 4).

Plant Height at Seedling Stage and Length at Mature Stages							
		Seedling stage		Vegetative stage		After harvesting	
Variety (a)	**NaCl Concentration (b)**	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
Waltham	0	5.4a	6.4a	5.7a	9.5a	215.3a	196.9a
	25	3.8a	5.6b	5.0a	8.1b	154.7b	177.2b
	50	3.6a	4.5c	4.9a	7.3c	117.7bc	154.8c
	75	3.2a	3.8d	4.5a	6.6d	94.3c	121.9d
	100	3.2a	3.2e	4.4a	5.6e	84.0c	100.5e
Jupiter	0	5.3a	6.3a	7.1a	9.4a	124.2a	165.0a
	25	5.1a	5.4b	6.0ab	8.0b	112.7ab	146.5b
	50	4.5a	4.8c	5.6ab	7.0c	85.2ab	129.8c
	75	4.0a	3.6d	5.5ab	6.0d	80.2ab	106.0d
	100	3.8a	3.1e	4.0b	5.2e	73.2b	88.7e
NaCl concentration (b)		0.711	<.0001	0.1119	<.0001	<.0001	<.0001
variety (a)		0.1825	0.484	0.1096	0.0045	<.0001	<.0001
a × b		0.4083	0.3261	0.4309	0.3096	0.0035	0.0247

Table 4: Effect of different NaCl concentrations on the plant height/length (mm) of Waltham and Jupiter.

3.4. Effect of salinity on Plant girth

In season one, there were significant ($p \leq 0.05$) differences in plant girth reductions among the NaCl treatments compared to the control except during the seedling stage for Jupiter and after harvesting for Waltham. The decrease occurred with an increase in NaCl concentration (Table 5). In season two, significant ($p \leq 0.05$) differences in plant girth reductions among the NaCl treatments compared to the control were observed with increasing NaCl concentration in Waltham and Jupiter in all the growth stages (Table 5).

Plant Girth							
		Vegetative stage		Reproductive stage		After harvesting	
Variety (a)	**NaCl Concentration (b)**	**Season 1**	**Season 2**	**Season 1**	**Season 2**	**Season 1**	**Season 2**
Waltham	0	8.2a	9.2a	9.6a	10.1a	13.4a	14.3a
	25	8.0a	8.2b	9.5ab	9.3b	11.1a	13.1b
	50	6.0ab	7.1c	8.5ab	8.8c	10.8a	12.4c
	75	5.2b	5.4d	7.1ab	7.4d	10.3a	10.6d
	100	5.0b	5.0e	6.5b	7.0e	8.9a	9.9e

Jupiter	0	10.6a	11.6a	12.1a	12.3a	12.8a	14.9a
	25	10.5a	10.2b	11.2ab	11.0b	12.5a	14.7b
	50	9.5a	9.7c	11.0ab	10.6c	11.4ab	14.2c
	75	8.3a	8.1d	10.0ab	9.5b	10.4ab	12.6d
	100	7.3a	6.2e	8.4b	7.2e	9.0b	9.3e
Nacl Concentration (b)		0.0003	<.0001	0.0032	<.0001	0.3871	<.0001
variety (a)		<.0001	<.0001	0.0009	<.0001	0.3623	<.0001
a × b		0.8888	0.0715	0.9119	0.0022	0.3468	0.0012

Table 5: Effects of different NaCl concentrations on plant girth (mm) of Waltham and Jupiter.

4. Discussion

The observed decrease in the germination percentage of Waltham and Jupiter butternut varieties in NaCl concentration higher than 50 mM NaCl may be as a result of decreased water uptake. Decreased water uptake could be attributed to a decrease in osmotic potential due to a high concentrated medium and reduced root mass at higher levels of salinity. Water is necessary for mobilization of nutrients that enhances germination [8], activation of stored food required for emergence hence a longer period for breakdown of seed dormancy causing a delayed germination [9]. The observed decrease in germination could also be as a result of the sodium and chloride ions being toxic to the developing embryo following germination [8]. A high level of salinity in the soil solution leads to osmotic and specific toxicity which causes reduction of germination percentages [8]. Jupiter had a higher germination percentage compared to Waltham and this can be attributed to more roots mass hence more water uptake. The results of this study correspond with Rahman et al. [10] who reported, reduction in germination percentage in beans (*Phaseolus vulgaris*) is directly proportional to the concentration of salt in the soil. The results were also in agreement with those of Rajeev et al. [11] which showed that, reduced percentage of germination in wheat (*Triticum*), could be due to an increase in the soil osmotic pressure as a result of highly concentrated soil solution. Similar results were also reported by Shirazi [12], Lallu and Dixit [13] in mustard (*Brassica*) and Bera et al. [14] in chickpea (*Cicer arietinum*).

Effect of salinity on the number of leaves per plant

Reduction in the number of leaves observed in Waltham and Jupiter butternut varieties can be an avoidance mechanism to minimize the loss of water via transpiration. The reduction can be attributed to the decrease in leaf area which reduced the evaporation surface hence minimizing water loss and reduction in cell turgor due to decreased water uptake. The decrease in leaf number could also be due to leaf abscission caused by high NaCl concentration accumulating in the leaves which later fall to excrete the excess NaCl. Waltham had fewer leaves than Jupiter in all the treatments indicating that, Jupiter had a greater ability to continue leaf formation with an increase in NaCl concentration.

High salinity stress inhibits the formation of leaf primordia hence fewer number of leaves [15]. Sodium chloride accumulation in the cytoplasm and cell walls of older leaves results to less number of leaves [16]. Similar responses were observed by Jamil et al. [17] who reported a significant decrease in the number of leaves per plant in all mustard species (*Brassica)* with varying levels of NaCl and Li et al. [18] and Sharifi et al. [19] who reported a significant decrease in the number of leaves with increasing soil salinity.

Effect of salinity on the leaf area of Waltham and Jupiter

The significant decrease in the leaf area of Waltham and Jupiter butternut varieties observed may be attributed to the decrease in water uptake due to a highly concentrated medium and less root mass hence less leaf turgor. Reduced leaf turgor leads to reduction in extensibility of expanding cell walls [20]. Reduced leaf area is related to low osmotic potential and toxic effects caused by accumulation of ions on tissues of plants [21]. Reduced leaf area could be an adaptation to reduce ion uptake by roots [22]. The results of this study are in agreement with those of Meena et al. [23] who observed a significant decrease in the area of the leaf with increasing soil salinity, Grieve et al. [24] who stated that leaf area decreases consistently and significantly as salinity increases and Musyimi et al. [25] who reported reduction in leaf area of *Solanum scabrum* as a result of toxicity of NaCl ions and decreased uptake of water.

Effect of salinity on plant height/length of Waltham and Jupiter

Reduction in plant height and length observed in this study could be attributed to low water uptake due to reduced root mass and osmotic potential of soil solution as well as unbalanced uptake of nutrients by the plants due to the high concentration of sodium and chloride ions in the soil solution. Low water uptake reduced the turgidity of the cells. Salinity inhibits growth of the roots leading to minimal water uptake and mineral nutrients uptake from the soil [26]. Shoot and root length of Waltham and Jupiter are important parameters. Their lengths can provide information on the response of both varieties to salt stress. The results of this study are in agreement with those of Bernardo et al. [27] and Prakash et al. [28] who reported that there is significant reduction in plant height with increasing salinity-induced stress in *Vigna unguiculata* (cowpea) cultivars. Similar observations were also reported by Jamil and Rha [26] that salinity significantly reduces root and shoot length in sugar beet (*Beta vulgaris*) and cabbage (*Brassica oleracea*).

Effect of salinity on plant girth of Waltham and Jupiter

The observed decrease in plant girth of Waltham and Jupiter butternut varieties with increasing NaCl concentration can be attributed to low osmotic potential of the soil solution leading to reduction in cell division and cell turgor. High NaCl concentration reduces the osmotic potential of the soil solution hence less water uptake and cell turgor [25]. The results of this study were in agreement with those of Khalid et al. [29] who reported that plant thickening of *Acacia ampliceps* is suppressed with combined soil salinity and sodicity stress. The results also corresponded with those Musyimi et al. (25) who reported that increase in salinity significantly reduced the stem diameter of African nightshades (*Solanum Scabrum Mill.*). Reduction in plant girth under salinity stress was also reported by Kaya et al. [30] and Ramoliya et al. [31] in sunflower (*Helianthus annus L*) genotypes.

Conclusion

From the results obtained in this study, Waltham and Jupiter butternut varieties are sensitive to high salinity stress above 75 mM NaCl and therefore to achieve high growth rate of the two, relatively low to moderate salinity must be maintained. The depressive effect of salt was less marked on growth parameters of Jupiter and thus it can be identified as the more salt tolerant variety compared to Waltham. Jupiter is therefore recommended for cultivation in environments where salinity problems are endemic. Further studies should be done on Jupiter variety as a source of genes for salt tolerance that could be exploited in future breeding programs.

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