

# The Effect of Salt Concentration on Growth and Yield of Two Forage Sorghum (*Sorghum bicolor* (L.) Moench) Lines

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**Abstract:** A nursery experiment was conducted during the summer of 2007 at the nursery of the Faculty of Agriculture, University of Khartoum, latitude 15° 40' and longitude 32° 32', to investigate the effect of salt concentration on growth and yield of two lines of forage sorghum. The salt levels were: the control that no salt was added to the tap water, adding 40 gramme of NaCl to a liter of tap water to give an electric conductivity (E. C.) of 6 dsm<sup>-1</sup>, adding 50 gramme of NaCl to a liter of tap water to give E. C. of 8 dsm<sup>-1</sup> and adding 60 gramme of NaCl to a liter of tap water to give E. C. of 10 dsm<sup>-1</sup>. The two lines of sorghum were R5 and KHS. The treatments were randomly assigned in a Factorial experiment as completely randomized design with ten replications. The growth parameters that were measured included: stem diameter (mm), average relative growth rate (ARGR), and average relative leaf area rate (ARLAR), dry weight per plant, in addition to the percentage of some elements. The effect of the treatments on stem diameter was significant regarding the two selected genotypes only at 37 and 48 days after sowing, while there was no significant difference between salt levels and the interaction at all sampling occasions. On the other hand, the effect of the treatments on ash, Na<sup>+</sup> and P was not significant, but the effect of the genotypes and the interaction on K<sup>+</sup> was significant. Average relative growth rate increased with plant age, and KHS line was superior to R5. Average relative leaf area rate decreased at the end of crop life and R5 genotype obtained higher ARLAR that was 3.7 than KHS, which were 3.4 with the overall mean 3.5.

**Keywords:** Salinity, Forage Sorghum, Biological Harvest of Salts

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## 1. Introduction

Salinity and sodicity problems in agriculture have an ancient history, and presently have become a very cumbersome problem in agricultural and farming activities. These problems are especially of great concern for countries that their economies rely to a great extent on agriculture, and according to the Food and Agricultural Organization (FAO) of the United Nations, total salt-affected area of the world has been estimated to be over 800 million ha, 80.5 million ha in Africa (Pessarakli and Szabolcs, 2011). It is estimated that 20% of all cultivated land and nearly half of irrigated land is salt-affected, greatly reducing yield well below the genetic potential (Jenks and Hasegawa, 2005).

Salinity problems are of common occurrence in many parts of Sudan and resulted in substantial yield reductions. Ahmed

and Ahmed (2007) recorded that the information on the subject has developed appreciably in recent years, and the problem essentially lies in our inability to predict the rate of plants stress and its effect on high levels of plant organization from the physiological perturbations caused by salinity. The stressed environment developed in saline soils is mediated by a toxic concentration of salts (commonly NaCl), combined with an osmotic stress incited by the soil solution. Sobhanian *et al.*, (2009) stated that salt stress will be very important to identify strategies for improving the resistance of plants to salt stress so as to enable the tolerance of crops to salt stress to be increased through the use of genetic engineering technologies. However, salt stress causes a water deficit, ion toxicity, and nutrient deficiencies, and these effects decrease the growth and yields of plants and in extreme cases can lead to plant death. As Owens (2001) illustrated, the excess salinity in soil has devastating effects plant growth, reducing

crop yield worldwide and even leading to complete crop failure in the worst-affected areas.

Using some forage crops to harvest salts biologically from the affected soils resulted in more palatable forages. It could be considered a cheap as well as friendly environment method compare to other soil treatments. Abuswar and Abbaker (2009) mentioned that the utilization of halophytic plants in pastures and fodder production in saline soil is the only economic solution presently available. Some halophytes not only tolerate high levels of salinity but reach the optimal level of growth under saline conditions. However, selecting the perfect and suitable crop is a key function in such cases of stress. Therefore, the main objective of this study is to determine the performance of two sorghum lines under four levels of salinity.

## 2. Materials and Methods

A nursery experiment was conducted during the summer of 2007 at the nursery of the Faculty of Agriculture, University of Khartoum, latitude 15° 40' and longitude 32°32', to investigate the effects of salt stress on growth and yield of two lines of forage sorghum. The four salinity levels were prepared by addition of different salt (NaCl) weights to a liter of tap water. These were:

- No salt was added to the tap water (control)
- Adding 40 gramme of NaCl to a liter of tap water to give an electric conductivity (E. C.) of 6 dsm<sup>-1</sup>
- Adding 50 gramme of NaCl to a liter of tap water to give an electric conductivity (E. C.) of 8 dsm<sup>-1</sup>
- Adding 60 gramme of NaCl to a liter of tap water to give an electric conductivity (E. C.) of 10 dsm<sup>-1</sup>.

The two lines of forage sorghum used in the study were: R5 and KHS. Seeds of sorghum were sown in 9- inch pots containing 1:1 sand to loam soil mixture. Ten seeds were sown in each pot and then thinned to three, two weeks after germination. All experimental units received an equal quantity of water until the crop was established.

The treatments were randomly assigned in a Factorial experiment as complete block design with ten replications. The irrigation levels were determined by 75% of field capacity that was 500 ml for a single irrigation depending on the soil mixture. Treatment with different salt concentration was started 27 days after sowing. Samples were taken from pots after 37, 48, 59 and 70 days from sowing.

### 2.1. Data Collection

Samples were taken from pots after 37, 48, 59 and 70 days from sowing to determine the following parameters:

1. Stem diameter (mm)
2. Average Relative Growth Rate (ARGR)
3. Average Relative Leaf area Rate (ARLAR)
4. Dry weight (g/plant)
5. Percentage of chemical compositions

#### 2.1.1. Stem Diameter (mm)

Stem diameter had been measured by using vernier scale for the three plants.

#### 2.1.2. Dry Weight Plant (g)

Plant samples were oven dried at 80°C (±) to a constant weight and then weighed using a sensitive balance to determine the dry weight of the plant.

#### 2.1.3. Average Relative Growth Rate (ARGR)

Was calculated as follow:

$$ARGR = \frac{W_2 - W_1}{T}$$

Where:

W1 = The first dry weight (weight at time T1)

W2 = The second dry weight (weight at time T2)

T = Days between W1 and W2

#### 2.1.4. Average Relative Leaf Area Rate (ARLAR)

Was calculated as follow:

$$ARLAR = \frac{LA_2 - LA_1}{T}$$

Where:

LA1 = The first leaf area

LA2 = The second leaf area

T = Days between LA1 and LA2

### 2.2. Statistical Analysis

The collected data were subjected to the analysis of variance using the method described by Gomez and Gomez (1984) for each of the studied characters. The table shows the forms of the individual and combined analysis of variance for factorial complete randomized design.

#### 2.2.1. Coefficient of Variation

The coefficient of variation (C.V. %) for each character was determined according to the following formula:

$$C.V\% = \sqrt{\frac{\text{The error mean square}}{\text{Grand mean}}} \times 100$$

#### 2.2.2. Mean Separation

The means were separated using the least significant difference (LSD) at 0.05 and 0.01 levels according to Gomez and Gomez (1984) as follow:

$$LSD = t_{\alpha} \sqrt{\frac{2EMS}{r}}$$

Where:

EMS = Error mean square

r = Level of significant for t value

### 2.3. Chemical Analysis

The chemical analysis Included: ash,  $K^+$ , P and  $Na^+$  content by dry aching. The procedure was that of Chapman and Pratt (1961) with slight modifications by Reeney and Miller (1982).

A portion of ground plant material was weighed (2.00 g) in a 50 ml Pyrex glass beaker, and then put into a cool muffle furnace and increased the temperature gradually to 550°C, and then the muffle furnace shut off and opened the door cautiously for rapid cooling.

After cooling the beaker was taken out, and dissolved the cool ash in 5ml portions 2N hydrochloric acid (HCl) and mixed with a plastic rod. After 20 minutes, the volume makeup (50 ml) and used distilled water, and mixed thoroughly, allow to stand for 30 minutes and used the filter Whatman, discarding the first portion of the filtrate analyze the aliquots for P by colorimetry (by Ammonium Vanadate Ammonium Molybdate yellow color method, for K and Na by flame photometry.

## 3. Results and Discussion

Significant differences among genotypes appeared at the early stages only, which showed an increase in stem diameter (Table 1) for R5 lines. At 59 and 70 days after sowing, KHS gave thicker stem diameter. Also, it was observed that the highest salt levels induced thicker stem diameter with or without significant effect. This could be due to the enhancement of growth by high levels of salts.

With respect to the Average Relative Growth Rate (Table 2), R5 genotype had lower dry matter accumulation. However, KHS line was more tolerant than R5, and hence, it had a higher ARGR at the highest salt levels. Both sorghum lines obtained the lowest ARGR at 8E.C. Reduction in dry weight of plant tissues reflects the increased metabolic energy cost and reduced carbon gain, which are associated with salt adaptation; it also reflects salt impact on tissues (Netondo *et al.*, 2004). In addition, when a water solution containing a relatively large amount of dissolved salts cause a shrinkage of the protoplasmic lining, due to the osmotic movement of the water, that leads to a collapse of the cells. This was with an agreement with Allen *et al.*, (1994) that mentioned that salinity might also cause reduced Adenosine Tri Phosphate (ATP) and growth regulators. Ahmed and Ahmed (2007) provided a proof that shoot growth reduction under salinity is not mediated by turgor loss in wheat and barley on a short term basis. This would provide further support to factors other than water relations in mediating plant injury by salinity. On the other hand, Ames (2000) suggested that saline water has the high osmotic pressure that reduces water uptake by the roots, resulting in the inhibition of the plant growth, and a yield reduction of 10.25% can be expected depending on many factors such as varieties. The peak of ARGR recorded for KHS at 6E.C. and at 0E.C. for R5, which may reflect the range of tolerance of the two lines to salts.

The genetic influence, salt levels, and their interaction did not affect dry yields (Table 3) significantly. This may be due to Ahmed and Ahmed (2007) findings who claimed that the lack of turgor- loss symptoms in a salinized plant that lead to water stress is relatively unimportant in causing injury by salinity, because plant adjusts osmotically in response to salinity, and therefore may not show the symptoms of wilting. Also, the involvement of plant hormones is mediating plant response to salinity is the attractive proposition Abscissic acid (ABA) content of the shoot was indeed found to remain high in salinized plants, which retained their turgor. A possible role for ABA increases in the shoot and cytokinin decrease in the root under salinity stress remains to establish. El Tayeb (1991) suggested that high salt concentrations resulted in a reduction of yield of fodder sorghum by over 20 percentages. However, although there were no significant different between the lines in dry weight, KHS lines gave higher dry weight at all accessions.

KHS genotype obtained higher average relative leaf area rate (Table 4) at the highest salt concentration (10E.C.) than the other line (R5) at the same concentration. The previous explanation of leaf area could be considered in the case of this parameter.

Salt treatments did not significantly affect elements percentage (Table 4) in the two sorghum lines. These include P,  $Na^+$  and ash which were in agreement with Mohamed Ahmed (1988) when growing wheat on salt affected soils, but the differences in  $K^+$  percentage was significant.

Brown *et al.*, (1999) mentioned that halophytes, including the two sorghum lines, appear to have the same basic method of osmotic adjustment: accumulation of inorganic salts, mainly NaCl, in the vacuole and in the cytoplasm's vacuoles may have a modified lipid composition to prevent leakage of  $Na^+$  back to the cytoplasm. Some theory mentioned by Johnson (1981) who found that halophytes accumulate  $Na^+$  and it in order to be adjusted osmotically. The two sorghum lines obtained the same percentage of  $Na^+$ , but the concentration was highest in the control. This conforms to the theory by Levitt (1972) that supposed halophytes resistance depends on the ability in mobilizing energy to extrude  $Na^+$  from the cell and keep up  $K^+$ , which explained the higher percentage of  $K^+$  than  $Na^+$  at the lower concentration of the salt solution. The capacity of plants to maintain intracellular  $K^+ / Na^+$  homeostasis is crucial for salt tolerance  $Na^+$ , particularly at concentrations in saline soils, interferes with  $K^+$  acquisition potentially creating a deficiency for this essential element.  $Na^+$  competes with  $K^+$  for intracellular uptake through both low and high-affinity transport systems and  $Ca^{+2}$  facilitates  $K^+ / Na^+$  selective accumulation (Jenks and Hasegawa, 2005). Also, Johnson (1981) mentioned that according to several reports of NaCl promoting increased  $K^+$  uptake into the roots of halophytes. Also, Na concentration increases soil pH between 8 and 8.5. At this range, according to Brady (1974), there is a full availability for  $K^+$ , while P becomes less available.

It was found that P percentage increased with the increase of electric conductivity, and the peak was at 8electric

conductivity. This may be due to Johnson (1981) explanation, that salinity damage the mechanisms that control the intracellular P concentration, so that it is possible according to this theory, to judge on the performance of lines and determine R5 genotype more tolerant to salinity due to the lower percentage of P. On the other hand, Devline *et al.*, (1993) explained the lower percentage of elements at the higher salt concentration by that the roots that become heavily suberized when to get older, so that, roots will not be efficient to absorb.

## 4. Conclusion

1. Forage sorghum in this season proved its capability to adapt well in the salty soil according to the applied levels of salts, although the two lines exhibited some variation in responding to the treatments.
2. KHS line was better than R5 and produced better vegetative growth at high salt concentration.
3. The effects of salt concentrations and the interaction between the treatments appeared only on the percentage of  $K^+$ .
4. Average relative growth rate increased with plant age, and KHS line was superior to R5. Average relative leaf area decreased at the end of crop life and R5 genotype obtained higher ARLAR.
5. According to the preliminary results which were promising, more work is needed to test these lines under affected field conditions by a multi-disciplinary team to analyze the soil salt content regularly before growing season and after each harvest.
6. Since the salt problem is of widespread, the development of tolerant genotypes through breeding is of high importance.

**Table 1.** The effect of salt concentrations on the mean stem diameter (mm) of two forage sorghum lines.

Salt concentrations \ Lines	Plant age (days)											
	37			48			59			70		
	R5	KHS	Mean	R5	KHS	Mean	R5	KHS	Mean	R5	KHS	Mean
0E.C.	4.1	3.0	<b>3.6</b>	4.3	3.3	<b>3.8</b>	4.3	4.5	<b>4.4</b>	4.7	5.4	<b>5.1</b>
6E.C.	4.4	2.6	<b>3.5</b>	4.8	1.8	<b>3.3</b>	1.9	5.6	<b>3.8</b>	2.9	6.4	<b>4.7</b>
8E.C.	3.4	3.2	<b>3.3</b>	3.7	3.2	<b>3.5</b>	4.7	3.9	<b>4.3</b>	4.7	4.9	<b>4.8</b>
10E.C.	3.9	3.6	<b>3.8</b>	4.6	3.6	<b>4.1</b>	4.8	5.8	<b>5.3</b>	5.1	5.9	<b>5.5</b>
Mean	<b>3.95</b>	<b>3.1</b>		<b>4.4</b>	<b>2.98</b>		<b>3.9</b>	<b>4.95</b>		<b>4.4</b>	<b>5.7</b>	
LSDV5%	14.1			19.05			20.4			22.4		
LSDE.C.5%	19.9			21.1			28.9			31.6		
LSDV×E.C.5%	28.1			29.8			40.9			44.7		

**Table 2.** The effects of salt levels on the average relative growth rate and average relative leaf area rate of two forage sorghum lines.

Plant age (days) ARGR					Plant age (days) ARLR				
Treatments	48	59	70	$\bar{X}$	Treatments	48	59	70	$\bar{X}$
0R5	0.15	0.03	1.1	<b>0.43</b>	0R5	1.89	7.02	-	<b>4.46</b>
0KHS	0.18	0.08	1.5	<b>0.59</b>	0KHS	4.07	0.77	1.77	<b>2.20</b>
6 R5	0.07	-	0.6	<b>0.34</b>	6 R5	-	3.04	1.59	<b>2.32</b>
6KHS	0.11	0.01	1.9	<b>1.01</b>	6KHS	3.18	5.33	2.29	<b>3.60</b>
8R5	0.02	0.07	0.53	<b>0.19</b>	8R5	0.45	6.93	2.91	<b>3.43</b>
8KHS	-	-	0.64	<b>0.36</b>	8KHS	-	1.90	-	<b>1.90</b>
10R5	0.02	-	0.50	<b>0.26</b>	10R5	5.67	4.22	2.97	<b>4.29</b>
10KHS	0.17	-	1.37	<b>0.77</b>	10KHS	7.0	4.66	-	<b>5.83</b>
$\bar{X}$	0.103	0.048	1.02		$\bar{X}$	3.71	4.23	2.31	
KHS mean	<b>0.67</b>				KHS mean	<b>3.70</b>			
R5 mean	<b>0.30</b>				R5 mean	<b>3.40</b>			

**Table 3.** The effects of salt levels on the mean dry matter per plant (g) of two lines of forage sorghum.

Salt concentrations \ Lines	Plant age (days)											
	37			48			59			70		
	R5	KHS	Mean	R5	KHS	Mean	R5	KHS	Mean	R5	KHS	Mean
0E.C.	0.3	0.4	<b>0.35</b>	1.0	1.3	<b>1.15</b>	1.2	1.7	<b>1.45</b>	6.5	9.0	<b>7.75</b>
6E.C.	0.4	0.6	<b>0.50</b>	0.8	1.2	<b>1.0</b>	0.7	1.0	<b>0.85</b>	3.5	10.5	<b>7.00</b>
8E.C.	0.2	0.8	<b>0.50</b>	0.3	0.5	<b>0.4</b>	0.4	0.8	<b>0.60</b>	3.0	4.0	<b>3.50</b>
10E.C.	0.5	0.5	<b>0.50</b>	0.6	1.3	<b>0.95</b>	0.5	0.7	<b>0.60</b>	3.0	7.5	<b>5.25</b>
Mean	<b>0.35</b>	<b>0.58</b>		<b>0.68</b>	<b>1.1</b>		<b>0.70</b>	<b>1.1</b>		<b>4.0</b>	<b>7.8</b>	
LSDV5%	0.5			1.0			1.0			4.4		
LSDE.C.5%	0.7			1.4			1.4			6.2		
LSDV×E.C.5%	0.9			2.0			1.9			8.8		

**Table 4.** The effects of salt levels on some elements percentage of two forage sorghum lines .

Salt concentrations \ Lines	Element (%)											
	Na <sup>+</sup>			P			K <sup>+</sup>			Ash		
	R5	KHS	Mean	R5	KHS	Mean	R5	KHS	Mean	R5	KHS	Mean
0E.C.	0.22	0.16	<b>0.19</b>	0.14	0.22	<b>0.18</b>	1.20	1.0	<b>1.1</b>	17.3	23.6	<b>20.5</b>
6E.C.	0.13	0.23	<b>0.18</b>	0.10	0.28	<b>0.19</b>	0.93	1.1	<b>1.0</b>	17.8	24.5	<b>21.2</b>
8E.C.	0.20	0.14	<b>0.17</b>	0.15	0.28	<b>0.22</b>	0.90	1.0	<b>0.95</b>	16.3	21.2	<b>18.8</b>
10E.C.	0.18	0.17	<b>0.18</b>	0.22	0.13	<b>0.18</b>	0.78	1.3	<b>1.04</b>	20.6	14.4	<b>17.5</b>
Mean	<b>0.18</b>	<b>0.18</b>		<b>0.15</b>	<b>0.23</b>		<b>0.95</b>	<b>1.1</b>		<b>18.0</b>	<b>20.9</b>	
LSDV 5%	0.14			0.09			LSD V 1%0.041			8.7		
LSD E.C. 5%	2.0			0.13			0.40			12.4		
LSD V× E.C.5%	0.3			0.18			LSD V×E.C.1% 0.28			17.5		

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