Effect of Mixed Red Sea and Well Waters on Grain Yield of Three Sorghum (Sorghum bicolor (L.) Monech) Cultivars in the Red Sea State, Sudan

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Abstract: A field experiment was conducted in the Ministry of Agriculture and Animal Resources Farm in the Red Sea coast at Arim, for two seasons (2011/2012 and 2013/2014) to investigate the effect of diluted Red Sea waters on the grain yield of sorghum (Sorghum bicolor). The treatments consisted of three cultivars: forage sorghum (Abusabien), Aklomoy and White milo, three electrical conductivities (ECiw): 0.48, 5.4, and 9.4 dS/m, and three replicates. The treatments were arranged in a split-plot design, where ECiw treatments were designated main plots and sorghum cultivars subplots. Data were collected from the following yield parameters: Number of heads m⁻², mean number of seeds per head, thousand grain weight and grain yield in tons ha⁻¹. The main effect of ECiw on number of heads (NH) was significant only in the first season. With the exception of White milo in the first season, all varieties gave steady linear decrease of NH with increase of ECiw. The main effect of variety on NH was significant at the 5% level in both seasons and it was in following order: White milo > Aklamoy = Abusabien. The main

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effects of ECiw and variety and their interaction on the number of seeds per head (NS) were not significant in both seasons. However, the main effect of ECiw showed steady linear decrease of NS with increase of ECiw. The overall average NS was 359 in the first and 488 in the second season. The main effect of ECiw and its interaction with variety on thousand grain weight (TGW) was not significant in both seasons. However, the main effect of ECiw showed steady significant linear decrease of TGW with increase of ECiw. The overall mean thousand grain weight was 40g in the first season and 35.6g in the second season. In both seasons, the main effect of variety on the TGW was significant at the 5% level, and it was in following order: Aklamoy = Abusabien > White milo. In both seasons the main effects of ECiw and variety and their interaction on the sorghum grain yield (GY) were not significant. Nonetheless, the quantitative trends of GY in the two seasons were different. In the first season, the main effect of ECiw showed steady linear decrease of sorghum (GY) with increase of ECiw according to the following equation.

\[GY = -0.2399 \text{ECiw} + 5.3087 \quad (r^2 = 0.9107)\]

In the second season the trend was quadratic showing an initial decrease followed by an increase. However, GY decreased with increase of salinity of the irrigation water.

**Key words:** Sorghum, Red Sea water, grain yield

**INTRODUCTION**

Sudan consists of extensive arid and semi-arid lands and a limited portion of dry sub-humid land. Because of aridity, crop productivity in these lands is limited by two main desertification processes, namely salinity/sodicity and wind erosion (Mustafa, 1986; Mustafa, 2014). In some states, e.g. the Red Sea, scarcity of good quality water constitutes a third major constraint in the production of food (Ibrahim et al., 2008). In such states, water and food security are closely related, reliable access to good quality water increases agricultural yield and provide more food and higher income in the rural areas (FAO, 2003).
Salinity/sodicity causes considerable reduction in crop growth and production due to three adverse effects: (a) an osmotic effect, (b) specific ion effect consisting of nutritional imbalance and plant toxicity and (c) deterioration of soil physical properties. The osmotic effect is due to the total salt concentration, which increases the negative osmotic potential and consequently limits the uptake of water by plants. The higher uptake of one ion may impair the uptake of another causing nutritional imbalance as reflected in inhibition of many physiological and biochemical processes. Whereas, the concentration of some specific ions such as sodium and chloride may reach toxic levels in some plants and impair their growth plant. Furthermore, sodicity reduces water soil water movement and conservation (Munns and Tester, 2008; Katerji et al. 2009). The effect of salinity and sodicity depend on stage of plant growth. High salinity at germination stage causes physiological drought and reduction in leaf expansion. This salinity stress may continue and result in inhibition of cell division and expansion as well as stomata closure (Munns, 2002). If plant exposed for long time to salinity, it may face ionic stress, which can lead to premature senescence of adult leaves, and thus a reduction in the photosynthetic area available to support continued growth (Cramer and Nowak, 1992). Plants have several salt tolerance mechanisms. They may eliminate salt from their cells and may tolerate its presence within these cells (Munns and Tester, 2008). In general, crops vary in their levels of salt tolerance (Katerji et al., 2009).

In Sudan comprehensive research was conducted on the impact of soil salinity and sodicity on its properties and on the growth and productivity of crops (Mustafa, 2014).

Very limited work was undertaken on the impact of saline water on crop productivity. In the Red Sea state the major limitation is shortage of good quality water. However, there is plenty of sea water. It is envisaged that although this saline water resource is usually neglected, it can be used for growing halophytes and many salt-tolerant crops (Daoud et al., 2004).

The Red Sea has a total area of 212,410 km$^2$, approximately 55% of this area is rangeland, 42% is salt-affected and desertified and 3% is relatively good agricultural land. Only 30% of the this agricultural land is utilized because shortage of good quality water since most of the water of the
seasonal streams is lost through drainage into the red sea or into the sand dunes (Ministry of agriculture, Animal Resources and Irrigation, 2000). Agricultural lands within the immediate fringe of the Red Sea are very scarce due to high soil salinity and low rainfall, which is insufficient to support any reliable rain-fed cultivation. However sporadic small holdings of seasonal cultivation are confined to the catchment’s area of seasonal streams. Farming activities include cultivation of a limited number of crops such as tomato, okra, watermelon and sweet beans. The seeds of these crops are sown in the moist subsoil after the removal of the dry surface soil layer. Proposals were made for the use of seasonal stream waters to grow salt-tolerant vegetation in the beds and banks of these streams (Ali and Mohamed, 1991). Magbol et al. (1996) visualized sea water agriculture that opens up coastal lands which were previously unusable for agriculture production due to fresh water shortage. These proposals were not followed up by scientific experimental research.

The main agricultural constraints in the Red Sea State are shortage of good quality water, salinity and desertification. There is shortage in food crops and there is lack of a good range in the State. Hence, the UNESCO Chair of Desertification Studies (UCDS), Khartoum University, formulated a national research project entitled: "The Use of Mixed Red Sea and Well Waters and Seasonal Water Streams for Cultivating Salt-tolerant Trees, Forage and Field Crops in the Coast Land". The main hypothesis is that the beds and banks of the seasonal streams and the coastal land in general may be cultivated using mixed sea water and stream and or well water to grow salt tolerant forage, forest and field crops.

The main objective of the project was to explore the potential of using diluted Red Sea water with well and stream waters for growing relatively tolerant forage, tree and field crops to promote food security in the state. To achieve this main objective, several initial pot and laboratory experiments were conducted on quality of the Red Sea and well Waters, salinity and sodicity of soils at the Red Sea coast, and the potential use of diluted Red Sea water for irrigation of some food, pasture and tree crops (Ahmed and Mustafa, 2009; Abusuwar and Abbaker, 2009; Ahmed and Mustafa, 2010a,b).
To our knowledge no scientific field experiment was conducted to investigate the potential use of mixed Red Sea and well waters on the productivity of sorghum in the Red Sea coast. Thus, the objective of this study was to investigate the effect of mixed Red Sea and well water on the yield and yield components of sorghum on the Red sea coast at Airem.

MATERIALS AND METHODS

A field experiment was conducted in the Ministry of Agriculture and Animal Resources Farm in the Red Sea coast (7 km from the sea) at Arim for two seasons (2011/2012 and 2013/2014) to investigate the effect of three diluted Red Sea waters on the growth and yield of three sorghum (Sorghum bicolor) varieties: Aklomoy, White mailo and forage sorghum (Abusabien). The soil of the farm was as Typic Torrifluvents. Soil samples were collected from a typical profile and analyzed using standard procedures of the Department of Soil and Environmental Sciences, Faculty of Agriculture (Table 1).

Table 1: Main chemical properties of the soil profile and soil texture of experimental site

<table>
<thead>
<tr>
<th>Soil properties</th>
<th>Soil depth (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0-5 cm</td>
</tr>
<tr>
<td>Sand</td>
<td>81.7</td>
</tr>
<tr>
<td>Silt</td>
<td>1.6</td>
</tr>
<tr>
<td>Clay</td>
<td>16.7</td>
</tr>
<tr>
<td>Texture</td>
<td>Sandy loam</td>
</tr>
<tr>
<td>SP (%)</td>
<td>27.6</td>
</tr>
<tr>
<td>pH</td>
<td>6.0</td>
</tr>
<tr>
<td>ECe (dSm⁻¹)</td>
<td>0.470</td>
</tr>
<tr>
<td>SAR</td>
<td>3.6</td>
</tr>
<tr>
<td>CaCO₃</td>
<td>4.5</td>
</tr>
</tbody>
</table>

The seeds of Abusabien and White mailo were obtained from the Sudanese Arab Seeds Company, and those of Aklomoy were obtained from Khashm Elgirba Research Station.
**Irrigation water**

Three Red Sea: well water ratios used were: 0:1, 1:10 and 1:5, resulting in the following consecutive electrical conductivity (ECiw): 0.48, 5.4, 9.4 dS/m. Plants were irrigated during initial establishment phase, which continued for four weeks, by Setrab well water to insure uniform germination and crop establishment. Irrigation with mixed water of different dilutions was initiated after this stage.

A system of four large water tanks of different sizes: two of 4000 liters, one of 2000 liters and one of 1000 liter fitted with delivery hoses and two water meters. One of the large tanks was filled with seawater and one with well water the two were mixed in a specific ratio to give the required ECiw.

The treatments consisted of three ECiw levels: 0.48, 5.4, and 9.4 dS/m, and three sorghum varieties: Forage sorghum (Abusabien), Aklomoy and White mailo. These treatments were arranged in a split plot design with three replicates. The ECw treatments were designated the main plots and the sorghum varieties accommodated the subplots. The land was leveled, disc-ploughed to 30-cm depth and nine main plots, two meters apart were constructed. The area of each main plot (3 x 9 = 27 m²) was subdivided into three subplots. Each subplot contained three ridges each of three meter length. Sorghum seeds were sown on 29th of October in the two successive seasons. The seeds were sown in the middle of a flat ridge at spacing of 70 cm between ridges and 30 cm between plants in the same ridge. Seeds were sown at a rate of 5 seeds / hole then were thinned to three plants / hole after 2 weeks.

The reference evapotranspiration (ETr) was estimated by Jensen and Haise equation (Jensen et al., 1970). The crop coefficients (kc) of the crop growth stages: were estimated by the procedure outlined in a FAO document (Doorenbos and Pruitt, 1977).

The leaching fraction (LF) was calculated by the following relationship (Rhoades, 1974):

\[
LF = \frac{D_{dw}}{D_{iw}} = \frac{EC_{iw}}{5EC_e - EC_{iw}} \frac{1}{LE} \quad 3.12
\]
Table 2. The length, dates and crop coefficients (kc) for the different growth stages of sorghum at Port Sudan

<table>
<thead>
<tr>
<th>Growth stages</th>
<th>Days</th>
<th>Date</th>
<th>kc</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial</td>
<td>20</td>
<td>29/10 -18/11</td>
<td>0.50</td>
</tr>
<tr>
<td>Crop development</td>
<td>30</td>
<td>19/11 – 19/12</td>
<td>0.79</td>
</tr>
<tr>
<td>Mid-season</td>
<td>40</td>
<td>20/12 - 29/01</td>
<td>1.05</td>
</tr>
<tr>
<td>harvest</td>
<td>30</td>
<td>30/01 - 28/02</td>
<td>0.50</td>
</tr>
</tbody>
</table>


Where: ECiw = electrical conductivity of the irrigation water, ECe = electrical conductivity of the soil saturation extract that causes a given level of yield reduction of a given crop, LE = leaching efficiency which is taken as 90% for a sandy loam soil. The LF values were calculated by equation 3.12 for the three ECiw values of the mixed Red Sea-well waters, the corresponding ECe values for sorghum were obtained from the table of Ayers and Wescot (1976) and LE of 90%.

Crop water requirement (CWR) is defined as estimated by the following relationship:

\[ CWR = ET_{\text{crop}} + LR = \frac{ET_{\text{crop}}}{1 - LF} \]

Where \( ET_{\text{crop}} \) is estimated by the following relationship:

\[ ET_{\text{crop}} = kc \times ET_r \]

Yield parameters
(a) Number of heads per square meter
A meter quadrate was used for calculating the number of heads per square meter. The quadrate was placed in central row for each subplot randomly and the number of heads was calculated.

(b) Number of seeds per head
Number of seeds per head was estimated for each variety at each subplot. Grains were separated from the heads and counted.

(c) Thousand grain weight
The weight of thousand grains was made for each variety at each subplot.

(d) Grain yield
Grain yield was calculated from the average yield/ subplot as follows:

\[ \text{Grain yield (ton/ha)} = \frac{\text{Grain weight / subplot}}{\text{Area of subplot}} \times 10^4 \times 10^6 \]

The area of the subplot = 9 m².

**Statistical analysis**

Data were analyzed using analysis of variance (ANOVA). Mean separation was done using Duncan’s Multiple Range Test (DMRT).

**RESULTS**

Table 3 shows the effects of ECiw and sorghum variety on the number of heads/m². In the first season, White milo yielded significantly (P < 0.01) 73.1% and 98.5% head/m² (NHM) greater than Aklamoy and Abusabien, respectively. In the second season, White milo was significantly 52.9% and 62.5% greater than that of Aklamoy and Abusabien, respectively. In the first season, the impact of ECiw was
significantly (P < 0.05) in the following order: NHM\(_{0.48} = NHM_{5.4} > NHM_{9.4}.

In the second season, the effect of ECiw was not significant. Furthermore, the impact of the interaction of ECiw and variety was not significant in both seasons.

Table 4 shows the effect of ECiw and sorghum variety on number of seeds per head (NSH). In the two seasons ECiw, variety and their interaction had no significant effect on the NSH and its overall mean was 359 in the first and 488 in the second season.

Table 4: Number of seeds per head as affected by variety and electrical conductivity of irrigation water (ECw) in the two seasons

<table>
<thead>
<tr>
<th>Variety</th>
<th>ECw 0.48</th>
<th>ECw 5.4</th>
<th>ECw 9.4</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aklamoy</td>
<td>345.0</td>
<td>256.0</td>
<td>308.0</td>
<td>303.0</td>
</tr>
<tr>
<td>White milo</td>
<td>365.0</td>
<td>273.0</td>
<td>332.0</td>
<td>323.0</td>
</tr>
<tr>
<td>Abusabien</td>
<td>510.0</td>
<td>446.0</td>
<td>396.0</td>
<td>451.0</td>
</tr>
<tr>
<td>Mean</td>
<td>407.0</td>
<td>325.0</td>
<td>345.0</td>
<td></td>
</tr>
</tbody>
</table>

\[ \text{LSD}_{0.05} (\text{ECw}) = \text{NS}; \text{LSD}_{0.05}(V) = \text{NS}; \text{LSD}_{0.05}(\text{ECw} \times V) = \text{NS} \]

| Variety   | 441.0    | 387.0   | 559.0   | 462.0 |
| Aklamoy   |          |         |         |       |
| White milo| 444.0    | 213.0   | 393.0   | 350.0 |
| Abusabien | 704.0    | 785.0   | 469.0   | 653.0 |
| Mean      | 529.0    | 462.0   | 474.0   |       |

\[ \text{LSD}_{0.05} (\text{ECw}) = \text{N.S}; \text{LSD}_{0.05}(V) = \text{NS}; \text{LSD}_{0.05}(\text{ECw} \times V) = \text{NS} \]

V = variety, NS = not significant

Nonetheless, in both seasons Abusabien consistently yielded much higher NSH than the two other varieties. In the two successive seasons Abusabien yielded NSH 48.8% and 39.6%, and 41.3 and 87.0% greater than Aklamoy and White milo, respectively. However, the trend of the impacts of ECiw and variety in the first season was different from that in the second season.
**Thousand grain weight**

The effects of ECiw and variety on sorghum thousand grain weight (GW\(_{1000}\)) are presented in Table 5. In both seasons the impact of ECiw and its interaction with variety on GW\(_{1000}\) was not significant, whereas the impact of variety was significant. In both seasons the thousand grain weight was significantly (P ≤ 0.05) in the following order: Aklamoy = Abusaien > White milo. In the first season, GW\(_{1000}\) of Aklamoy was 30.5% greater than that of White milo, and 5% greater than that of Abusabien. In the second season, it was 23.1% greater than that of White milo and 7.2% greater than that of Abusabien.

In both seasons the thousand grain weight was significantly (P ≤ 0.05) in the following order: Aklamoy = Abusaien > White milo. In the first season, GW\(_{1000}\) of Aklamoy was 30.5% greater than that of White milo, and 5% greater than that of Abusabien. In the second season, it was 23.1% greater than that of White milo and 7.2% greater than that of Abusabien.

Table 5: The effect of variety and ECiw on thousand-grain weight (g) in the two seasons

<table>
<thead>
<tr>
<th>Variety</th>
<th>0.48</th>
<th>5.4</th>
<th>9.4</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aklamoy</td>
<td>42.9</td>
<td>44.0</td>
<td>45.3</td>
<td>44.1 a</td>
</tr>
<tr>
<td>White milo</td>
<td>38.7</td>
<td>38.3</td>
<td>24.3</td>
<td>33.8 b</td>
</tr>
<tr>
<td>Abusabien</td>
<td>49.3</td>
<td>37.6</td>
<td>39.1</td>
<td>42.0 a</td>
</tr>
<tr>
<td>Mean</td>
<td>43.7 a</td>
<td>40.0 a</td>
<td>36.2 a</td>
<td></td>
</tr>
<tr>
<td><strong>Second season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aklamoy</td>
<td>41.7</td>
<td>40.8</td>
<td>34.3</td>
<td>38.9 a</td>
</tr>
<tr>
<td>White milo</td>
<td>36.1</td>
<td>31.0</td>
<td>27.6</td>
<td>31.6 b</td>
</tr>
<tr>
<td>Abusabien</td>
<td>40.2</td>
<td>33.2</td>
<td>35.5</td>
<td>36.3 a</td>
</tr>
<tr>
<td>Mean</td>
<td>39.3 a</td>
<td>35.0 a</td>
<td>32.4 a</td>
<td></td>
</tr>
</tbody>
</table>

LSD\(_{0.05}\) (ECiw) = NS; LSD\(_{0.05}\)(V) = 7.0; LSD\(_{0.05}\)(ECiw x V) = NS

Although the effect of ECiw on the thousand grain weight (GW\(_{1000}\)) of the three varieties was not significant in both seasons, the mean GW\(_{1000}\) of the three varieties decreased with increase of ECw in both seasons as shown by the following two highly significant trend lines:

**First Season:** \(GW_{1000} = -0.8375 \text{ ECw} + 44.232\) \((r^2 = 0.9955)\)

**Second season:** \(GW_{1000} = -0.7773 \text{ ECw} + 39.526\) \((r^2 = 0.9933)\)
**Sorghum grain yield (ton/ha)**

Table 6 shows the effect of ECiw and sorghum variety on sorghum grain yield. These results show that in the two seasons ECiw, varieties and their interaction had no significant impact on sorghum grain yield. The trends of the impacts of both ECiw and variety in the first season were different from those in the second season. In the first season, sorghum grain yield showed a significant decrease with increase of ECiw according to the following relationship:

\[
Y = -0.2399x + 5.3087 \quad (r^2 = 0.9107)
\]

<table>
<thead>
<tr>
<th>Variety</th>
<th>0.48</th>
<th>5.4</th>
<th>9.4</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aklamoy</td>
<td>3.9</td>
<td>3.1</td>
<td>1.8</td>
<td>2.9</td>
</tr>
<tr>
<td>White milo</td>
<td>5.9</td>
<td>6.4</td>
<td>3.4</td>
<td>5.2</td>
</tr>
<tr>
<td>Abusabien</td>
<td>5.3</td>
<td>3.7</td>
<td>3.3</td>
<td>4.1</td>
</tr>
<tr>
<td>Mean</td>
<td>5.02</td>
<td>4.40</td>
<td>2.84</td>
<td></td>
</tr>
<tr>
<td>LSD&lt;sub&gt;0.05&lt;/sub&gt; (ECiw) = NS; LSD&lt;sub&gt;0.05&lt;/sub&gt;(V) = NS; LSD&lt;sub&gt;0.05&lt;/sub&gt; (ECiw x V) = NS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Variety</th>
<th>0.48</th>
<th>5.4</th>
<th>9.4</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Second season</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aklamoy</td>
<td>3.9</td>
<td>2.7</td>
<td>3.1</td>
<td>3.2</td>
</tr>
<tr>
<td>White milo</td>
<td>4.3</td>
<td>1.4</td>
<td>3.1</td>
<td>2.9</td>
</tr>
<tr>
<td>Abusabien</td>
<td>3.0</td>
<td>4.5</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Mean</td>
<td>3.7</td>
<td>2.9</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>LSD&lt;sub&gt;0.05&lt;/sub&gt; (ECiw) = N.S; LSD&lt;sub&gt;0.05&lt;/sub&gt;(V) = NS; LSD&lt;sub&gt;0.05&lt;/sub&gt; (ECiw x V) = NS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the first season, White milo gave grain yield 1.8 and 1.3 fold that of Aklamoy and Abusabien. This may be because White milo gave 1.7 and 2.1 fold NHP than Aklamoy and Abusabien, respectively. In the second season, Abusabien gave grain yield 1.2 and 1.3 fold that of Aklamoy and White milo, respectively. This may be due to the fact that Abusabien gave 1.4 and 1.9 fold NSH than Aklamoy and White milo, respectively.

The overall mean sorghum grain yield was 4.1 and 3.3 ton/ha in the first and second seasons, respectively.
DISCUSSION

The number of heads per square meter
The main effect of ECiw was significant in the first season, but not significant in the second. With the exception of White milo in the first season, all varieties gave steady linear decrease of the number of heads per square meter (NH) with increase of ECiw. The drop in NH as the concentration of salt increased is expected to be due to the osmotic effect. It was reported that as the salt concentration increases, the osmotic potential decreases limiting water availability to plants and consequently causing yield depression (Mustafa, 2007; Hester et al., 2001). In the case of White milo variety, it was observed that this variety produced more heads when exposed to salinity stress and when exposed to a higher salinity level heads number dropped. This may be due to the forming of tillers and additional head-bearing-tillers. It was reported that in low soil moisture conditions resulting from osmotic effects, tillering varieties of forage sorghum recover to a certain extent water deficits by forming additional head-bearing-tillers and the resulting yield reduction can be partially offset by additional head-bearing-tillers (FAO, 2001).

In both seasons, the main effect of variety on NH was significant at the 5% level, and it was in following order: White milo > Aklamoy = Abusabien. The interaction between ECiw and variety was not significant in both seasons.
On the average NH in the first season was greater than that in the second season. The low number of heads in the second season was attributed to the infection of sorghum by stem borers.

The number of seeds per head
In both seasons the main effects of ECiw and variety and their interaction on the number of seeds per head were not significant. However, the main effect of ECiw showed steady linear decrease of the number of seeds per head with increase of ECiw. This trend agrees with some research workers who indicated that salinity reduces growth and productivity (Cramer and Nowak, 1992; Munns, 2002). In the first season, Abusabien gave number of seeds per head equal to 1.5 and 1.4 fold that of Aklamoy and White milo, respectively. In the second season it gave 1.4 fold that of Aklamoy and 1.9 fold that of White milo. On the average the number of
seeds per head in the second season was greater than that in the first season.

**Thousand grain weight**
The main effect of ECiw and its interaction with variety was not significant in both seasons. However, the main effect of ECiw showed steady significant linear decrease of the thousand grain weight with increase of ECiw. This trend agrees with some research workers who indicated that salinity reduces growth, productivity and quality of some crops (Cramer and Nowak, 1992; Munns, 2002). In both seasons, the main effect of variety on the thousand grain weight (TGW) was significant at the 5% level, and it was in following order: Aklamoy = Abusabien > White milo. Aklamoy gave TGW value equal to 1.3 fold that of White milo and 1.1 that of Abusabien in the first season, and it gave 1.2 fold that of White milo and 1.1 that of Abusabien in the second season.

**Sorghum grain yield (ton / ha)**
In both seasons the main effects of ECiw and variety and their interaction on the sorghum grain yield were not significant. Nonetheless, the quantitative trend of the grain yield in the two seasons was inconsistent. In the first season, White milo gave grain yield equal to 1.8 fold of that of Aklamoy and 1.3 fold that of Abusabien. This was because White milo gave NH equal to 2.0 and 1.7-fold that of Abusabien and Aklamoy. While in the second season Abusabien gave grain yield equal to 1.2-fold that of Aklamoy and 1.3-fold that of White milo. This was because Abusabien gave NH equal to 1.4-fold that of Aklamoy and 1.89-fold that of White milo, respectively.

On the average the grain yield in the first season was greater than that in the second season. This was because the first season gave NH greater than that of the second season. Nonetheless, in the first season, the main effect of ECiw showed steady linear decrease of sorghum grain yield with increase of ECiw according to the following equation:

\[
GY = -0.2399 \text{ECiw} + 5.3087 \quad (r^2 = 0.9107)
\]

This trend agrees with the finding of some research workers (Mustafa, 2007; Munns and Tester, 2008) who reported that salinity causes
considerable reduction in crop growth and production due to the total salt concentration, which increases the negative osmotic potential and consequently limits the uptake of water by plants. In the second season the trend was quadratic showing an initial decrease followed by an increase. However, grain yield decreased with increase of salinity of the irrigation water.

CONCLUSIONS

The Red Sea water mixed with well water (EC =0.48 dS/m) at a ratio of 1:5 giving an ECiw equal to 9.4 dS/m can be used for irrigating sorghum varieties cultivated in the sea coast to produce acceptable yields. The results showed that, thousand grain weight and grain yield decreased with increase of ECiw. Regression analysis showed that yield components decreased significantly and linearly with increase of ECiw. Significant genotypic differences in sorghum number of heads and thousand-grain weight were observed.

REFERENCES


أثر ماء البحر الأحمر المخلوط بماء الآبار على إنتاجية الحبوب لثلاثة أصناف من الذرة الرفيعة في ولاية البحر الأحمر، السودان * Sorghum bicolor (L) Moench.

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المستخلص: أجريت تجربة حقلية بمزرعة وزارة الزراعة والثروة الحيوانية بساحل البحر الأحمر بولاية البحر الأحمر، السودان بمنطقة ايرم، لموسمين (2022/2022 و 2022/2022) لدراسة أثر ماء البحر الأحمر المخفف على نمو وإنتاجية الذرة الرفيعة (Sorghum bicolor). كانت المعاملات هي: ثلاتة أصناف من الذرة وهي أبوسبعين، أكل موى والمايلو الأبيض، وثلاث تراكيز من ماء البحر المختلط بمياه الآبار لها توصيل كهربائي (ECiw) مختلف هو 0.48 و 5.4 و 9.4 dS/m واستخدمت ثلاث مكررات. وسرعت المعاملات في تصميم القطع المنتشرة حيث وضعت المعاملات المائية في القطع الرئيسي واصناف الذرة في القطع الفرعية. وجمعت المعلومات من مكونات الإنتاجية التالية: عدد القناديل في المتر المربع، وزن الالف حبة، ونسبة وزن الالف حبة، ونسبة إنتاجة حبوب الذرة في القطع الرئيسي. وتم استخدام الاختبارات التحليلية في معرفة الأثر الرئيسي للالتزام الكهربائي على عدد القناديل وعدد الحبوب، وكذلك الأثر الرئيسي للالتزام الكهربائي والاصناف وتفاعلهما على وزن الالف حبة.


*جزء من أطروحة الدكتوراه التي قدمت لجامعة الخرطوم بواسطة المشرف الأول.
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الكهرباء إنخفاضاً مسمراً في إنتاجية حبوب الذرة مع زيادة التوصيل الكهربائي وفقاً للمعادلة التالية:

\[ GY = -0.2399 \text{ECiw} + 5.3087 \quad (r^2 = 0.9107) \]

وفي الموسم الثاني فإن الاتجاه كان تربيعياً مظهراً انخفاضاً أولياً تتبعه زيادة. غير أن انتاجية الحبوب انخفضت مع زيادة ملوحة مياه الري.

كلمات مفتاحية: الذرة الرفيعة، ماء البحر الاحمر، انتاجية الحبوب