Impact of Blending Saline Water with Fresh Water on Germination and Growth Rate of Sorghum (Sorghum bicolor L. Moench)

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Abstract*-Food production for the increasing population in the world is limited by water scarcity. One attempt to overcome the water shortage is to utilize water from different sources. To use Saline water blended with fresh water as alternative water source for irrigation requires the experimental quantification of the effects of such blended water on plant growth rate and germination at the early growth stages of Sorghum. The laboratory experiments used five salinity levels (Ec. 0.24, 4, 6, 9, and 18 dS.m^{-1}), and two main local cultivars (Wad Ahmed and Tabat) of Sorghum (Sorghum bicolor L. Moench). Germination percentage, seedling length and mean germination time were taken as growth evaluation parameters. The results obtained showed that cultivars did not vary significantly in their ability to grow at various salinity values in clay cracking soils. At a higher salinity (Ec. 18 dS.m^{-1}), the rate of germination was decreased and the mean germination time was increased for Sorghum seeds irrigated with saline water of Ec. 0.3- 4 dS. m^{-1}. It was found that in Tabat cultivars, there was a significantly higher percentage of geminated seeds. Data obtained indicated that plant height was indirectly related to salinity levels with higher stem lengths for all cultivars grown in fresh water or saline water of Ec. 4 dS.m^{-1}. Growth of Tabat cultivar expressed via stem length was found to supersede the Wad Ahmed cultivar. Blended water with salinities up to Ec of 9 dS. m^{-1} resulted in no negative impacts on germination and growth of both Tabat and Wad Ahmed cultivars. The results may be used as a tool to screen salt tolerance in the early growth stages of large quantities of sorghum genotypes.

Keywords- Sorghum; Germination; Seedling; Salinity; Sea Water; Water Blending

I. INTRODUCTION

Availability of high quality, non-saline irrigation water is one of the major constraints to produce sufficient food for the increasing population in arid areas of Sudan. This is because Sudan's share of Nile water is limited. One of the possible ways to get enough water for irrigation is to use ground water, which normally is a saline water resource. Many scholars reported that continuous irrigation using salty water end up with saline soil, which reduces both germination of plants and their growth rate. However, Saline soils are estimated to constitute 5–10% of the world's arable land [1-2]. Moreover, reference [3] reported that saline areas are spreading, which is largely due to a low level of management of irrigation.

Reference [4] stated that salinity may result in severe reductions in crop growth rate and percentage of germination, which in turn leads to the establishment of uneven stands and a sharp reduction in crop yields.

Crop yield reduction in most soils is a function of salinity level and crop cultivar [5-6]. References [7-8] stated that stresses caused by high concentrations of salts in soils decrease dry matter and relative water content while enhancing activities of enzyme and electrolyte leakage. The severity of yield reduction varies with the genetic makeup of the crop species. The relative growth rate of the plants in response to differential salinity levels is known as their salt tolerance. The negative impacts of the presence of high salt build up in soil on plant growth rate are more pronounced at the germination stage. The mal-effects of the accumulation of a high salt content in soil include: retardation of seed germination and root emergence, presence of negative osmotic pressure, poisonous and imbalanced nutrition and water status in the crop [7-9].

To avoid such yield reduction by high salinity levels, it is advised to improve water management practices, adopt advanced irrigation technology and keep proper maintenance of soil physical and chemical properties. Another possible avenue is to mix saline water with fresh water to grow crops if the proper salinity level of the water mixture is determined. It is also possible to use saline water to determine and select a suitable crop or its verity that tolerates acceptable threshold level of salinity [10].

Soils of arid regions are rated as mostly saline, based on their pH, electrolytic conductivity (ECe), and exchangeable sodium percentage (ESP). In addition, these soils are characterized by scarce water resources that constrain attainment of high crop productivity. The orthodox practice to solve this problem of saline soils is leaching with fresh water, which is usually adopted. Therefore, it is highly needed to look for other, different techniques to overcome this constraint to obtain a high crop yield [4, 11-13].

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Most of the irrigated agricultural schemes in the arid parts of Sudan are dominated by cracking clay soil. Clay soils are characterized by their low percolation rate and their resulting reduced downward water leaching capacity.

Determination of the sensitivity of a crop to the saline level of irrigation water is a complex undertaking due to the variation of sensitivity of crops verities with crop growth rate.

Many salt-sensitive crop cultivars grow in the soil with increased salt concentrations levels, e.g. Sorghum, tomato [14-15]. In contrast, the most salt tolerant crops such as cotton [16] and sugar beet [17] are salt sensitive during germination. Sorghum (Sorghum bicolor (L.) Moench) has been considered relatively more salt tolerant than other crops and has potential as a grain and fodder crop for salt-affected arid areas. However, the presence of large genotypic variation for tolerance to salinity reported in sorghum [18-20], has made the determination of a suitable genotype a difficult task.

Although the vegetative growth of halophytes is stimulated by salinity, they are sensitive to salinity at their germination stage [21]. According to [22-24] sensitivity of Sorghum, barley, wheat, rice and corn is a function of the crop early growth stage, while they tolerate salt accumulation at other later stages.

Efforts to evaluate loss of crop yields under salinity stress have not yet been quantified with respect to the wide range of genotypes within and across species. This is due to lack of authentic knowledge needed for the adoption of selection criteria of the most suitable genotype [25]. In response to this deficiency of evaluation criteria, reference [26] calls for the development of acceptable and complete schemes to identify, screen and rank traits associated with salinity tolerance from the large candidate population of plant genotypes.

The main objective of this study was to determine the effects of different salt concentrations on the germination percentage (growth rate) of currently grown Sorghum cultivars. Focusing on these issues is expected to generate knowledge to help in building valuable programs for improving production of Sorghum crop in arid soils.

II. MATERIALS AND METHODS

A. Plant and Growth Conditions

Seeds of Sorghum (Sorghum bicolor L. Moench), Wad Ahmed and Tabat were used as test plant cultivars, and these were taken from the Agricultural Research Corporation (ARC), Sudan. Randomized experiments were conducted at the Department of Agricultural Engineering of the College of Agricultural Studies, Sudan University of Science and Technology, Shambat. The plants were sown in cracking black cotton clay soil in plastic pots (15 × 10 × 10 cm).

B. Irrigation Water

Red Sea water was transported from Port Sudan (ECe 48 dSm^{-1}) and mixed in calculated quantities with River Nile water (ECe 0.3 dsm^{-1}) to obtain concentrations of: 4 dSm^{-1}, 6 dSm^{-1}, 9 dSm^{-1}, and 18 dSm^{-1} in accordance with [28]:

$$ECSN = (ECs*Vs+ ECn*Vn)/(Vs*Vn) \quad (1)$$

Where:

ECsn = Electric conductivity of Sea Water + Nile River fresh Water

Vs and ECs = Volume and Electric conductivity of Sea water

Vn and ECn = Volume and Electric conductivity of Nile River fresh water

The irrigation water demand was applied by one dose of 150 ml per pot for each day.

As depicted in Table 1, standard chemical and physical tests for water quality were run at the laboratory of the Department of Agricultural Engineering of College of Agricultural Studies, Sudan University of Science and Technology, Shambat in accordance with the methods described by [27].

TABLE 1 CHEMICAL CHARACTERISTICS OF THE IRRIGATION WATER

EC (ds/m)	**pH**	**soluble anions (meq/l)**			**soluble cations (meq/l)**			**SAR $(meq)^{0.5}$**
		HCO_3	**Cl**	**SO^-_4**	**Ca +Mg**	**Na**	**K**	
0.3*	**6.6**	**1.2**	**1.6**	**0.2**	**2.0**	**0 7**	**0.3**	**1.0**
4.0	**7.4**	**2.4**	**36.0**	**2.1**	**11.0**	**28.7**	**0.8**	**12.0**
6.0	**7.5**	**2.5**	**53.0**	**5.1**	**16.3**	**43.5**	**0.8**	**15.0**
9.0	**7.6**	**2.7**	**72.0**	**17.9**	**29.3**	**60.8**	**2.5**	**15.0**

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18.0	**7.9**	**3.0**	**139.0**	**40.3**	**84.3**	**95.5**	**2.5**	**15.0**

C. Soil Characteristics

The soil was crushed and sieved through a 5 mm sieve. The physical and chemical properties of the test soil are shown in Table 2.

TABLE 2 PHYSIO-CHEMICAL CHARACTERISTICS OF THE STUDIED CLAY SOIL

chemical properties										
EC	Exchangeable cations m			CEC meq./100 g	SP%	O.C%	Total	Ca co_3	ESP	SAR
0.4	Ca + Mg	K	Na	46	76	0.7	0.1	5	2	1
	43.8	1.3	0.9							
Chemical properties					physical properties					
Soluble cation (meq/L)			Soluble anions (meq./L)		Particle Size Distribution					
Ca + Mg	K	Na	Hco3	Cl	sand	silt	clay		PH	
2.5	0.1	1.5	3.1	0.4	12	39	49		7.7	

D. Experimental Design and Analysis

A randomized block design was used with four replications. After crop planting, irrigation water was given with blended and fresh water for fourteen consecutive days. Counting of germinated seeds started after 7 days from crop sowing and was then performed every other day onwards till the end of the planned two weeks. The number of germinated seedlings and in-situ seedling shoot lengths was measured every other day, and the percentage and average time of germination were calculated following [28].

The overall effect of salinity on Sorghum crop growth was also studied by measuring seedling length in relation to seedling shoot length when using Nile Fresh water (control or base length) at the end of the experiment. Analysis of Variance was used for data analysis.

III. RESULTS AND DISCUSSION

A. Germination Percentage

The impacts of different levels of salt water on germination are shown in Fig. 1. The figure indicates that irrigation with water of different salinity levels significantly affected both the rate of germination and the germination percentage for both cultivars of Tabat and Wad Ahmed. These effects are more pronounced, with sea water of EC4 salinity, in Wad Ahmed (60 % germination) compared with Tabat (90% germination) cultivars.

Both cultivars (Tabat and Wad Ahmed) resulted in seed germination which was significantly ($P < 0.05$) higher than those values obtained with all other levels of saline water (100% and 99.15%, respectively). The minimum percentage of germination was obtained in cultivar Wad Ahmed (0%) in plants irrigated with water of EC18, while the lower level recorded by Tabat at the EC 18 at level of salinity was 20%. The Tabat cultivar showed fast seed germination (started on day 3) at EC4 level.

This is in agreement with [27] who stated that salinity is a major stress parameter that affects seed germination. The observed results also showed that the different sorghum cultivars were able to grow at different salinity concentrations. As shown in Fig. 1, the germination percentage of Wad Ahmed did not decrease linearly with increasing salinity levels in irrigation water, and no germination was recorded at EC 18.

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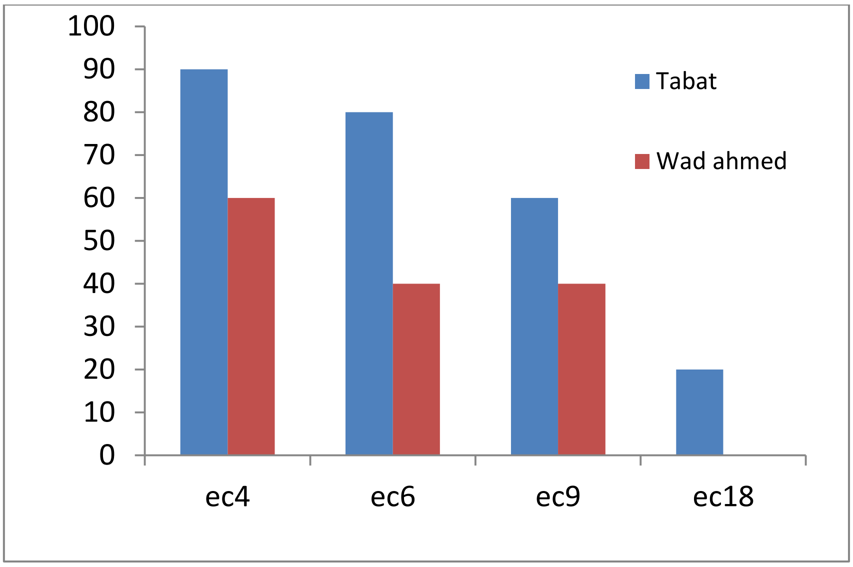

Fig. 1 Effects of different concentrations of salinity in irrigation water on percentage of germination of sorghum cultivars

B. Seedling Lengths

Fig. 2 exhibits the variation of seedling lengths as percentage of control treatment (fresh water) for the different investigated cultivars. The figure indicates that the seedling lengths in Tabat and Wad Ahmed cultivars were directly related to increase of salinity levels. It is evident from Fig. 2 that Tabat outperformed Wad Ahmed at all salinity levels. Using fresh water for irrigation, all cultivars showed equal lengths to those of cultivars irrigated with saline water of EC 4. The highest length of stem (10.5 cm) occurred in cultivar Tabat irrigated with fresh water. From the results of both Figs. 1 and 2, it can be inferred that the stages of germination and seedling are very sensitive to salinity. Consequently, failure to develop seedlings will definitely lead to failure in yield production under saline irrigation practices.

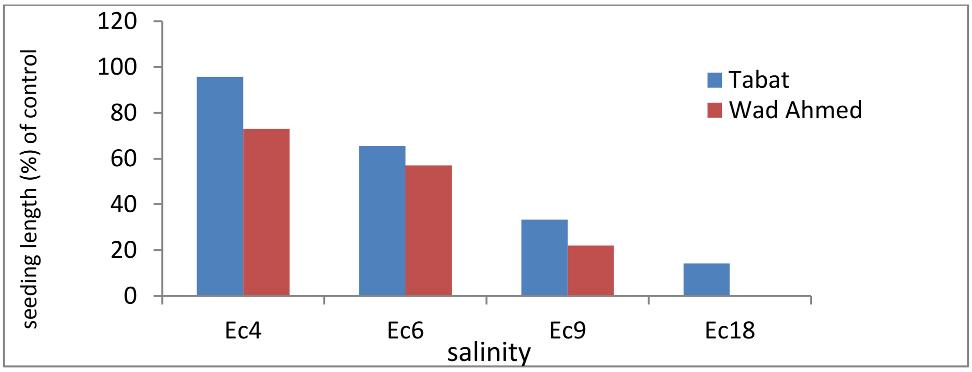

Fig. 2 Relative Percentage Seedling lengths (%) for the tested sorghum cultivars using saline and fresh irrigation water

C. Mean Germination Time

As reported by [11], germination is an important factor in plant development, for it affects both the initial and maturity stages of the plant and thereby determines the final productivity. The recorded data given in Fig. 3 shows that a gradual incremental increase in salinity levels (EC) of irrigation water positively hampered germination; it delayed it, but did halt the germination process of sorghum seedlings completely in Tabat cultivar. In contrast, an increase of salinity level resulted in a direct and sharp delay in time of germination, and with EC 18, the plants stopped stem elongation. Seedlings irrigated with sea water at a concentration of EC 18 resulted in the highest decrease in germination percentage.

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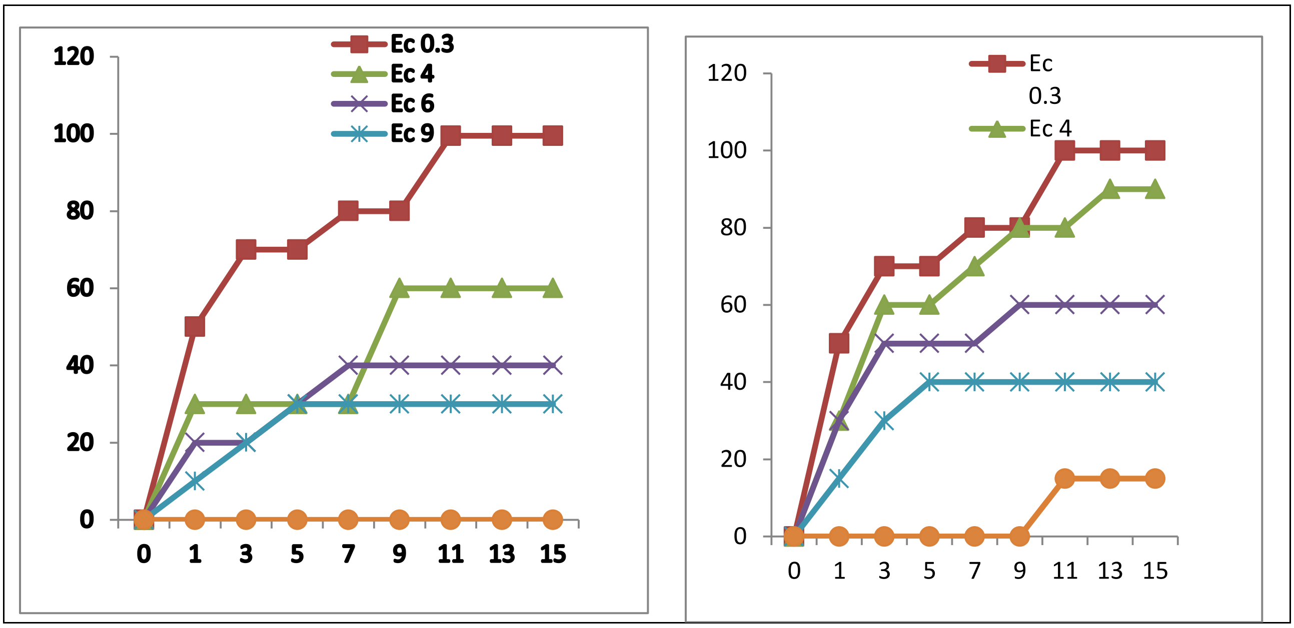

Fig. 3 Average germination times of sorghum cultivars irrigated with sea water of different EC-values

The delay in germination time may be attributed to the salinity buildup in the clay soil by evaporation and lack of leaching of water down the soil profile due to the low infiltration rate.

IV. CONCLUSIONS

Blending sea water with fresh water for purposes of irrigation of crops can conserve scarce fresh water. The results obtained showed that cultivars do not vary significantly in their ability to germinate at different salinity levels in clay cracking soils.

At a higher salinity (EC 18 ds/m), the rate of germination was lowest and resulted in a longer mean germination time compared to Sorghum seedlings irrigated with saline water of EC 0.3-4 dS/m. Tabat cultivars recorded the highest percentage of germination of seedlings by a significant margin. However, poor germination often restricts the final crop yield. Results obtained indicate that plant height is reduced with increased EC levels. However, plant height was found to be same when cultivars were irrigated with fresh water or with saline water of EC 4 ds/m.

Plant growth as measured by seedling length is found to be better in Tabat compared with Wad Ahmed cultivar. Blended sea water of salinities up to an EC of 9 dS/m was perfect for irrigation of the two cultivars and resulted in no adverse impacts on germination or plant growth. To assess the negative impacts of different levels of saline water in other soils, more studies are needed.

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