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Response of Sorghum (*Sorghum bicolor* L.) Cultivars to Salinity Levels at Early Growth Stages

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Abstract

The study was conducted to investigate the effect of salinity levels on seed germination and seedling characteristics of sorghum (*Sorghm bicolor* L.) cultivars. A laboratory experiment was conducted using new sorghum phenotype Barbarei (Abu-ragaba and Abu-kungara) cultivars in comparison with other two locally improved varieties (Tabat and Wad-Ahmad). Fifty seeds of each of the cultivars were germinated in Petri dishes containing filter paper of 9 cm diameter. Treatments comprised of control (distilled water), 0.5%, 1.0% and 1.5% Sodium Chloride (NaCl) were laid in a factorial experiment in completely randomized design (CRD) with 4 replications. Data recorded was subjected to analysis of variance (ANOVA). Least Significant Differences (LSD) method was used to test the differences between treatment means at 5% and 1% probability level. Number of germinated seeds was significantly affected by salinity level, especially by the higher salt concentrations compared to the control. Germination percentage and seedling vigor index (SVI) were decreased with increasing salinity level. The differences between treatments were highly significant ($p \leq 0.01$). The highest seed germination percentage (97.5%) and seedling vigor index (3.79) were found with the control (0% NaCl) and the lowest values were found with 1.5% concentration. Plumule length and radical length decreased significantly as concentration of NaCl increased. Results indicated that cultivar had a highly significant effect ($p \leq 0.01$) on the parameters measured. Results indicated that Barbarei cultivars were found to be sensitive to salinity when compared to Tabat and Wad-Ahmed, Tabat seems to be more salt tolerant cultivar. The interaction of salinity level × cultivar exerted significant effect ($p \leq 0.05$) on pumule length, radical length and final germination percentage.

Keywords

Sorghum Cultivars, Salinity, Germination, Seedling Characteristics

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1. Introduction

Sorghum is a widely grown cereal crop, particularly in Africa, sorghum ranks 5th in global cereal production. Grain sorghum is a dominant summer crop in Sudan; many varieties are grown under rain-fed areas and under irrigation in some central states. Unique Phenotype (or may be unique genotype) of sorghum bicolor species locally named (Barbarei) is widely grown in South and West Darfur States and it plays an important economic and nutritious role but no studies were done about it so far. This species includes wide diversity of phenotypes (Abu- ragaba and Abu- kungara) both with different seeds color. The Barbarei phenotypes seems to have different behavior compared to other cultivated species or varieties of sorghum in Darfur, where the plants produces flowers and grain only when weather gets cooler (October-November), although the plant heads continue to form normally (Bahar *et al*., 2013). In nature plants are subjected to multifarious harmful environmental stresses through their life cycle (such as salinity, alkalinity and drought) which reduce plant productivity. Salinity is one of the major

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environmental problems facing global agriculture, leading to crop damage and affects crop production in arid and semi-arid lands, where evaporation is high and the rain is not enough to leach the salt out of the root zone (Al-Hilal, 1999; Ghazizade *et al.*, 2012). In arid and semi-arid regions many physiological and metabolically changes are induced in plants affecting their growth, development, seed germination and early seedling growth (Saroj and Soumana, 2014). Seed germination and early seedling growth are important stage for the establishment of plants population. Increasing salinity levels significantly decreased germination parameters, shoot and root length, shoot and root fresh and dry weights of some forage sorghum cultivars (Kandil *et al.,* 2012). Tabatabaei and Angholi (2012) reported that increasing in saline treatments more than 10dsm^{-1} was consisted with considerable reduction of the rate of germination, furthermore, as the salinity increased the shoot and root length of some forage sorghum genotypes decreased. El Naim *et al.,* (2012), reported that the high levels (4, 8 and 16 dsm^{-1}) inhibited the seed germination significantly. The strongest inhibition of germination occurred at the higher salt concentrations. Growth of young seedlings was also reduced, especially at the higher salt concentrations. Results obtained by Behzadnejad and Tohidinejad (2014) revealed that salinity caused a significant decreased in germination characteristics and seedling growth of sorghum. Increasing in salinity concentration led to a significant decrease in the germination percentage, germination rate and mean germination time and seedling dry weight. Similar results were reported by Dadar *et al.,* (2014) that with increasing salinity level the germination percentage, rate of germination, radical and pumule length and pumule weight of sorghum decreased. As reported by Geressu and Gezaghegne (2008) germination rate and seedling root length of sorghum were more salt affected than the final germination percentage and seedling shoot length. Some sorghum accessions were found to be salt tolerant during germination and seedling growth. However, others were salt sensitive during germination but later became salt tolerant at seedling growth. Results attained the presence of broad intra-specific genetic variation among sorghum accessions for salt tolerance. Results recorded by Tigabu *et al*., (2012) indicated that all parameters measured showed to have inverse relationship with increase in salinity levels. The study affirmed presence of wide genotypic variation among the sorghum genotypes for NaCl salt tolerance. Results of the study conducted by Almodares *et al.,* (2007) showed that in all sorghum cultivars as the salt concentration increased, seed germination and seedling fresh weight decreased significantly. Salt stress adversely affects plants and crops at all stages of their life cycle as reported by many researchers (Radhouane, 2013; Yakubu *et al.,* 2010, Saddam *et al*., 2013 and Francois *et al.,* 1984). The objective of this study was to investigate seed germination and seedling growth characteristics of sorghum cultivars as affected by different salinity levels.

2. Materials and Methods

A laboratory experiment was conducted in 2014 in Biology laboratory, Faculty of Education, University of Zalingei, Sudan. The aim of the experiment was to evaluate germination and seedling characteristics of sorghum Barbarei phenotypes (Abu-ragaba and Abu-kungara) in comparison with other two locally improved varieties (Tabat and Wad-Ahmad) under different salinity levels. Pre-treatment germination test was done for the seeds of different cultivars using Petri dishes containing a 9 cm diameter filter paper. Fifteen seeds were placed in every Petri dish after adding 5 ml of distilled water. Germination percentage (GP) was calculated according to the International Seed Testing Association (ISTA).

GP = Number of normally germinated seeds / number of total seeds planted ×100 (Ilori *et al*., 2012).

The treatments comprised of control (distilled water), 0.5%, 1.0% and 1.5% of sodium chloride (NaCl). The treatment solutions were prepared by solving NaCl in distilled water, each experimental unit included a Petri dish contains filter paper of 9 cm diameter with 50 seeds of each cultivar. Treatments were arranged in a factorial experiment in completely randomized design (CRD) with 4 replications. 5 ml solution of each concentration was applied to each Petri dish. The control plates received the same volume of distilled water devoid of any salt. All Petri dishes were kept at room temperature, counting of germinated seeds started from the next day of placing seeds. The seeds were considered germinated when radicals appeared and are visible enough to be counted. Germination count was made through the experimental period until all the seeds were either germinated and/or dead.

2.1. Parameters Measured

The parameters measured include number of daily germinated seeds, germination percentage, seedling vigor index (SVI), Plumule and radical length. SVI calculated by the flowing formula:

SVI = (seedling length (cm) × germination percentage) / 100 (Abdul-Baki and Anderson, 1970)

2.2. Statistical Analysis

The analysis of variance (ANOVA) was carried out for the results and the treatment means were separated using the Least Significant Differences (LSD) at 5% and 1%

probability level according to the procedure described by Gomez and Gomez (1984).

3. Results and Discussion

3.1. Effect of Salinity on Seed Germination and Seedling Characteristics

Table 1. Result of variance analysis of the number of germinated seeds under salinity levels

Mean Square				
S.O.V	**1st count**	**2nd count**	**3th count**	**4th count**
Salinity	58.5**	80.65**	74.53**	56.36**
Cultivar	8.78**	9.07*	9.63**	11.62**
Salinity ×Cultivar	2.29*	1.38ns	1.63ns	2.6*
Error	38.21	63.96	63.97	69.46
C.V%	25.1	26.5	25.3	23.7
LSD	25.1	5.68	5.69	5.9

(*'** significant at 0.05 and 0.01 levels, respectively)

Table 2. Result of variance analysis of the number of germination percentage at different count

Mean Square				
S.O.V	**1st count**	**2nd count**	**3th count**	**4th count**
Salinity	247.3**	73.4**	74.5**	52.04**
Cultivar	15.3**	8.1**	9.6**	11.90**
Salinity × Cultivar	2.3*	1.3ns	1.63ns	2.75*
Error	101.96	279.6	255.92	278.83
C.V%	20.6	27.7	25.3	23.7
LSD	7.2	11.9	11.4	11.87

Results of statistical analysis for number of germinated seeds and germination percentage at different counting days have been shown in tables (1 and 2). Analysis of variance revealed that salinity level made a significant difference on most of the considered characteristics.

Table 3. Effect of salinity levels on germination and seedling characteristics

Salinity level	PL	RL	FGP	SIV
0% Na Cl	3.9a	3.4a	97.5a	3.79a
0.5% Na Cl	2.4b	3.0a	89.5a	2.11b
1% Na Cl	1.1c	1.3b	64.1b	0.69c
1.5% Na Cl	0.6cd	0.4c	30.6c	0.22cd
C.V%	22	33.4	23.7	47.2
LSD	0.62**	0.51**	11.87**	0.57**

Note: Means within the column having the same letter are not significantly different SIV= Seedling vigor index, FGP= Final germination percentage, PL= Pumule length (cm), RL= Radical length (cm).

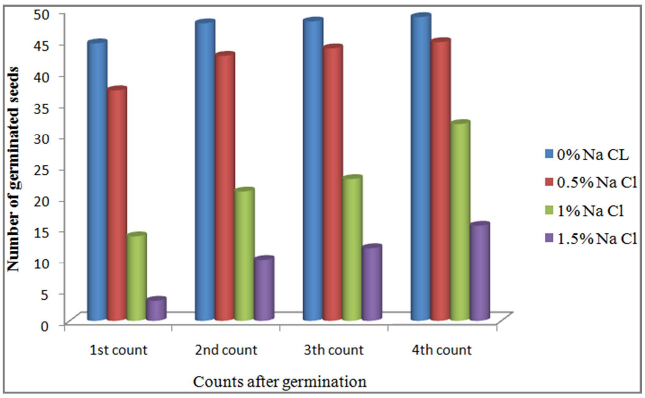

Fig. 1. Effect of salinity on number of germinated seeds

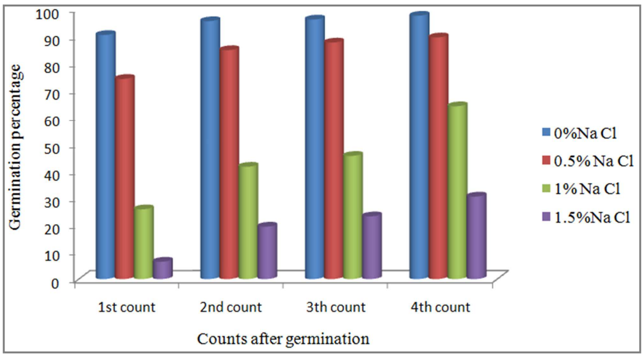

Fig. 2. Effect of salinity level on germination percentage

The number of germinated seeds was significantly ($p \leq 0.01$) affected by salinity level at all counting days, especially at the higher salt concentrations as illustrated by (Fig.1 and Table 1). The less number of germinated seeds during the germination period was obtained at 1.5% NaCl (3.2-15.3). For 1.0% and 0.5% NaCl concentrations, (13.6-31.7) and (37.1-44.8) germinated seeds, respectively, were recorded compared with the control (0% NaCl) which recorded (44.6 - 48.8). Results indicated that germination percentage significantly ($p \leq 0.01$) decreased with increasing salinity level at all counting days during germination period (Fig.2 and Table 2). The highest seed germination percentages (90.4 - 97.5) were found with the control (0% NaCl) followed by 0.5% (74.2 – 89.5) and 1% (25.9 – 64.1) respectively, the lower seed germination percentages (6.4 – 30.6) were found with 1.5% concentration. Results in (Table 3) indicated that the final germination percentage and seedling vigor index decreased with increasing salinity level. The difference between treatments were highly significant ($p \leq 0.01$), the higher seed germination percentage (97.5%) and seedling vigor index (3.79) were found with the control, whereas, the lower germination percentage (30.6) and seedling vigor index (0.22) were found with 1.5% NaCl concentration. Germination percentage and seedling vigor index decreased in 1.5% NaCl concentration by 68.6% and 94.2% respectively from the control, while the reduction in the other treatments (0.05 and 0.01 NaCl) from control were 34.3%

and 8.2% for germination percentage and 81.8% and 44.3% for seedling vigor index respectively. The effect of salinity on seed germination was clearly demonstrated in this study, low level of salinity (control) increased germination percentage and seedling vigor index, these parameters decreased as the level of salinity increased. High salinity levels inhibit seed germination significantly; this agrees with previous records of Kandil (2012) who recorded that increasing salinity level significantly decreased germination percentage, germination index and seedling vigor index of some forage sorghum cultivars. The seed germinates best in non-saline level (control) and then seed germination percentage and seedling vigor index decreased as salinity increased. Similar results were obtained by (Sonam *et al.*, 2013) that germination percentage decreased as the salt concentration increased compared to control, this also in line with results obtained by (El Naim *et al.*, 2012). Results in Table 3 indicates that the plumule length and radical length decreased significantly ($p \leq 0.01$) as the concentration of NaCl increased. The tallest plumule was obtained by the control (3.9cm) flowed by 0.5% (2.4 cm), 1.0% (1.1 cm) and the shortest one in 1.5% NaCl concentrations (0.6 cm). The tallest radical length 3.4 cm and the shortest length 0.4 cm were obtained by the control and 1.5% NaCl concentration respectively. The reductions in the plumule length with increasing salinity level were 84.6%, 71.8% and 38.5% for 1.5%, 1% and 0.5% NaCl respectively. Whereas, for the radical length the reduction was 88.2%, 76.5% and 11.8% for the above salinity levels respectively. This may be explained by the fact that salt had effect in the root zone of the plant and hence might alter wide changes of physiological process resulting in reduction of plant growth. These results agreed with results recorded by many workers (Al-Hatlani, 1995; Ali *et al.*, 2014; Tabtabaei and Angholi, 2012 and Reddy and Vora, 1983).

3.2. Effect of Cultivar on Seed Germination and Seedling Characteristics under Salinity Levels

Figs.3 and 4 showed the effect of cultivar on number of germinated seeds and germination percentage under different salinity levels during counting time. Results indicated that cultivar had highly significant effect ($p \leq 0.01$) on the parameters measured. Wad-Ahmed and Tabat recorded the higher number of germinated seeds and germination percentage during the counting period compared with Barbarei cultivars (Abu-ragaba & Abu-kungara). Within Barbari cultivars Abu-kungara exerted higher number of germinated seeds and germination percentage. Results in Table (4) showed that cultivar significantly ($p \leq 0.01$) affected the radical length and the final germination percentage, whereas; the differences were not significant for plumule length and seedling vigor index. These results indicated that Barbarei cultivars were found to be sensitive to salinity compared to the locally improved cultivars (Tabat and Wad-Ahmed). Tabat seems to be more salt tolerant cultivar. These results were similar to findings obtained by El Naim *et al.*, (2012) that Wad-Ahmed cultivar was found to be salt tolerant during seedling biomass production compared with other cultivars studied, and they revealed a broad intra specific variation in sorghum varieties for salt stress with respect to their early biomass production.(Almodares and Dosti, 2007; Almodares *et al.*, 2013; Tabtabaei and Angholi, 2012 and Tigabu *et al.,* 2012) observed remarkable difference among some sorghum cultivars. Asfaw (2011) affirmed the presence of broad intra-specific genetic variation in sorghum accessions for salt stress.

3.3. Treatments Interaction

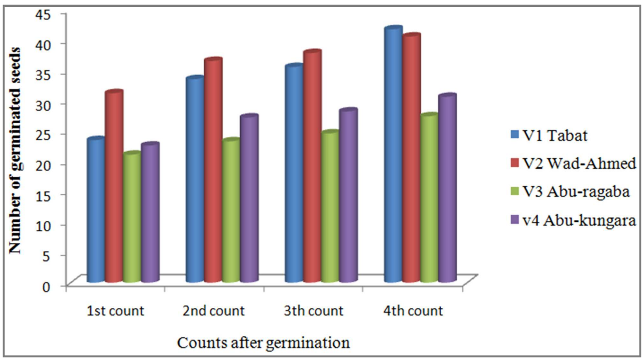

Fig. 3. Effect of cultivar on number of germinated seeds

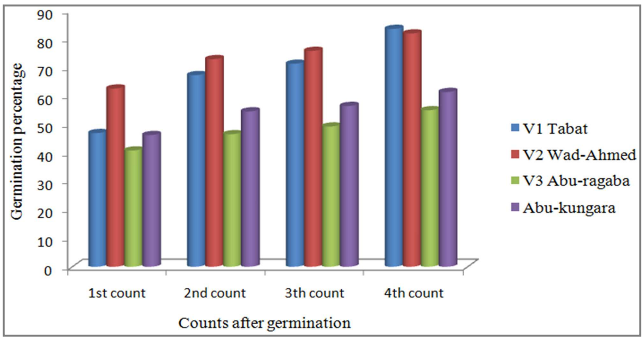

Fig. 4. Effect of cultivar on germination percentage

The interaction of salinity level × cultivar exerted significant effect ($p \leq 0.05$) on plumule length, radical length and final germination percentage, as showed in (Tables 5, 6 and 7). The shortest plumule length was produced by Wad-Ahmed and Tabat cultivars under higher salinity level (1.5% NaCl). Radical length followed the same trend of the plumule length, whereas the lower germination percentage were obtained with Barbarei cultivars (Abu-kungara and Abu-ragaba) respectively. This might be due to genetic variation of the sorghum cultivar to salt tolerance. Kandil *et al.,* (2012) reported that results clearly showed that germination index, seedling vigor index, shoot and root lengths, shoot and root fresh and dry weights, seedling height reduction and relative dry weight significantly affected by the interaction between forage sorghum cultivars and salinity concentrations.

Table 4. Effect of cultivar on germination and seedling characteristics under different salinity levels

Cultivar	PL	RL	FGP	SIV
Tabat	2.1a	1.9b	83.5a	1.85a
Wad-Ahmed	1.8a	1.8b	81.9a	1.63a
Abu-ragaba	2.1a	2.0b	55b	1.59a
Abu-kugara	0.6a	2.9a	61.4b	1.74a
C.V%	22	33.4	23.7	47.2
LSD	0.62ns	0.51**	11.87**	0.57 ns

Note: Means within the column having the same letter are not significantly different

SIV= Seedling vigor index, FGP=Final germination percentage, PL= Plumule length (cm), RL= Radical length (cm).

Table 5. Effect of interaction of salinity × cultivar on plumule length (cm)

Treatments	V1 Tabat	V2 Wad-Ahmed	V3 Abu-ragaba	V4 Abu-kungara
0% NaCl	3.5b	3.63b	3.5b	4.93a
0.5 % NaCl	2.5c	2.3c	3.13b	1.53d
1% NaCl	1.38d	0.43d	0.9d	1.63d
1.5 % NaCl	0.9d	0.9d	0.2e	0.28de
Mean	2.07	1.81	1.93	2.84

Note: Means within the column having the same letter are not significantly different

Table 6. Effect of interaction of salinity × cultivar on Radical length (cm)

Treatments	V1 Tabat	V2 Wad-Ahmed	V3 Abu-ragaba	V4 Abu-kungara
0% NaCl	3.5b	3.88b	3.5b	4.93a
0.5 % NaCl	2.53c	2.05c	2.63c	4.63a
1% NaCl	1.15c	1.13c	1.35c	1.75c
1.5 % NaCl	0.5d	0.3d	0.43d	0.33d
Mean	1.92	1.84	1.98	2.91

Note: Means within the column having the same letter are not significantly different

Table 7. Effect of interaction of salinity × cultivar on germination percentage

Treatments	V1 Tabat	V2 Wad-Ahmed	V3 Abu-ragaba	V4 Abu-kungara
0% NaCl	96.5a	98.5a	97a	98a
0.5 % NaCl	96.5a	97.5a	76.5b	87.5a
1% NaCl	79ab	93.5a	36e	48d
1.5 % NaCl	62c	38de	10.5h	12h
Mean	83.5	81.9	55	61.4

Note: Means within the column having the same letter are not significantly different

4. Conclusion

The current study indicated that increasing NaCl concentration affected seed germination, germination percentage, seedling vigor index plumule length and radical length, of sorghum cultivars. Barbarei cultivars were found to be sensitive to salinity when compared to locally improved cultivars (Tabat and Wad-Ahmed); Tabat seems to be more salt tolerant cultivar. Field experiments should be conducted to confirm the results.

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Biography

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