Effect of Salinity on Growth of Some Cultivars of Sorghum in Nigerian Sudan Savannah Region

ABSTRACT

This research work was carried out to determine the effect of different concentrations of sodium chloride (NaCl) on the growth performance of three cultivars of Sorghum (*Sorghum bicolor)* viz., SAMSORG 46 (Zabuwa), SAMSORG 45 (Deco) and Farfara. Nursery experiment was conducted at Botanical Garden of the Department Federal University Dutse (FUD). The experiment was laid in completely randomized block design, which had three replicates. Treatment employed consist of different concentrations of NaCl, with electric conductivity (EC) of 1.0 dsm^{-1}, 2.0 dsm^{-1}, 3.0 dsm^{-1}, 4.0 dsm^{-1}, and 5.0 dsm^{-1}, in addition to 0.0 dsm^{-1}, which served as control. Growth parameters assessed were Plant height, Number of branches, Fresh Weight and Dry Weight. The data collected was analyzed using analysis of variance (ANOVA). The result revealed that salinity different concentrations growth parameters by suppressing growth and development at times. Poor growth was showed in Deco cultivars in both plant height, number of leaves, fresh and dry weight, by the time salinity exceeds 5dsm^{-1} might perish. Thus, there was no significant interactions in most of the characters studied. The Study concludes that high concentrations of salt has effect on the plant growth, though the effect and the different variety differs, as such screening exercise in respect of salinity tolerance of other cultivars and for optimum vegetative growth and yield. Thus, further studies should be carries out on the cytology characteristics of the Sorghum cultivars.

Key words: Farfara, Deco, Salinity, Sorghum, Sudan Savannah, Zabuwa

1.0 INTRODUCTION

Salinity of arable land is one of the major abiotic stresses, which along with the world population is increasing simultaneously at very rapid pace [1]. In some of the developing countries especially those located in the arid regions, more than 50% of our arable lands are affected by salinity [2], while it is anticipated that that about 6.8 billion of anticipated 8 billion people would be living in these countries [3]; [4]. Sorghum and sorghum based food are our major primary nutrition which needs to be increased by 40% if food security is to be ensured to this much population. This is possible only through cultivation of saline lands provided.

The beginning of 21st century is marked by global scarcity of water resources, environmental pollution and increased salinization of soil and water [5]. Increasing human population and reduction in land available for cultivation are two threats for agricultural sustainability [6].

Numerous environmental stresses, high winds, extreme temperatures, soil salinity, drought and flood have affected the production and cultivation of agricultural crops, among this soil

salinity is one of the most devastating environmental stress, which causes major reductions in cultivated land area, crop productivity and quality [7][8].

Moreover, it has been estimated that worldwide 20% of total cultivated and 33% of irrigated agricultural lands are afflicted by high salinity [9] [4]. Furthermore, the salinized areas are increasing at a rate of 10% annually for various reasons, including low precipitation, high surface evaporation, weathering of native rocks, irrigation with saline water, and poor cultural practices. It has been estimated that more than 50% of the arable land would be salinized by the year 2050 [4] [10].

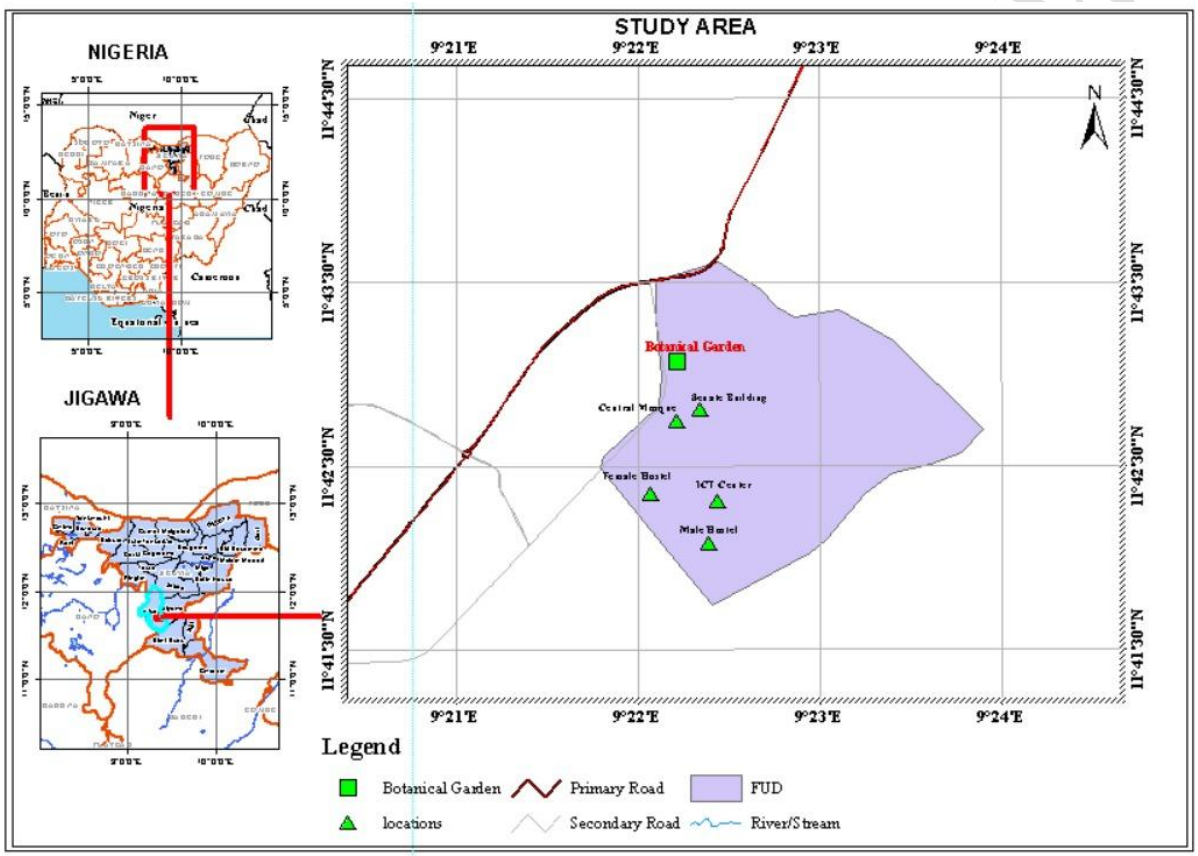
The current global climate change is affecting agricultural and other human activities. Flooding and drought resulting from the change, the coastal areas of Nigeria are getting affected heavily by salinization. Salinity survey of irrigated schemes in the northern Nigeria [11] have shown that certain soils in Borno, Adamawa, Kano and Sokoto states vary from non-saline to moderately saline. Other areas include Hadejia-Jama'are wetland, Nguru wetland, and Kura Kadawa among others [12]. Salinity is a serious threat affecting our food production today. While some plants can tolerate salts some cannot. This implies that many researchers are still interested in how salinity impacts cellular organelles and metabolic processes. Therefore, the study was aimed at assessing the effect of salinity on growth of some of selected cultivars of sorghum plant (*Sorghum bicolor* (L) Moench) viz. SAMSORG 46 (Zabuwa), SAMSORG 45 (Deco) and Farfara (Local cultivars).

2.0 MATERIALS AND METHODS

2.1 Study Area

Dutse is the capital city of Jigawa State in northern Nigeria. With an estimated population of 153,000 [26].With an estimated population of 153,000 [27]. Dutse is currently the largest city in Jigawa State followed by Hadejia (111,000), Gumel (43,000) and Birnin Kudu (27,000). The state was created in 1991 during the military regime of General Ibrahim Badamasi Babangida. Dutse (Dutsi, in earlier notes) got its name from the rocky topography peculiar to the area. Different forms of rocks can be seen widely spread across the town. Mostly igneous in nature, the rocky town got its name from this naturally endowed resources, Dutse (Hausa term for rock). Dutse and its environ are well known for Date Trees (Dabino) of different variety. The area is characterized with undulating topography and hilly walls. The name Jigawa (from Jigayi) is attributed to such topology. The city stands on an average elevation: 437 m. Peculiar to the North-Western states, the population of Dutse are

predominantly Hausa and Fulani. With availability of agrarian land, the inhabitants of Dutse are predominantly farmers; other occupations typical to rural area are also available among the populace. The dry season in Dutse is partly cloudy and hot all year round, whereas the wet season is muggy and cloudy. The average annual temperature ranges between 54 and 103 degrees Fahrenheit, with lows of 49 and highs of 107 degrees being rare (Weather spark, 2023). May is the hottest month in Dutse, which has a hot season from March 18 to May 23. January is the coldest month during the cool season, which runs from December 4 to January 28 [28].



Source: (Field work, 2021)

Figure 1: Map Showing Experimental Site (Botanical Garden-FUD)

2.2 Sample Procurement and Authentication

Three different cultivars of sorghum seeds were obtained from the International Crop Research Institute of Semi-Arid Tropics, Kano substation (ICRISAT) Nigeria, which consist of 2 improved cultivars and one local cultivar, the various sorghum genotypes obtained were kept in airtight polythene bag, in a dry place in the laboratory. In addition, Nursery experiment was conducted at the Botanical Garden, Federal University Dutse (FUD) (Fig. 1).

2.3 Salinity Preparation

The perfect and suitable salinity level (artificial salt stress factor) ionized salt (NaCl) was obtained from the post graduate laboratory of the Federal University Dutse (FUD). A stock solution was prepared by using distilled water and NaCl, with an electric conductivity meter (HI 9813-6) up to 6-7dsm^{-1}.

2.4 Experimental Site and Procedure

The experimental procedure was Complete Randomized Design (CRD) with three replications; The Treatment combination involved 3 cultivars of sorghum referred to as Zabuwa, Deco, and Farfara, and five salt levels including 0dsmol^{-1}, 1dsmol^{-1}, 2dsmol^{-1}, 3dsmol^{-1}, 4dsm^{-1}, and 5dsmol^{-1}, referred to as S_0, S_1, S_2, S_3, S_4, and S_5, respectively. The three cultivars and five salt levels were factorially combined giving 18 treatment combinations which were replicated three times.

The different cultivars of sorghum were grouped in individual polythene pot in a square division of 3 replications each containing 18 seedlings in a polythene pot, each was tagged with the treatment salt concentration and the type of sorghum cultivars, in addition to control (distilled water).

Table 1: Treatment Combinations

Cultivar	Salt Level					
	Control 0dsm^{-1} (S_0)	**Salt treatment 1dsm^{-1} (S_1)**	**Salt treatment 2dsm^{-1} (S_2)**	**Salt treatment 3dsm^{-1} (S_3)**	**Salt treatment 4dsm^{-1} (S_4)**	**Salt treatment 5dsm^{-1} (S_5)**
Zabuwa 46 (V_1)	V_1S_0	V_1S_1	V_1S_2	V_1S_3	V_1S_4	V_1S_5
Deco 45 (V_2)	V_2S_0	V_2S_1	$V_2S_{2\backslash}$	V_2S_3	V_2S_4	V_2S_5
Farfara (V_3)	V_3S_0	V_3S_1	V_3S_2	V_3S_3	V_3S_4	V_3S_5

(V1) SAMSORG 46 (Zabuwa), (V 2) SAMSORG 45 (Deco), (V3) Local cultivars (Farfara), Concentration of the salt (S).

2.5 Soil Preparation

The method of Aghalibe *et al.* [29] with slight modification was adopted. The soil sample used for the study was collected from the top soil of the botanical garden, FUD using a soil auger. The cow dungs were obtained from the university farm (FUD-Farm). The two (soil and cow dung) were mixed at a proportion of (50:50 ratio). The mixture were packaged in a polythene bag measuring (30cm×15cm) labeled appropriately according to the treatment combinations (aforementioned).

2.6 Sowing

The three Sorghum cultivars (Zabuwa, Deco and Farfara) were planted manually in the polythene bag and labeled appropriately according to the treatment combinations, each polythene bag was planted with 8 seed of the sorghum, to enable weekly examination of the growth parameters. Weeds were controlled manually weeks after planting.

2.7 Growth Parameters

The following are the parameters were measured: Plant height, and the number of leaves [13], fresh weight, and dry weight [14].

2.7.1 Plant Height of Zabuwa, Deco and Farfara Sorghum cultivars

Plant height (cm) was measured subsequently at 7 day intervals starting at first week after planting (WAP) up to 5 weeks after planting (WAP). The height was determined by measuring by using a measuring tape for each replicate sample from the 3 block respectively and the mean average was taken per section.

2.7.2 Number of Leaves of Zabuwa, Deco and Farfara Sorghum cultivars

The number of leaves per plant was determined by counting weekly for each treatment.

2.7.3 Fresh Weight of Zabuwa, Deco and Farfara Sorghum cultivars

Each plant per treatment combination were uprooted and weighed in the laboratory by using a weighing balance (ATY224 Model no. De0753144) with the capacity of 220g at 0.1mg, and the average height was taken in grams [15].

2.7.4 Dry Weight of Zabuwa, Deco and Farfara Sorghum varieties

Each plant per treatment combination were oven dried at 70°C for 48hrs and weighed in the laboratory using a weighing balance, and the average height was taken in grams [15].

2.8 Data Collection and Analysis

Determination of growth parameters was done as follows, plant height, and the number of leaves, and was taken weekly for 5 weeks, fresh weight, and dry weight were taking at two weeks interval. The obtained data were further analyzed for statistical significance using two way ANOVA, and significance means were subjected to post hoc analysis using least significant different (LSD) at 5%.

3.0 RESULTS

3.1 Growth Parameters

3.1.1 Effect of Salinity on the Plant Height of Zabuwa, Deco and Farfara Sorghum cultivars

The result revealed that at 1st week after planting, treatment 4dsm^{-1} had an increase in plant height while treatment 3dsm^{-1} had a shortest plant, but as the plants grow over time in 5th week after planting, treatment 3dsm^{-1} and 4dsm^{-1} produces the tallest plants while treatment 5 has the shortest plants (Table 2). Among the three verities studied, variety one (zabuwa) produces the tallest plant in 1st week, while variety 2 (Deco) has the shortest plants, but as the plant grow over time in 5th week variety 2 (Deco) produces the tallest plant while variety one (Zabuwa) has the shortest plants. Thus, there was no significant interactions between the salts and the different varieties studied.

Table 2: Effect of Different Salinity levels on the Height (cm) of Sorghum Plants

Treatments	**Mean height (cm) of sorghum cultivars at weeks after planting**				
Salinity	**1WAP**	**2WAP**	**3WAP**	**4WAP**	**5WAP**
0 dsm^{-1}	6.3[a]	11.1[a]	25.1[bc]	42.1[a]	48.0[a]
1 dsm^{-1}	7.8[a]	11.3[a]	36.4[a]	45.7[a]	51.9[a]
2 dsm^{-1}	7.6[a]	9.0[a]	36.9[a]	45.0[a]	52.2[a]
3 dsm^{-1}	6.0[a]	11.6[a]	23.1[c]	46.0[a]	48.3[a]
4 dsm^{-1}	8.4[a]	19.8[a]	33.4[ab]	46.2[a]	54.2[a]
5 dsm^{-1}	6.4[a]	10.9[a]	30.1[abc]	43.1[a]	47.6[a]
LSD (P≤ 0.05)	2.31	10.09	8.24	7.74	6.82
Sorghum cultivars					
Zabuwa (V1)	9.5[a]	11.7[a]	33.1[a]	42.6[a]	49.7[a]
Deco (V2)	5.6[b]	12.2[a]	25.9[b]	45.6[a]	51.6[a]
Farfara (V3)	6.2[b]	12.9[a]	33.6[a]	45.9[a]	49.7[a]
LSD (P≤ 0.05)	1.63	7.13	5.83	5.48	4.82
Interactions					
Sal *S Var	**NS**	**NS**	**NS**	**NS**	**NS**

Values within columns in Table above followed by the same letter are not significantly different at P≤ 0.05 according to LSD.

(V1) SAMSORG 46 (Zabuwa), (V 2) SAMSORG 45 (Deco), (V3) Local Variety (Farfara), (NS) Not Significant

3.1.2 Number of Leaves of *Zabuwa, Deco* and *Farfara* Sorghum varieties

The result revealed that at the earlier sampling period that is week 1, treatment 4dsm^{-1} has the highest number of leaves while treatment 3dsm^{-1} has the least number of leaves, but as the plants grow over time in 5th week, treatment 3dsm^{-1} and 1dsm^{-1} produces the highest number of leaves, while treatment 4dsm^{-1} and 5dsm^{-1} has the least number of leaves (Table 3).

Among the three cultivars studied, variety one (*Zabuwa*) produces a large number of leaves in week one, while variety 3 (Deco) has the least number of leaves, but as the plant grow over time in 5th week variety 3 (Farfara) produces. A large number of leaves while variety one (Zabuwa) has the least number of leaves. There were no significant correlation between salinity and cultivars studied.

Table 3: Effect of different salinity levels on the number of leaves of sorghum plants.

Treatments	Mean Number of leaves of Sorghum Plants at Weeks After planting				
Salinity Levels	**1WAP**	**2WAP**	**3WAP**	**4WAP**	**5 WAP**
0 dsm^{-1}	22.9^{ab}	13.8^{abc}	26.7^{a}	35.1^{a}	29.6^{a}
1 dsm^{-1}	27.8^{ab}	16.3^{ab}	28.9^{a}	34.2^{a}	30.4^{a}
2 dsm^{-1}	30.4^{ab}	16.9^{a}	26.4^{a}	33.7^{a}	29.7^{a}
3 dsm^{-1}	20.9^{b}	12.2^{c}	25.6^{a}	35.3^{a}	30.4^{a}
4 dsm^{-1}	32.4^{a}	16.7^{a}	26.0^{a}	33.3^{a}	28.6^{a}
5 dsm^{-1}	29.6^{ab}	13.0^{bc}	26.6^{a}	33.2^{a}	28.6^{a}
LSD (P≤ 0.05)	8.87	3.35	7.88	9.31	10.24
Sorghum cultivars					
Zabuwa (V1)	42.2^{a}	16.9^{a}	25.9^{a}	32.0^{a}	28.5^{a}
Deco (V2)	20.9^{b}	12.3^{b}	26.2^{a}	34.2^{a}	28.8^{a}
Farfara (V3)	18.8^{b}	15.2^{a}	28.0^{a}	36.2^{a}	31.3^{a}
LSD (P≤ 0.05)	6.27	2.37	5.57	6.58	7.24
Interactions					
Sal *S Var	NS	NS	NS	NS	NS

Values within columns in Table above followed by the same letter are not significantly different at P≤ 0.05 according to LSD.

(V1) SAMSORG 46 (Zabuwa), (V 2) SAMSORG 45 (Deco), (V3) Local Variety (Farfara), (NS) Not Significant

3.1.3 Fresh Weight and Dry Weight of Zabuwa, Deco and Farfara Sorghum varieties

The result reveals that at the early stage of the plant growth, treatment $1dsm^{-1}$ had more fresh weight, and treatment $3dsm^{-1}$, $5dsm^{-1}$, and the control had less fresh weight, while in the fourth week treatment $1dsm^{-1}$ also has more fresh weight and treatment $3dsm^{-1}$ has the least fresh weight.

In the second week of the dry weight observed, all the plants weigh the same while in the second week treatment $2dsm^{-1}$ and the control has more weight than the rest.

Among the different verities at early stage of the plant growth, variety 1 (Zabuwa) showed more weight in the fresh weight, while variety 2 (Deco) was the least in fresh weight of the plant, while in the later stage V3 (Farfara) has more weight, variety 2 (Deco) was still the least on weight. The dry weight were seen to be averagely equal in all the three varieties across the weeks observed respectively (Table 4).

Table 4: Effect of different levels of salinity on the weight of fresh and dry tissues of sorghum plants

Treatments	Mean weight (g) of Fresh and Dry Tissues of Sorghum Plants at Weeks After planting			
Salinity Levels	**Fresh Tissues**		**Dry Tissues**	
	2ND WAP	**4TH WAP**	**2ND WAP**	**4TH WAP**
0 dsm^{-1}	0.4 [a]	1.0 [a]	0.1 [a]	0.3 [a]
1 dsm^{-1}	0.6 [a]	1.3 [a]	0.1 [a]	0.2 [a]
2 dsm^{-1}	0.5 [a]	1.1 [a]	0.1 [a]	0.3 [a]
3 dsm^{-1}	0.4 [a]	0.3[b]	0.1 [a]	0.2 [a]
4 dsm^{-1}	0.5 [a]	1.0 [a]	0.1 [a]	0.2 [a]
5 dsm^{-1}	0.4 [a]	0.9 [a]	0.1 [a]	0.2 [a]
LSD (P≤ 0.05)	0.22	0.7	0.04	0.16
Sorghum cultivars				
Zabuwa (V1)	0.6 [a]	1.0 [a]	0.1 [a]	0.2 [a]
Deco (V2)	0.3[b]	0.5[b]	0.1 [a]	0.2 [a]
Farfara (V3)	0.5 [a]	1.3 [a]	0.1 [a]	0.2 [a]
LSD (P≤ 0.05)	0.16	0.46	0.03	0.11
Interactions				
Sal *S Var	NS	NS	NS	NS

Values within columns in Table above followed by the same letter are not significantly different at P≤ 0.05 according to LSD.

(V1) SAMSORG 46 (Zabuwa), (V 2) SAMSORG 45 (Deco), (V3) Local Variety (Farfara), (NS) Not Significant

4.0 DISCUSSION

4.1 Growth Parameters

4.1.1 Plant Height of Zabuwa, Deco and Farfara Sorghum Plants

The result of the findings revealed that, as the plant grows over time, variety 2 (Deco) generates the tallest plant whereas variety 1 (Zabuwa) has the shortest plants among the three cultivars under study in the fifth week. Variety 1 (Zabuwa) initially develops the tallest plant among the three types tested in the first week. This indicates the plant needs mineral salts for growth at early stage to a reasonable quantity just like the plant needs water. These observations agree with the findings of [15], while working with cowpea he discovered that high concentration of salinity specifically in the range of 4.0 to 5.0 dsm^{-1} inhibited plant growth. Some of the requirements of the plant are mineral salts including Na^{+} and Ca^{+} ions. However, these ions are required in desirable concentration in `the soil, concentration of salts beyond the desired limit required by the plant can lead to disruption [16]. Obviously, the leaf length showed that as salinity levels increases, leaf length reduces significantly and steadily. These results corresponds with the findings of [17] on their research on Response of onion to salinity which shows how different cultivars react to salinity in terms of leaf height.

Although sorghum is a moderately salt-tolerant crop, genotypic differences exist among cultivars. Within the first three weeks (3WAP) of the plant growth variety two (Deco) were the shortest, which proves that some varieties are salt tolerant at early stage while others at growth. Similar works were reported by [18] [19] which says the retardation of growth in the first phase was shown to be due to osmotic stress and in the second phase to ion-related effects caused by high NaCl concentrations. Hence, long term salt stress led to chlorosis and impaired photosynthesis in older leaves [19]. Plant to grow, processes including cell division, cell expansion and maturation are necessary. Any genetic or environmental factor that can interfere with any of such factors will naturally inhibit growth [20]. The effect of excess salt is harmful to plants, causing physiological stress that plants growth characters including height, number of leaves and branches were suppressed [21].

4.1.2 Effect of Salinity on the Number of Leaves

Some cultivars are sensitive at 1^{st} week some at 2^{nd}, 3^{rd}, 4^{th}, or 5^{th} week depending on the morphology of the variety. It is evident that just like water, the plant needs Na^{-} and Cl^{-} ions for growth at early stage to a reasonable amount. The results shows that, in week one,

variation one (Zabuwa) generates the most leaves, while variety three (Farfara) had the few. However, as the plant grows, in week five, variety three (Farfara) produces the most leaves, and variety one (Zabuwa) has the fewest. Concentration of the salt and individual varieties was more prominent at later time of the salt application, suggesting that as plant grow older they absorbed more salts which invariably become more stressing, where by the period overlap with the period of vacoulation and maturation of the plant cells [15][22].

However, concentration of salts beyond the desired limit required by the plant can lead to disruption of the plant [16][15], this is one of the environmental stresses the plant today is seriously battling with particularly because plants do not have specialized excretory organs to eliminate excess salts. The experiment showed that the salinity effect caused some degree of retarding effect on the number of leaves of the plant.

The interchanging ratio of growth among the three varieties studied, proves that some varieties are salt tolerant at early stage while others at later stage of growth. Läuchli, and Grattan [23], reported that in sorghum plants, a notable salt-stress phenotype was observed after 4 days of growth in 200 mM NaCl.

4.1.3 Effect of Salinity on the Fresh and Dry Weight of Sorghum

The results from the fresh weight, showed how genotypic differences exist among cultivars, the statistical analysis indicated that, increased concentration of NaCl reduced the production of fresh and dry matter in all varieties of sorghum. This showed that there is significant difference in integration effects. However, there is no significant difference between the sorghum varieties (no significant difference in main effects) at columns in all NaCl concentrations same thing was reported by Birhane *et al.* [22], who discovered that maximum reduction of root fresh and dry matter of sorghum was observed at the maximum concentration of NaCl. The highest fresh weight of sorghum varieties was observed in Zabuwa and Farfara, whereas Deco was the least one.

The dry weight where seen to be averagely equal in all the three varieties across the weeks observed respectively. But however the plant weight was unimpressive These observation agrees with findings of [24] who observed a decrease in rate of photosynthesis and dry matter content in *Phargnites australis* species due to treatment with Na^- and Cl^- ions.

Variety 2 (Deco) recorded poorly in both the second week and fourth week observed, which shows that variety 2 (Deco) sensitive under saline conditions. This confirmed the work of

[15] who reported that, the inhibition of the salt on shoot dry weight was observed to be greater in plant treated with high concentration of $CaCO_3$ compared to other salts. However generally as the greater the concentration, the lighter the shoot dry weight. He also stated that level of leaf chlorophyll content in a leaf depends on the level of its biosynthesis and rate of its degeneration, which was discovered to increase with salt stress by [25], as compared with the investigated cultivars.

5.0 CONCLUSION

The study concludes that there was no significant interactions in most of the characters studied i.e. most of the cultivars didn't show much significant difference in regards to the stress level used here, so evidently by the time salinity exceed $5dsm^{-1}$, suppression in growth of Deco was observed. This connotes higher concentration of salt has effect on the plant growth, though the effect varies among the cultivars. Hence, it is recommended that factors responsible for increasing soil salinity such as improper method of irrigation, mono cropping, excessive inorganic fertilizer application among others should be studied, checked and controlled to avoid the negative effect of salinity particularly as it is challenging to our food security.

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