International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 09, September-2019

Grain Sorghum Yield and Yield Components Influenced by the Effect of Potassium Fertilizer and Saline Irrigation Water under Arid Land Conditions

Umar Kyari Wulgo, Samir G. M. Al-Solaimani, Fahad M. Alghabari
Department of Arid Land Agriculture, Faculty of Meteorology,
Environment & Arid Land Agriculture, King Abdulaziz University P.O. Box 80208,
Jeddah: 21589, Saudi Arabia

Abstract:- **The study was conducted in 2018 season in order to investigate the effect of K2O fertilizer (0, 100 and 200 kg/ha) using saline irrigation water (2500, 5000 and 7500mg/l) on yield and yield components of two grain sorghum cultivars (Shandaweel and Dorado). The experiment was conducted in the Agricultural Research station of King Abdulaziz University at Hada Al-sham. The layout of the experiment was split-spilt plot design with 4 replicates. The results indicates that there were significant effects of the treatments and there interactions on the Sorghum yield and yield components. Potassium fertilizer (200kg/ha) has increased panicle length, 100 grain weight, grain yield and biological yield. Irrigation water salinity of 7500 (mg/l) has significantly reduced panicle length, 100 grain weight, grain yield and biological yield. The highest 100 grain weight, grain yield and biological yield were recorded from Dorado Cultivar while panicle length is highest in Shandaweel cultivar.**

Keywords: Sorghum, Potassium, yield, components, Salinity, Cultivar.

I. INTRODUCTION

Sorghum (bicolor (L.) Moench) is a significant grain harvest of warm mild regions of moderately low rainfall, high temperatures and saline soils (Boursier and Lauchli, 1990; Alghabari et al., 2015; Barber et al., 2015; Temizgul et al., 2016). Sorghum is one of the five noteworthy cultivated species on the planet since it has a few financially significant potential uses, for example, sustenance (grain), feed (grain and biomass), fuel (ethanol generation), fiber (paper), fermentation (methane creation) and compost (use of organic results) (Tari et al., 2013). Sorghum originates from Africa, from the southern region of the Sahara Desert, where a few firmly related wild species are found (Legwaila et al. 2003). In the European Union and in the USA, sweet sorghum has been reproduced as a promising energy crop (Berenji and Dahlberg 2004), and it is likewise proposed as a possibility for biofuel generation in hot and dry (arid) nations, for example, Nigeria, India, Australia or Mexico (Almodares and Hadi 2009). Despite the fact that sorghum is generally tolerant to drought, a significant number of the territories possibly reasonable for sorghum development experience the ill effects of raised soil salinities, and if soil saltiness outperforms a specific limit, crop development, yields, and quality are decreased (Netondo, Onyango, and Beck, 2004).
High salt concentrations in the saline soils discourage development to a changing degree in crop plants by bringing down water potential and intemperate gathering of ions influencing diverse metabolic processes (Kingsbury, Epstein, and Pearcy, 1984; Sandhu and Dhaliwal, 2018). Saltiness is one of the essential issues that impacts agricultural practice in numerous districts of the kingdom of Saudi Arabia (Aly et al., 2015) Godfrey et al., (2004) revealed that the two sorghum assortments seem to sequester Na+ dominatingly in roots, stems, roots sheaths and old leafs sharp edges saving the developing tissues as resilience system. All things considered, incredibly decreased centralizations of Ca2+, K+ and Mg2+.
Potassium is a significant macronutrient that assumes basic roles identified with the osmotic change, to keeping up turgor and to managing the membrane potential, cytoplasmic homeostasis, protein synthesis, and catalyst activation under salt pressure (Honghua et al., 2018). Potassium (K+) is a basic component for plant development and advancement and is the most bounteous cation in plants, making up 3–5% of a plant's all out dry weight (Marschner 1995). This macronutrient is basic for some, plant procedures, for example, enzyme actuation, protein sunthesis, photosynthesis, osmoregulation during cell extension, stomatal developments, solute phloem transport, electrical balance, regulation of membrane potential, cotransport of sugars, and the support of cation–anion balance in the cytosol just as in the vacuole (Maser et al., 2002). Potassium was found to be a vital factor in the plants' capacity to oversee water deficiency (Parsons et al., 2007). Potassium is a soil aggregating agent which is known to positively affect soil physical properties and in this manner crop yields (Hamza and Anderson, 2003).

II. MATERIALS AND METHODS

Experimental site

The research was conducted in the agricultural research station of king Abdulaziz University, at Hada Al-Sham during the agricultural season (2018/2019). Split-split plot design with 4 replicates was used. The main plots were occupied with 3 irrigation water salinity: S1= 2500 mg/L, S2: 5000 mg/L, S3: 7500 mg/L, subplots contained 2 cultivars of sorghum: CV1 Egyptian local cultivar named Dorado and CV2 another Egyptian cultivar named Shandaweel, and the sub-subplot treatments were 3 K fertilizer at different rates of 0, 100 and 200 kg k2O/ha. Sub-subplot sized 3.2 X 2 m with row distance of 40cm and hill spacing of 30cm with one plant/hill. The plots were fertilized with concentrated superphosphate CSP (P205 at 100kg/ha) and K2O fertilizer at 100 and 200kg/ha according to the design prior to planting. Nitrogen fertilizer was applied at 120kg/ha rate in 5 equal doses in 15, 30, 45, 60 and 75days after planting.

Analysis of Soil before planting

Representative random soil samples from surface layer (0-30 cm depth) were collected from the experimental site before planting for analysis. All samples were homogeneously mixed to form a typical sample for analysis. Samples were air dried, sieved and analyzed for the desired analysis. Soil pH and EC (electrical conductivity) were determined by mixing soil with water 1:1 (W:V) and measured using pH and EC meter . Total organic matter % (OM) in the soil were also determined using the methods that described by Pansu and Gautheyrou (2006). Total soil nitrogen content will be measured by Kjeletec Auto 1030 analyzer using the methods described by Pansu and Gautheyrou (2006). Soil content of P will be determined using Spectrophotometer at light wave 640 nanometer. Soil content of potassium (K) was determined using VARIAN (ICP- Optical Emission Spectrometer).

TABLE (1) INITIAL SOIL ANALYSIS BEFORE PLANTING

pH	**OM (%)**	**EC**	**Macronutrients**					
			N	**P**	**K**	**Ca**	**Mg**	**Na**
		dS/m	%					
7.83	1.34	4.37	0.05	0.0011	0.0535	0.132	0.0975	0.0132

Soil depth (cm)	**Soil particles distributions (%)**			**Soil texture**
	Sand	Silt	Clay	
0-30	83.7	12.4	7.64	Loamy Sand

Measurement

Ten random Sorghum samples were taken from each plot and the following readings were recorded:

Panicle length (cm), 100 grain weight t/ha, Grain yield t/ha and Biological yield.

Data Analysis

Statistical analysis was conducted for the recorded information according to the experimental design. Analysis of variance of the treatment means were conducted using SAS program (SAS, 2006). The statistical comparison of the treatment means were tested by RLSD at ($P \le 0.05$) according to according to El-Nakhlawy (2010).

III. RESULTS

Analysis of Variance of Sorghum yield and yield components

It was revealed that statistical analysis of the effect of irrigation water salinity on the sorghum yield and components viz; panicle length, 100 grain weight (g), grain yield t/ha and biological yield t/ha were statistically significant at ($P \le 0.01$) as presented in (table 2). The effect of sorghum cultivars (Dorado and Shandaweel) on the other hand were found to be non-significant at ($P \le 0.05$) on the sorghum yield and yield components. The effects of K2O fertilizer on sorghum yield and yield components mentioned above were found to show significant variation among the studied sorghum parameters as presented in (table 2) at ($P \le 0.01$).

The interaction effect of irrigation water salinity and cultivar as presented in (table 2) shows no significant variations among the studied sorghum yield and yield components at ($P \le 0.05$). Interaction effect of irrigation water salinity and K2O fertilizer at (table 2) depicted that all the determined parameters of sorghum yield and yield components were not significantly different at ($P \le 0.05$) except plant gain weight (t/ha) which is highly significant at ($P \le 0.01$). The effect of cultivar and K2O fertilizer indicated no significant variations at ($P \le 0.05$) among the studied sorghum yield and yield components. Three factor interaction effects of irrigation water salinity, cultivar and K2O fertilizer were observed to have no significant variations at ($P \le 0.05$).

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 09, September-2019

TABLE (2) ANALYSIS OF VARIANCE OF PANICLE LENGTH, 100 GRAIN WEIGHT, GRAIN YIELD AND BIOLOGICAL YIELD UNDER THE EFFECT OF IRRIGATION WATER SALINITY, CULTIVAR AND FERTILIZER RATES 2018/2019 SEASON.

Source of variation	**Df**	**Ms**			
		Panicle length (cm)	**100 grain weight (g)**	**Grain yield (t/ha)**	**Biological yield (t/ha)**
Replicate	3	8.8	0.28	2.79	234.3
Irrigation water salinity (a)	2	146.6 **	6.67 **	26.95 **	73.4 **
Error (a)	6	7.1	0.17	0.15	5.7
Cultivars (b)	1	1.7	0.35	0.63	493.7
a*b	2	4.0	0.41	0.12	5.4
Error (b)	9	7.8	0.26	0.49	212.8
Fertilizer (c)	2	170.1 **	5.10 **	24.21 **	1204.0 **
a*c	4	9.3	0.47	0.70 **	15.2
b*c	2	18.2	0.18	0.10	17.3
a*b*c	4	5.8	0.06	0.04	9.3
Error (c)	36	8.23	0.23	0.146	20.29

NS: Not significant at P≤0.05
* : significant at P≤0.05
** : significant at P≤0.01

Effect of K2O fertilizer on Sorghum yield and yield components

Panicle length and 100 grain weight

The results of the means of panicle length and 100 grain weight under the K2O fertilizer treatment indicates that they have the highest mean values of 28.83cm and 2.98g as influenced by 200 kg/ha of the fertilizer and least value of 23.55cm and 2.06g at the control (zero kg/ha) as seen in (table 3.0) respectively. Both panicle length and 100 grain weight seem too responded positively to K2O fertilizer showing significant variations among the means.

TABLE (3) MEANS OF PANICLE LENGTH, 100 GRAIN WEIGHT, GRAIN YIELD AND BIOLOGICAL YIELD UNDER THE EFFECT OF IRRIGATION WATER SALINITY, CULTIVAR AND FERTILIZER RATES 2018/2019 SEASON.

* Means followed by the same letter are not significantly different according to LSD at P≤0.05

Source of variation	**Panicle length**	**100 grain weight (g)**	**Grain yield (t/ha)**	**Biological yield (t/ha)**
Irrigation water salinity(mg/l)				
2500	28.33 a	3.05 a	4.60 a	24.96 a
5000	26.23 b	2.53 b	3.49 b	23.41 a
7500	23.41 c	2.00 c	2.48 c	21.47 b
LSD	1.89	0.294	0.277	1.68
Cultivars				
Shandaweel	26.14	2.46 a	3.43 a	20.66 a
Dorado	25.83	2.60 a	3.62 a	25.90 a
LSD	1.49	0.276	0.375	7.77
K2O fertilizer (kg/ha)				
Zero	23.55 c	2.06 c	2.55 c	16.36 c
100	25.59 b	2.55 b	3.47 b	22.97 b
200	28.83 a	2.98 a	4.56 a	30.51 a
LSD	1.67	0.284	0.224	2.63

TABLE (4) MEANS OF PANICLE LENGTH, 100 GRAIN WEIGHT, GRAIN YIELD AND BIOLOGICAL YIELD UNDER THE INTERACTION EFFECT OF IRRIGATION WATER SALINITY AND CULTIVAR 2018/2019 SEASON.

* Means followed by the same letter are not significantly different according to LSD at P≤0.05

Source of variation		**Panicle length(cm)**	**100 grain weight (g)**	**Grain yield (t/ha)**	**Biological yield (t/ha)**
Irrigation water salinity(mg/l)	Cultivars				
2500	Shandaweel	28.94	2.83	4.50	22.88
	Dorado	27.73	3.27	4.71	27.05
5000	Shandaweel	26.04	2.57	3.47	20.42
	Dorado	26.42	2.50	3.50	26.41
7500	Shandaweel	23.45	1.97	2.33	18.69
	Dorado	23.36	2.02	2.64	24.25
LSD		NS	NS	NS	NS

TABLE (5) MEANS OF PANICLE LENGTH, 100 GRAIN WEIGHT, GRAIN YIELD AND BIOLOGICAL YIELD UNDER THE INTERACTION EFFECT OF IRRIGATION WATER SALINITY AND K2O FERTILIZER 2018/2019 SEASON.

Source of variation		Panicle length (cm)	100 grain weight (g)	Grain yield (t/ha)	Biological yield (t/ha)
Irrigation water salinity(mg/l)	**K2O fertilizer rates (kg/ha)**				
2500	Zero	27.24	2.27	3.43	18.9
	100	27.47	3.17	4.39	24.2
	200	30.30	3.72	5.98	31.6
5000	Zero	23.10	2.17	2.54	16.0
	100	25.71	2.56	3.42	22.0
	200	29.87	2.87	4.51	32.0
7500	Zero	20.31	1.73	1.68	14.0
	100	23.59	1.91	2.59	22.5
	200	26.32	2.35	3.18	27.7
LSD		NS	NS	0.387	NS

* Means followed by the same letter are not significantly different according to LSD at P≤0.05

TABLE (6) MEANS OF PANICLE LENGTH, 100 GRAIN WEIGHT, GRAIN YIELD AND BIOLOGICAL YIELD UNDER THE INTERACTION EFFECT OF CULTIVAR AND K2O FERTILIZER 2018/2019 SEASON.

Source of variation		Panicle length(cm)	100 grain weight (g)	Grain yield (t/ha)	Biological yield (t/ha)
Cultivars	**K2O fertilizer (kg/ha)**				
Shandaweel	Zero	24.5	2.05	2.53	14.7
	100	25.7	2.52	3.35	19.6
	200	28.1	2.81	4.41	27.6
Dorado	Zero	22.5	2.07	2.57	18.0
	100	25.4	2.58	3.59	26.2
	200	29.5	3.15	4.70	33.4
LSD		NS	NS	NS	NS

* Means followed by the same letter are not significantly different according to LSD at P≤0.05

TABLE (7) MEANS OF PANICLE LENGTH, 100 GRAIN WEIGHT, GRAIN YIELD AND BIOLOGICAL YIELD UNDER THE INTERACTION EFFECT OF IRRIGATION WATER SALINITY, CULTIVAR AND K2O FERTILIZER 2018/2019 SEASON.

Source of variation			Panicle length (cm)	100 grain weight (g)	Grain yield (t/ha)	Biological yield (t/ha)
Irrigation water salinity(mg/l)	**Cultivars**	**K2O fertilizer (kg/ha)**				
2500	**Shandaweel**	Zero	29.4	2.20	3.32	16.49
		100	27.7	2.97	4.33	22.10
		200	29.6	3.33	5.84	30.03
	Dorado	Zero	25.0	2.35	3.54	21.39
		100	27.2	3.37	4.46	26.44
		200	30.9	4.10	6.13	33.31
5000	**Shandaweel**	Zero	23.9	2.27	2.67	14.76
		100	25.9	2.67	3.35	18.52
		200	28.2	2.76	4.39	27.98
	Dorado	Zero	22.2	2.07	2.41	17.38
		100	25.5	2.46	3.48	25.64
		200	31.4	2.98	4.62	36.20
7500	**Shandaweel**	Zero	20.3	1.67	1.60	12.84
		100	23.6	1.92	2.36	18.45
		200	26.3	2.34	3.01	24.78
	Dorado	Zero	20.3	1.79	1.76	15.28
		100	23.5	1.90	2.82	26.70
		200	26.2	2.37	3.35	30.77
LSD			NS	NS	NS	NS

* Means followed by the same letter are not significantly different according to LSD at P≤0.05

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 8 Issue 09, September-2019

Grain yield t/ha and Biological yield t/ha

The grain yield and Biological yield that sums up to about 4.56t/ha and 30.51t/ha were recorded as the highest means portrayed by the parameters in question as influenced by 200kg/ha K2O fertilizer while 2.55 and 16.36t/ha were observed as their least mean values under the influence of the treatment control (zero kg/ha) as presented in table (3).

Effect of Irrigation water salinity on Sorghum yield and yield components

The main effect of irrigation water salinity on the sorghum yield and yield components was found to show a significant variation according to LSD ($P \leq 0.05$) among the means of all the parameters determined presented in table (4) except biological yield (25.90) at 5000 (mg/l) which depicted non-significant variation. Quantitatively, 2500 (mg/l) has the highest mean values for panicle length (28.33cm), 100 grain weight (3.05g), grain yield (4.60 t/ha) and biological yield (24.96 t/ha) respectively.

Effect of Cultivar (Shandaweel and Dorado) on Sorghum yield and yield components

The main effects of sorghum cultivars (Dorado and Shandaweel) revealed no significant variations among the studied sorghum yield and yield components as presented in table (4) at LSD ($P \leq 0.05$). Among the presented mean values, panicle length (26.14cm) has the highest value under Shandaweel followed by biological yield (25.90t/ha), grain yield (3.62 t/ha) and 100 grain weight (2.60g) under Dorado cultivar.

Interaction effects of irrigation water salinity and cultivar

Even though the interaction shows no significant difference among the means of the parameters presented in table (5), the interaction level of 2500 (mg/l) irrigation water salinity and Dorado cultivar ranked first in influencing the performance of biological weight (27.05t/ha), grain yield (4.71t/ha) and 100 grain weight (3.27g) respectively, while with Shandaweel, panicle length of (28.94cm) was recorded as the highest. Least mean values are indicated at the interaction level of 7500 (mg/l) irrigation water salinity and Shandaweel cultivar for biological yield (18.69t/ha), grain yield (2.331t/ha) and 100 grain weight (1.97g) respectively except panicle length (23.36cm) exhibited with Dorado.

Interaction effect of irrigation water salinity and K2O fertilizer

The result indicated that all the parameters in question show no significant variations among their means in table (5) except plant grain weight (t/ha) showing variations. It was found that 2500 (mg/l) irrigation water salinity and 200kg/ha K2O fertilizer had a greater influence on panicle length (30.30cm), grain yield (5.98t/ha) and 100 grain weight (3.72g) while biological yield (32.0t/ha) responds better to 5000 (mg/l) and K2O fertilizer.

The interaction effect of Cultivar and K2O fertilizer

The results show that there is no significant difference among the means as presented in table (6). By comparison, it can be observed that the interaction of Cultivar Dorado and 200kg/ha K2O fertilizer have the highest mean values for biological weight (33.4t/ha), panicle length (29.5cm), grain yield (4.70t/ha) and 100 grain weight (3.15g) respectively. Cultivar Shandaweel and control K2O fertilizer (zero kg/ha) has the least means for Biological yield (14.7t/ha), grain yield (2.53t/ha) and 100 grain weight (2.05g).

Interaction effects of Irrigation water salinity, Cultivar and fertilizer

There is no significant difference among the means of the studied parameters as seen in table (7). It can be evaluated that Biological yield (36.20t/ha) and panicle length (31.4cm) had their highest mean values at the interaction of 5000 (mg/l) irrigation water salinity, Dorado and 200kg/ha K2O fertilizer. Biological yield (12.84t/ha) is lowest at 7500 (mg/l), Cultivar Shandaweel and control K2O fertilizer (zero kg/ha). Grain yield (6.13t/ha) and 100 grain weight (4.10g) had their highest mean values at 2500 (mg/l), Dorado and 200kg/ha K2O fertilizer and the same grain yield (1.60t/ha) and 100 grain weight (1.67t/ha) had their lowest at 7500 (mg/l), Shandaweel and K2O fertilizer (zero kg/ha).

IV. DISCUSSIONS

The sole purpose of the study was to determine the effect of K fertilizer adding in enhancing sorghum yield and yield attributes under an environmentally arid condition. The results of the findings clearly indicates the significance and the effect of potassium fertilizer (K2O) in improving the sorghum yield and yield components viz; panicle length, 100 grain weight, grain yield t/ha and biological yield t/ha according to the rate of the fertilization. This is ascertained from the results as the K2O levels increases from zero kg/ha to 200kg/ha and the mean values of the parameters increases apparently in its main effects and interactions with other treatments. The results indicates that increase in K2O fertility levels increases the panicle length as well as 100 grain weight of sorghum which may be attributed to the Role of K in increasing photosynthesis as result of an increasingly effective photosynthetic action, expanding leaf size and number and progressively compelling translocation of photoassimilates and amino N compounds into conceptive organs by means of the phloem (Cakmak 2005; Pettigrew 2008).The findings were in conformity with a study conducted by Asgharipour et al., (2011) on Effect of potassium supply on drought resistance in sorghum: plant growth and micronutrient content. The findings on grain yield and Biological yield as shown in (Table 4) weight indicates a remarkable variation among their means which may likely be related to ability of K20 fertilizer in enhancing moisture tolerance as Despite the fact that moisture was the constraining component yet this could be defeated to a limited degree by potassium application (upto 60 ppm) Umar et al.,(1993) in every one of the circumstances. Mengel and Brunschweig (1972) have likewise announced the importance of K under dry condition. The data obtained from this study suggest that there is a close relationship between K application status and the increment in yield and yield components in sorghum plant. The effect of K supply on growth was significant under drought stress conditions since vegetative growth parameters, yield and yield attributes of plants irrigated were greater at Plots fertilized with the K2O in a rate of 100 and 200 kg/ha than control (without K fertilizer). All the studied parameters of panicle length, 100 grain yield, grain yield and biological yield were unquestionably affected by the high salinity levels. This can be observed in table (3) where the recorded mean values of the parameters in question show an apparent decline as the salinity levels change from 2500 (mg/l) to 5000 (mg/l) and finally 7500 (mg/l). It can be seen that all the parameters performed best at 2500 (mg/l): 3.05(g), 4.60 (t/ha), 24.96 (t/ha) and 28.33(cm) for 100 grain weight, grain yield, biological yield and Panicle length respectively. 100 grain weight, grain yield, biological yield and Panicle length all least performed at 7500 (mg/l) with their mean values dropped to 2.00 (g), 2.48 (t/ha), 21.47 (t/ha) and 23.41 (cm) respectively. This is likely due to the fact that salts have the ability to reduce water availability and slow some biochemical processes in plants including sorghum to some extent. This observation is in accordance with (Hasegawa et al., 2000; Munns, 2002) which states that Salts in soil and water can reduce water availability to crops at all stages of plant development and affect physiological and biochemical processes via ion toxicity, osmotic stress and mineral deficiencies to such an extent that yields can be affected.

V.CONCLUSION

The results from this study on sorghum, will significantly add to the available information in an effort to examine the effect of K2O fertilizer in enhancing the Plants yield and yield components under a dry spell. The application of K2O fertilizer up to the range of (200 kg/ha) has improved beyond doubt sorghum yield and yield components viz; panicle length, 100 grain weight, grain yield and Biological yield despite the moisture stressed situation. The sorghum Cultivars Shandaweel and Dorado portrayed non-significant variation on all the studied parameters, however, Dorado cultivar was observed to have higher mean values in 100 grain weight, plant grain yield and biological weight while on the contrary, Shandaweel was only influential on panicle length. The Productivity of both the cultivars as well as the K20 rates applied decline apparently as the salinity levels increases from 2500 (mg/l) to 7000(mg/l).

REFERENCES

[1] A. Almodares, & M. R. Hadi, "Production of bioethanol from sweet sorghum": A review. African Journal of Agricultural Research, 4(9), 772-780. 2009.

[2] A. A. Aly, A. M. Al-Omran, & M. M. Alharby. "The water quality index and hydrochemical characterization of groundwater resources in Hafar Albatin, Saudi Arabia". Arabian Journal of Geosciences, 8(6), 4177-4190. 2015.

[3] H. M. Barber, J. Carney, F. Alghabari, & M. J. Gooding. "Decimal growth stages for precision wheat production in changing environments?." Annals of applied Biology, 166(3), 355-371.2015.

[4] M. R. Asgharipour, & M. Heidari. "Effect of potassium supply on drought resistance in sorghum": plant growth and macronutrient content. Pak. J. Agri. Sci, 48(3), 197-204. 2011.

[5] J. Berenji, & J. Dahlberg. "Perspectives of sorghum in Europe". Journal of Agronomy and Crop Science, 190(5), 332-338. 2004.

[6] Boursier, Patrick, and Andre Lauchli. "Growth Responses and Mineral Nutrient Relations of Salt-Stressed Sorghum." Crop Science. 1990.

[7] I. Cakmak. "The role of potassium in alleviating detrimental effects of abiotic stresses in plants". Journal of Plant Nutrition and Soil Science, 168(4), 521-530. 2005.

[8] F. S. El-Nakhlawy. "Experimental design and analysis in scientific research". Sci. Pub. Center, King Abdul Aziz University, Saudi Arabia. 2010.

[9] J. Godfrey, C. Onjango, & E. Beek. "Sorghum and salinity". Crop Science, 44, 806-811. 2004.

[10] M. A. Hamza, & W. K. Anderson. "Responses of soil properties and grain yields to deep ripping and gypsum application in a compacted loamy sand soil contrasted with a sandy clay loam soil in Western Australia". Australian Journal of Agricultural Research, 54(3), 273-282. 2003.

[11] P. M. Hasegawa, R. A. Bressan, J. K. Zhu, & H. J. Bohnert. "Plant cellular and molecular responses to high salinity". Annual review of plant biology, 51(1), 463-499. 2000.

[12] R. W. Kingsbury, E. Epstein, & R. W. Pearcy. "Physiological responses to salinity in selected lines of wheat". Plant physiology, 74(2), 417-423. 1984.

[13] G. M. Legwaila, T. V. Balole, & S. K. Karikari. "Review of sweet sorghum: A potential cash and forage crop in Botswana". UNISWA Journal of Agriculture, 12(1), 5-14. 2003.

[14] R. C. Littell, G. A. Milliken, W. W. Stroup, R. D. Wolfinger, & S. Oliver.. "SAS for mixed models". SAS publishing. 2006.

[15] H. Marschner. "Mineral nutrition of higher plants". 2nd. Edn. Academic Pres. 1995.

[16] P. Mäser, M. Gierth, & J. I. Schroeder. "Molecular mechanisms of potassium and sodium uptake in plants". In Progress in Plant Nutrition: Plenary Lectures of the XIV International Plant Nutrition Colloquium (pp. 43-54). Springer, Dordrecht. 2002.

[17] K. Mengel, & L. C. Von Braunschweig. "The Effect of Soil Moisture upon the Availability of Potassium and its Influence on the Growth of Young Maize Plants (zea Mays L). Soil science, 114(2), 142-148. 1972.

[18] R. Munns. "Comparative physiology of salt and water stress". Plant, cell & environment, 25(2), 239-250. 2002.

[19] Netondo, Godfrey Wafula, John Collins Onyango, and Erwin Beck. "Sorghum and Salinity: II. Gas Exchange and Chlorophyll Fluorescence of Sorghum under Salt Stress." Crop Science. 2004

[20] M. Pansu, & J. Gautheyrou. "Mineralogical separation by selective dissolution". Handbook of Soil Analysis: Mineralogical, Organic and Inorganic Methods, 167-219. 2006.

[21] K. J. Parsons, V. D. Zheljazkov, J. MacLeod, & C. D. Caldwell. "Soil and tissue phosphorus, potassium, calcium, and sulfur as affected by dairy manure application in a no-till corn, wheat, and soybean rotation". Agronomy journal, 99(5), 1306-1316. 2007.

[22] F. Alghabari, M. Z. Ihsan, S. Hussain, G. Aishia, & I. Daur. "Effect of Rht alleles on wheat grain yield and quality under high temperature and drought stress during booting and anthesis". Environmental Science and Pollution Research, 22(20), 15506-15515. 2015.

[23] W. T. Pettigrew. "Potassium influences on yield and quality production for maize, wheat, soybean and cotton". Physiologia plantarum, 133(4), 670-681. 2008.

[24] B. S. Sandhu, & N. S. Dhaliwal. "Evaluation of different wheat cultivars under salinity stress". Journal of Applied and Natural Science, 10(1), 479-481. 2018.

[25] I. Tari, G. Laskay, Z. Takács, & P. Poór. "Response of sorghum to abiotic stresses: a review". Journal of Agronomy and Crop Science, 199(4), 264-274. 2013.

[26] R. Temizgul, M. Kaplan, R. Kara, & S. Yilmaz. "Effects of salt concentrations on antioxidant enzyme activity of grain sorghum". Current Trends in Natural Sciences Vol, 5(9), 171-178. 2016.

[27] S. N. Umar, Rama Rao, G. S. Sekhon. "Differential effects of moisture stress and potassium levels on growth and K uptake in sorghum". Indian J. Plant Physiol., 36: 94-97. 1993.