Response of Sorghum (*Sorghum bicolor* L. Moench) Genotypes to Different Levels of Agricultural Sulfur

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Abstract: A field experiment was conducted in agricultural research station which is located at Al-Qurna district, 75 km north of Basrah governorate during the autumn season 2018. The aim was to study the effect of agricultural sulfur (0, 3, 6 and 9 t S.ha^{-1}) on growth and yield of three sorghum genotypes (Inkath, Rabeh and Kafier2). The experiment was conducted as randomized complete block design in a factorial arrangement with three replications. The results showed that there were significant differences among the genotypes. The genotype kafier2 gave the highest average of plant height of 171.5 cm while the genotype inkath gave the highest weight of 1000 seed (25.59 gm), grain yield (3.97 t.ha^{-1}). Genotype rabeh produced highest average of leaf area index and number of grain head of 3.10 and 1994.41 grain.head^{-1} respectively. The agricultural sulfur showed significant effect on most studied traits of sorghum (plant height, leaf area index, grain head, weight of 1000 grains and grain yield). The addition of agricultural suffer up to 9 t. ha^{-1} increased grain yield and produced 5.80 t.ha^{-1}. The interaction of genotypes and agricultural sulfur showed a significant effect on some traits of growth and grain yield. The genotype inkath supplied with 9 t.ha^{-1} of agricultural sulfur resulted in highest grain yield of 5.80 t.ha^{-1}, while the genotype rabeh supplied with 6 t.ha^{-1} of agricultural sulfur gave the highest average of leaf area index (3.54) and number of grains head (2106.33 grain.head^{-1}).

Keywords: Sorghum, Genotypes, Agricultural sulfur.

Introduction

Sorghum (*Sorghum bicolor* L.) is one of the important strategic forage and grain crop in the world, coming in fifth place after wheat, rice, maize and barley in terms of importance, cultivated area and total production, with a global world cultivated area of 41.25 million hectares and total production of 58.78 million t.ha^{-1}. In Iraq total cultivated area in 2017 reached to 11,064 ha^{-1} with a total production of 2943 thousand tons and average of yield reached to 1064 kg.ha^{-1} (USDA, 2018). The economic importance of sorghum it is considered as staple food for more than 750 million people, especially in Africa, Southeast Asia and Central and South America, In

addition, it is used as a main food for humans or mixed with wheat flour by 50%. The grain of sorghum contain 10% protein and 67% Carbohydrates as well as being a rich source of vitamins (Lupein, 1995). Sorghum and millited in human nutrition. (FAO Food and Nutrition series. No.27.). Sulfur is an essential element for plant growth and production. It involves in the formation of protein through the amino acids (Brosnan & Brosnan, 2006). The study of Al-Daraji (2010) revealed that there are significant differences among four varieties of sorghum, rabeh, babylon, inkath and kafier2. The genotype kafier2 produced higher plant height of 131.90 cm as compared to genotype inkath, which gave the lowest rate of 110.40 cm.

Ahmed & Abood (2016) found in their study that the response of two cultivars of sorghum differ significantly in leaf area. The genotype rabeh gave the highest rate of leaf area reached to 4348 cm^2 as compared to genotype Inkath which produced the lowest rate of 4116 cm^2. El-Fahdawi & Ali (2011) revealed that, the application of sulfur (0, 1000, 2000 and 3000 $kg.ha^{-1}$) lead to significantly increase grain yield and some yield component compensation. The adding of 3000 $kg.ha^{-1}$ to the soil gave the highest of number of grains head, the weight of 1000 grains and the grain yield of 2344 $grains.head^{-1}$, 26.6gm and 8.32 $t.ha^{-1}$ respectively. In recent study on the effect of agricultural sulfur and vitamin C on grain yield and yield components of maize, the results showed that the addition of 4 $Mg.ha^{-1}$ of sulfur increased protein content by 9.77% as compared to the control treatment by 9.15%. (Hussein, 2016).

The present study aims the effect of agricultural sulfur on growth and yield of three sorghum genotypes.

Materials & Methods

A field experimental study was conducted during Autumn growing season of 2018, in Al-Qurna Research Station of Agricultural Scientific Research, Ministry of Agriculture, located 75 km north of Basrah governorate to study the response of three genotype of sorghum (kafier 2, rabeh and inkath) and symbols (V_1, V_2 and V_3), respectively, and for agricultural levels of sulfur (0, 3, 6 and 9 t S.h^{-1}). The soil of the experiment plowed two times vertically using Mold Board Plough, thereafter the soil was grinded using disc harrows, leveled by leveling machine. The experiment carried out using randomized complete block design (RCBD) with three replications in a factorial arrangement. The area of experimental unite was 4.0×2.8 m contains four rows 4m long with distance of 70 cm among rows. Within the row, a distance of 25 cm has been left between plant and another. In order to prevent fertilizer movement among the experimental units a distance of 2.0 m was left. The seeds of Sorghum sowed on 20 July, 2018 by putting 4-5 seeds per seed bed. 15 days after planting the seedlings were thinned to one plant, so the plant density was 57142 $plant.ha^{-1}$. The agricultural sulfur (95% sulfur) was applied one month before planting. Phosphate fertilizer applied once before planting at rate of 100 $kg.ha^{-1}$ in form of triple superphosphate (45% P_2O_5). Nitrogen fertilizer was added at a rate of 200 $kg.ha^{-1}$ in the form of urea (46% N). Urea fertilizer was added in two times, the first one at planting, whereas the second one after 30 days from planting (Ali, 2012). The following

characteristics were measured: plant height, leaf area index, number of grains head, weight of 1000 grains and grain yield. Data were analyzed statistically according to the design used in the experiment, the average of traits were tested by using least significant differences (L.S.D.) at probability level 0.05 El-Sahoki & Wahib (1990).

Table (1) some physical chemical properties of the soil before planting.

Texture	S	K	P	N	Organic matter (gm kg^{-1})	E.C. (dsm^{-1})	pH
		soil (mg kg^{-1})					
Silty loam	95.20	166	19.80	22.27	1.82	3.52	7.45

Results & Discussion

Plant height (cm)

The results of analysis of variance (Table 7) showed that there were highly significant differences of genotypes and agricultural sulfur in plant height. The results of table (2) revealed that the genotype V_1 gave the highest average of plant height of 171.5 cm, while the genotype V_3 gave the lowest rate (121.08 cm). The differences among genotype in plant height could be attributed

to the genetic differences between the genotype and their responses to environment. This result is in consistent with Yaqoob *et al*. (2015) and Attiya (2015). The results indicated in table (2) revealed a significant effect for agricultural sulfur in plant height.

Table (2): Effect of sorghum genotypes, agricultural sulfur and their interaction on plant height (cm).

Sorghum genotypes	Agricultural sulfur levels t S.ha^{-1}				Genotypes mean
	S_0	S_1	S_2	S_3	
V_1	160.33	169.67	175.66	180.33	171.50
V_2	123.50	131.00	141.33	150.00	136.45
V_3	102.66	119.00	127.67	135.00	121.08
Mean sulfur	128.83	139.89	148.22	155.11	
L.S.D (0.05)	Genotypes	agricultural sulfur levels	agricultural sulfur X Genotypes		
	3.41	3.93	N.S		

The addition of S_3 level lead to produced highest plant height of 155.11 cm compared to control treatment S_0, which gave the lowest rate of 128.83 cm. These results are consistent with Zeboon & Al-Hilfy (2014) and Kadhim (2016).

Leaf area index

The results of analysis of variance (Table 7) indicated that there is high significant differences on the genotypes, agricultural sulfur and their interaction. The results of Table (3) revealed that the genotype V_2 (rabeh) gave the highest leaf area index of 3.10 while genotype V_1 (kafier2) gave the lowest leaf area index of 2.35. The differences among the genotypes in leaf area index could be related to the genetic differences between the genotypes, so this revealed that V_2 was more adapted to the local environmental condition as compared to other genotypes. These results are consistent with Al-Jubory & Al-Zubaidy (2013) & Ali *et al.* (2017). The results of table (3) revealed a significant effect foragricultural sulfur in leaf area index. The S_3 treatment gave the highest value of this characteristic (3.18) compared to

the control (S_0), which gave the lowest rate leaf area index (2.34). These results are consistent with Hamza & Al-Amri (2007), El-Fahdawi & Ali (2011) and Zeboon & Al-Hilfy (2014). The results of table (3) indicated a significant interaction among genotypes and the levels of agricultural sulfur. The genotype V_2 under the level S_3 of agricultural sulfur gave the highest rate of the leaf area index of 3.54, while the genotype V_1 under S0 agricultural sulfur gave the lowest leaf area index of 2.05. This type of response is due to the effect of single factors.

Grain numbers head

The results of analysis of variance (Table 7) showed that there is high significant differences between the genotypes, agricultural sulfur and their interaction. The results of table (4) indicated that genotype V_2 gave the highest average of grain number head of (1994.41 grain.head^{-1}) as compared to the genotype V_1 which gave the lowest average of (1436.91 grain.head^{-1}). The differences between the genotypes may be due to the difference in genetic traits for each genotype and thus the

Table (3): Effect of sorghum genotypes and agricultural sulfur and their interaction on leaf area index.

Sorghum genotypes	Agricultural sulfur levels t S.ha^{-1}				Genotypes mean
	S_0	S_1	S_2	S_3	
V_1	2.05	2.25	2.36	2.75	2.35
V_2	2.59	2.90	3.35	3.54	3.10
V_3	2.37	2.54	2.57	3.25	2.68
Mean sulfur	2.34	2.56	2.76	3.18	
L.S.D (0.05)	Genotypes	agricultural sulfur levels	agricultural sulfur X Genotypes		
	0.04	0.05	0.09		

number of flowers formed, which reflected in grains number head. These results are in consistent with results of Abdul-Hameed (2016) and Abood *et al*. (2017). The results presented in table (4) displayed a significant effect for the addition of agricultural sulfur in grains number.head^{-1}. The application of S_3 produced highest average of grains number per head of 2001.10 grain.head^{-1} with an increase reached to 367.17 grain.head^{-1} as compared to the control (S_0). The control treatment (S_0) produced the lowest average (1633.93 grain.head^{-1}).This is consistent with results of Joel *et al*. (2018) and Hussein (2016). The data in of table (4) exhibited a significant interaction between genotype and agricultural sulfur, the interaction $V_2 \times S_3$ gave the highest average of grain head of 2106.33 grain.head^{-1}, while the interaction of $V_1 \times S_0$ gave the lowest average of the grain head reached to 1076.66 grain.head^{-1}. This type of response was due to the effect of single factors.

Table (4): Effect of sorghum genotypes, agricultural sulfur and their interaction on grain number head.

Sorghum genotypes	Agricultural sulfur levels t S.ha^{-1}				Genotypes mean
	S_0	S_1	S_2	S_3	
V_1	1076.66	1330.33	1480.66	1860.00	1436.91
V_2	1995.66	1920.66	1955.00	2106.33	1994.41
V_3	1829.46	1925.00	1937.33	2036.66	1932.11
Mean sulfur	1633.93	1725.33	1791.10	2001.10	
L.S.D (0.05)	Genotypes	agricultural sulfur levels	agricultural sulfur X Genotypes		
	55.91	64.57	111.83		

Weight of 1000 grain (g)

The results of analysis of variance (Table 7) demonstrated that there is high significant differences among the genotypes and agricultural sulfur in grain number head. While the interaction of genotypes and agricultural sulfur has significant effect. The results of table (5) indicated that the genotypes V_1 gave the highest average of 1000 grains weight reached to 25.74 gm as compared to the genotype V_2 which gave the lowest average of 23.50 gm. The differences

between the genotypes may be due to the difference in genetic ability and so to the genotype response to environment. This results is consistent with the findings of Solag & Al-Ani (2011), Abdullah *et al.* (2012) and Al-Maeini & Al-Issawi (2017). The results indicated in table (5) revealed that the addition of agricultural sulfur lead to increase the weight of 1000 grain, the treatment of S_3 gave the lowest rate of weight of 1000 grain of 24.30 gm, while the S_0 (control treatment) gave the highest rate of this trait reached to 25.80 gm. The addition of agricultural sulfur lead to increase grain number head (see table 4) so this lead to increase the competition between formatting grains on photosynthesis product within the head, which reflect negatively on weight of 1000 grain. These results are consistent with the findings of El-Fahdawi (2008); Al-Jubory (2011) and Kadhim (2016). The results table (5) revealed a significant interaction between the genotype

and agricultural sulfur, the interference of $V_1 \times S_0$ gave the highest rate of weight of 1000 grain of 26.92 gm, while the interference of $V_2 \times S_3$ gave the lowest weight of 1000 grain of 23.17 gm.

Grain yield (t.ha^{-1})

The results of analysis of variance (Table 7) revealed that there is high significant differences between genotypes, agricultural sulfur and their interaction in grain yield. The results of table (6) displayed that the genotype V_3 produced the highest rate of grain yield of (4.97 t.ha^{-1}), while, the genotype V_1 produced the lowest grain yield of (3.59 t.ha^{-1}). The reason of increase grain yield in sorghum could be due to the difference in some growth characteristics such as plant height, grain number head and weight of 1000 grain, the results are consistent with previous results obtained by AghaAlikhani *et al*. (2012) and Attia (2016).

Table (5): Effect of sorghum genotypes, agricultural sulfur and their interaction on weight of 1000 grain (gm)

Sorghum genotypes	Agricultural sulfur levels t S.ha^{-1}				Genotypes mean
	S_0	S_1	S_2	S_3	
V_1	26.92	25.92	25.63	24.50	25.74
V_2	24.16	23.39	23.27	23.17	23.50
V_3	26.31	25.48	25.35	25.24	25.59
Mean sulfur	25.79	24.93	24.75	24.30	
L.S.D (0.05)	Genotypes	agricultural sulfur levels	agricultural sulfur X Genotypes		
	0.09	0.10	0.18		

The results presented in table (6) revealed that the addition of agricultural sulfur lead to increased grain yield. The highest level of agricultural sulfur (S_3) significantly increased grain yield and gave (5.10 t.ha^{-1}),while the control treatment S_0 gave the lowest grain yield of (3.76 t.ha^{-1}). The grain yield is an indicator for his components; these results are consistent with Al-Zubaidi *et al.* (2016), Hussein (2016) and Al-Tamimi *et al.* (2018). The results of table (6) indicated that there was significant interaction for the factors,. The interaction of $V_3 \times S_3$ gave the highest rate of yield reached to 5.80 t.ha^{-1} as compared to the interaction of $V_1 \times S_0$ which gave the lowest grain yield of 3.31 t.ha^{-1}.

The addition of agricultural sulfur lead to reduce the value of pH in soil and increase the availability of nutrients which led to the improve plant growth, moreover lead to increase grain number head (see table 4) which reflect positively to increase grain yield.

Table (6): Effect of sorghum genotypes, agricultural sulfur and their interaction on grain yield (t.ha^{-1}).

Sorghum genotypes	agricultural sulfur levels t S.ha^{-1}				Genotypes mean
	S_0	S_1	S_2	S_3	
V_1	3.31	3.60	3.46	4.01	3.59
V_2	3.53	4.42	4.59	5.50	4.51
V_3	4.45	4.65	5.00	5.80	4.97
Mean sulfur	3.76	4.22	4.35	5.10	
L.S.D (0.05)	Genotypes	agricultural sulfur levels	agricultural sulfur X Genotypes		
	0.05	0.06	0.11		

Table (7): Analysis of variance represented by mean square of traits measured.

Sources of variation	df	Plant height	Leaf area index	Number of grain/head	Weight of 1000 grain	Grain yield
Replicates	2	391.132**	0.050*	1095.743	0.419*	0.019
Agricultural sulfur (S)	3	1152.970**	1.145**	219124.543**	3.541**	2.782**
Genotypes (V)	2	8012.299**	1.662**	1119801.160**	18.940**	5.893**
Sorghum × agricultural sulfur	6	27.928	0.058*	71997.160**	0.383*	0.254**
Error	22	23.677	0.005	6364.162	0.017	0.006
Total	35					

* means significant differences was found among the treatment at 0.05 level.

** means significant differences was found among the treatment at 0.01 level.

Conclusions

The results showed the superiority of genotype Inkath in grain yield (4.97 t.ha⁻¹). Therefore, the genotype Inkath is more suitable planted in local environmental condition and to cultivated in this area. The addition of agricultural sulfur lead to improve Sorghum growth and productivity. The level of 9 t.ha⁻¹ produced the highest grain yield of 5.10 t.ha⁻¹. The interaction had a significant effect on the grain yield, the genotype Inkath gave the highest grain yield at 9 t.ha⁻¹ of agricultural sulfur reached to 5.80 t.ha⁻¹.

Acknowledgements

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