Effect of elemental sulphur extracted from gas associated with oil production on growth and yield of wheat and barley

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ABSTRACT

A field experiment was conducted at Basrah province, south of Iraq, Al-Qurna region during the growing season of 2019 - 2020 to study the effect of elemental sulphur on performance of wheat and barley crops in silty clay soil. Two elemental sulphur levels were used (0 and 80 kg S ha^{-1}) along with two rates of organic matter (0 and 5%). Total N and S n were estimated as well as total seed yield of the two crops. The results indicated that application of sulphur (80 kg S ha^{-1}) had a positive significant effect on sulfur concentration in wheat and barley grains. Application of organic matter (cow manure at rate of 5%) increased in sulfur concentration in seeds of the two crops. Nitrogen concentration in wheat and barley grains were increased with addition of elemental sulphur and organic matter as compared with controls. Results indicating that N/S ratio of wheat grains and barley grain, were decreased with addition of elemental sulphur and organic matter to reached 10.24 and 10.09, respectively. Wheat and barley grain yields were significantly influenced with the application of elemental sulphur and organic matter individual or together. Data showed that addition of organic matter for each level of elemental S increased grain yield reaching highest values (3550 and 3533 Kg ha^{-1}) at the application of 5% organic matter and 80 Kg S ha^{-1} for wheat and barley, respectively.

Keywords: sulphur, gas, oil production, growth, wheat, barley

INTRODUCTION

Yield and bread-making quality of wheat grain is influenced by the growing conditions, genotype and fertilization (Johansson et al., 2004). Sulphur (S) is an important and essential plant nutrient necessary for plant metabolism, growth and development. The average winter wheat sulphur consumption is about 25–30 kg of sulphur per hectare (Hagel, 2005). The main biochemical role of sulphur is to form disulphide bridges between peptide chains and stabilize the protein structures (Hawkesford and De Kok, 2006).Several researchers (Blake-Kalff et al., 2000;Aulakh, Malhi, 2004; Zhao et al., 2006; Järvan et al.,2008) indicated a positive effect of sulphur fertilization on cereal crop production; the positive response of cereal crops to sulphur fertilization was caused by the fact that the initial levels of plant-available sulphur in soil were low(Olfs et al., 2012).

Sulphur fertilization enhances the content of exogenous amino acids, in particular the component containing amino acids: methionine, cysteine and cystine dimer being cysteine (Hrivna, et al.,2016). This was confirm in studies by Barczak et al.,(2009), who found that sulphur fertilization, in comparison to non-fertilized controls, usually caused a significant increase in the content of most amino acids in proteins.

Sulphur plays an essential role in plant metabolism, its deficiency adversely affecting crop quality (Zhao et al. 1999). In the barley grain, the element is present in the form of sulphur amino acids (Hřivna et a,. 2011),and formation of protein structures, which greatly influences the quality of malting barley as the factors determining the same include protein content and fractional composition. Hulín et al. (2008) reports that an average barley grain contains 12.1% albumins, 8.4% globulins, 25% protamine and 54.5% glutens . The content of each fraction has a significant influence on the technological, nutritional and, indirectly, the hygienic quality of grain (Kuktaite, 2004).

The objective of the experiments in south of Iraq (Basrah province) is to assay the response of wheat and barley crops to added sulphur produced from gas emitted from oil in Basrah province, as a source of local S ,to increased growth , quality and yield of these crops and availability of S in soil .

MATERIALS AND METHODS

A field trials were carried out at Basrah province, south of Iraq at Al-Qurna region (30^{o}59$^-$ 25$^=$N,47^{o}26$^-$4$^=$E) 67 km north of Basrah center during the growing season of 2019 - 2020 to study the effect of mineral sulphur on performance of wheat and barley crops. A composite surface soil samples (0-30 cm) were collected from experimental sites, air-dried, passed through 2mm sieve, then physio-chemical properties of soils were measured according to methods described in Richards (1954) and Page et al.(1982) and listed in table 1.

Table 1: Some physio-chemical properties of used soil

Property	Value	Unit
pH(1:1)	7.35	-
EC(1:1)	3.50	dSm^{-1}
Organic matter	9.66	gm kg^{-1}
Available-P	20.10	mg kg^{-1}
Available-K	18.32	
Available-Mg	430.0	
Available-SO_4^{-2}	16.68	
Soil particles		
Sand	285.6	gm kg^{-1}
Silt	310.5	
Clay	403.9	
Texture	Silty clay	

Elemental sulphur was extracted from gas emission associated with oil production of Basrah oil field. Two sulphur levels were used (0 and 80 kg S ha^{-1}) along with two rates of organic matter (0 and 5%). Wheat (Triticumaestivum L., var. Bohooth 21) and barley (Hordeum vulgar L.,var.Local)were used. Each treatment was replicate four times.

The trial was laid out in private farm under randomized complete design for each crop. Field was plowed perpendicularly. For both crops, the individual plots consisted of 20 rows, 4m long and 3m width .Cattle manure was applied at mention level by mixing with 20cm upper layer. The chemical characteristics of manure were analyzed by methods described by Page et al.,(1982) and listed in table 2. Whole amount of elemental S was applied by mixing with 20cm upper layer. Both manure and elemental S were added at 30 days before sowing with continuous irrigation. Wheat and barley seeds were sown in bands on 1st Oct. and 2nd Oct. / 2019, respectively. Nitrogen, phosphorus and potassium were applied as NPK (20-20-20) fertilizer at sowing time at rate of 100 kg ha^{-1} .Urea also applied as broadcasting at rate of 50 kg N ha^{-1} at 30 days after sowing . River water was used for irrigation. Water characteristics were determined according methods described by Standards methods (APHA, 2015) and presented in table 3. Another agricultural practices were applied as recommended for Al-Qurna region.

Table 2: Some properties of cattle manure used in the experiment

E.C (1:5) dsm^{-1}	pH (1:5)	O.M (%)	Total N ppm	Total P ppm	Total K ppm	Total Mg Ppm	Total S ppm	Soluble ppm		C/N ratio	Bulk density Mgm-3
								P	K		
14.80	7.32	39.40	19100	9920	11120	1350	2600	4.65	11.54	11.96	0.8

Table 3: Some water characteristics of irrigation water

Property		Value		Unit
		Nov.2019	Feb.2020	
pH		7.10	7.25	-
EC(iw)		1.2	1.0	dS m^{-1}
Soluble ions	Calcium	2.75	2.65	mM l^{-1}
	Magnesium	2.67	2.45	
	Sodium	2.08	2.00	
	Potassium	0.2	1.87	
	Sulfate	3.3	3.2	
SAR		0.893	0.890	

At full maturity, seeds of wheat and barley were collected from 20 plants for each plot, sub – sampled ,oven dried at 70°C ,then digested and used to estimate total N and S with acid mixture of HNO_3+$HClO_4$(Karla,1998),then S assayed spectrophotometer as described in Page et al.1982). For N determination, samples were digested with acid mixture of H_2SO_4+ $HClO_4$ (Cresser and Parsons, 1979), then N assayed by steam distillation procedure (Bremner, 1970). At the end of season, seeds of 1 m^2 area were collected of each plot , weighted and used for estimating total seed yield.

Data were analyzed with analysis of variance (ANOVA) using GenSat procedure Library release PL.18.2. Differences among mean were evaluated with least significant differences test at 5% significant level.

RESULTS AND DISCUSSION

SULPHUR CONCENTRATION

The results of tables (4 and 5) indicated that application of sulphur fertilizer (80 kg S ha^{-1}) had a positive significant effect on sulfur concentration in wheat and barley grains , to reach 0.176% and 0.203% , respectively . While its concentration in control treatments for studied crops was 0.093% and 0.125%, respectively with increasing percent's of 89.25%, and 62.4%, respectively.The addition of sulphur fertilizer increased sulfate availability in soils, which induce plants to absorb it from soils, and increased crops tissues from sulfur. These results agree with the results of Zhao et al., 2016 and yroval and Ryant, 2020.

Table 4 : Effect of elemental sulphur on yield and grain quality of wheat

Treatments	N%			S%			N/S			Grain yield (Kg ha^{-1})		
	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean
S0	1.51 a	1.82 a	1.67 A	0.086 c	0.100 c	0.093 B	17.56	18.20	17.88	3000 b	3266 a	3133 B
S1	1.96 a	2.17 a	2.07 A	0.138 b	0.212 a	0.176 A	14.20	10.24	12.22	3300 a	3550 a	3425 A
Mean	1.74 B	2.00 A		0.112 B	0.156 A		15.53	12.82		3150 B	3408 A	

S0 : No addition of sulphur , S1 : 80 Kg S ha^{-1} of sulphur ; M0 : no addition of organic matter ; M1 : 5 % organic matter ; differences letters indicated significant differences between means of main factors (capital letters) and among means of interaction (small letters) at level of 0.05 .

Table 5: Effect of elemental sulphur on yield and grain quality of Barley

Treatments	N%			S%			N/S			Grain yield(Kg ha^{-1})		
	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean	M0	M1	Mean
S0	1.53a	1.81a	1.67 B	0.094a	0.155a	0.125 B	16.28	11.68	13.98	3100a	3250a	3175 B
S1	1.96a	2.29a	2.13 A	0.177a	0.228a	0.203 A	11.07	10.09	10.56	3533a	3533a	3467 A
Mean	1.75 B	2.05 A		0.136A	0.478A		12.87	10.88		3327 B	3392 A	

S0 : No addition of Sulphur , S1 : 80 Kg S ha^{-1} of Sulphur ; M0 : no addition of organic matter ; M1 5 % organic matter ; differences letters indicated significant differences between means of main factors (capital letters) and among means of interaction (small letters) at level of 0.05 .

Organic matter application significantly increased the concentration of sulfur in wheat and barley grain (tables 4 and 5). Its concentration in control treatment in wheat and barley grains were 0.112% and 0.136% respectively, and application of organic matter (cow manure at rate of 5%) increased in sulfur concentration to reached 0.156% and 0.478% with increasing percent's 39.29% and 251.47%, respectively. Application of organic matter caused decreased in soil pH (Martin-Rueda et al, 2007), as well as improved soil physical, chemical and biological properties of soils and increased native sulfur availability and absorption by plants roots, , at the same time organic matter is a source of organic sulfate in soils which will be mineralized and provide soil with mineral sulfate (Diacono and Montemurro, 2 010). Sulphur deficiency is more likely in soils with little SOM (Grant et al., 2012).

Application of organic matter with Sulphur fertilizer to soil had significant effect on sulfur concentration in wheat and barley grains (tables 4 and 5).The highest sulfur concentrations in wheat and barley grains fertilized with sulphur and organic matter was 0.212% and 0.228%, respectively. While the lowest concentrationwhich associated with controls were 0.086% and 0.094%, respectively. Eriksen (2009) found the differences in the rates of S mineralization among soils were small in organic matter, the amounts mineralized being 1.7-3.1% of the soil organic S pool. He also concluded that net mineralization, i.e. the supply of SO_4^{2-} -S from SOM, is the sum of two processes. Sulphur bonded to C will be mineralized together with C and N and will be made available for crop uptake at the same time as N becomes available.

NITROGEN CONCENTRATION

Nitrogen concentration in wheat grains and barley grains were affected by addition of sulphur (Tables 4 and 5). The effects were statistically significant at barleywith an increase of 27.54 %. The positive effect of elemental S or N concentration may be attributed to an increase in soil N availability due to reduction in soil pH , and consequently reduce ammonia volatilization . The acidifying role of elemental S results from its microbial oxidation to sulphuric acid over time (Vidyalakshmi et al., 2009). Rahman et al. (2011) stated that in alkaline soils, decrease pH increased the availability of nutrients, as well as sufficient S is essential to prevent undesired N losses due to reduced nitrogen utilization. According to Potarzycki (2003), using of sulfur fertilizers affects the greater the accumulation of N in the grain . AL-Tameemi et al.(2014) found that the reduction of ammonia loss was highly related to retention ammonium ion by functional groups of humic acid as well as low soil pH . This result agreed with the findings of Motior et al.(2011) and Klikocka et al.(2017) who found that increased N content in cucumber and wheat was obtained by element S application .

Application of organic matter (cow residue) had a significant effect on N concentration in wheat and barley grains (Tables 4 and 5). N concentration increased at percent’s of 14.94 and 17.14 % for wheat and barley, respectively. Addition of organic matter enhance soil biological activity which improves nutrient mobilization , enhance root growth due to better soil structure , release nutrients slowly , contribute to the residual pool of organic N in soil and reducing N losses (Mahrous etal.2014). Gijsman (1990) also stated that the presence of organic residues lead to increase the percentage of small particles in soil which increases the retention of soil moisture , that provides movement of nitrogen and increase uptake in plant. This result is in agreement with Read et al.(2019) and AL-delfi and Abdulkareem (2020) .

Results in tables 4 and 5 showed a positive effects of application elemental S along with organic matter on N concentration in wheat and barley grains, but with no significant differences. The highest N concentration obtained in the case of the application of 80 Kg S ha^{-1} and 5% organic matter that reached 2.17 and 2.29 % for wheat grains and barley grains, respectively. Data also indicated that the addition of organic matter to each dose of elemental S independently increased N concentration. That means the presence of organic matter enhances the role of elemental S for plant growth development.

NITROGEN-SULPHUR RATIO(N/S)

In simplest form, the use of ratios in the interpretation of plant analysis results involves the evaluation of two essential elements together recognizing the effect of one element on the other. The most commonly used ratio is N:S (Nitrogen to Sulfur). The ideal N:S ratio for most crops is 10–15. As the N: S ratio approaches and exceeds 18, sulfur is limiting in relation to nitrogen.

The concentration of S is often used as indicator of S nutrition status in plants .It has been established that for every 15 parts of N in protein there is 1 part of S which implies that the N:S ratio is fixed within a narrow range of 15:1. The N: S ratio in the whole plant in general is 20:1 (Cram, 1990). The N:S ratio should be between 10 and 15 for optimum yields. Maintain the N: S ratio between 5:1 and 15:1.

Results in tables 4 and 5 indicating that increasing rate of sulphur (80kg ha^{-1}) and organic matter (5%) significantly increased sulfur and nitrogen contain of wheat and barley grains. The concentration of S in wheat, barley, influenced by nitrogen –sulfur interaction, the usage of N/S ratio is better. Without added sulphur fertilizer, the N/S ratio of wheat grains, barley grain, was 17.88 and 13.98 , respectively. Adding sulphur fertilizer decreased N/S ration in wheat and barley grains to reached 12.22 and 10.56, respectively. For wheat grain, the N/S ratio must be lower than the critical value of 17 (Zhao et al., 1995; Sahota, 2006). In this trial field experiment application of sulphur fertilizer reduced N/S ratio from 17.88 to 12.22 in wheat grains. The positive effect of sulfur fertilization was particularly evident in the production and concentration of barley grains content from nitrogen and sulfur, so N/S ration decreased from 13.98 to 10.56. Grzebisz and Przygocka-Cyna (2007) reported that the ratio of N/S in barley grains not constant but changed from vegetation to maturity ,the growing season of barley of growth can be divided into two main phases using two line crossing models,. The first part of the developed models, mainly related to the vegetative growth of barley organs (leaves and stems), showed extremely high rates of the N: S ratio and then decline with maturity stage (Grains), which significantly responded to S rates. Zhao et al. (2005) found that S/N ratio of barley grain without adding sulfur was 20.3 and decreased with adding 10, 20 and 40 kg S ha^{-1} to 12.7, 11.9 and 11.7 , respectively. The effect of S applications on grain N concentration was probably due to a dilution of N in grain because of increased yield due to S.

Grain N: S ratio has been suggested as an indicator of the S status of crops, with the ratio of greater than 17 being associated with S deficiency (Randall et al., 1981). In this study, grain N: S ratio was generally decreased by addition of elemental S and organic matter (Tables 4 and 5) the values were below 15, our results support the idea that grain N: S ratio could be used as a retrospective indicator of the S status in the crop (Randall et al., 1981).

GRAIN YIELDS OF WHEAT AND BARLEY

Application of Sulphur fertilizer at rate of 80 Kg ha^{-1} had a significant effect wheat and barley (Tables 4 and 5). Yield was increased by 9.32 and 9.19 % with respect to the control treatment of wheat grains and barley grains, respectively. This increase may be attributed to that application of S had an essential effect on yield by contributing to the appropriate content of S and N , the development of shoot parts and the formation of root system (Podlesna , 2013) . Fotyma(2003) also emphasizes that S increases crop yield indirectly by influencing N transformation in the plant. The interaction of S and N at the levels needs of many plant metabolic processes is reflected in crop development, then affects yield level and quality. Data in tables 6 and 7 showed that yield well correlated with S and N concentrations in grains . This result coincide with the findings of Klikocka et al.(2017) for wheat .

Wheat and barley grain yield was significantly influenced with the application of organic matter (Tables 4 and 5) with an increase percents of 8.19 and 2.26 % with respect of the control treatment for wheat and barley, respectively. Organic fertilizers reducing N losses and P fixation , supply micronutrients , increase the organic matter content of soil , therefore improving the exchange capacity of nutrients , increasing soil water content , and promoting soil aggregates (Chen,2006). It can be observed that addition of organic matter resulted in greater N and S content , which reflected on increase plant growth, number of seeds and overall yields per plant. Similar results have also been reported by Kler and Walia(2006) and Ghaman and Sur (2006) who stated that applying organic residues greatly affected wheat growth and grain yield .

Analysis of the results in tables 4 and 5 showed no significant effect of the interaction between S and organic matter on grain yield for both crop. However , the addition of organic matter for each level of elemental S increased grain yield reaching highest values (3550 and 3533 Kg ha^{-1}) at the application of 5% organic matter and 80 Kg S ha^{-1}. This is consistent in accordance with results of Rossini et al.(2018) on durum wheat plant.

CONCLUSIONS

1. Elemental S produced from emitted gas of oil production processes can be used successfully as a source of S to plants.
2. Application of sulphur at rate of 80 kg S ha^{-1} increased yield of wheat and barley as well as enhanced yield quality.
3. Grain yield and quality of wheat and barley were enhanced by addition of 5% organic matter with sulphur.
4. The application of sulphur accompanied with increasing N and S availability and uptake for maximizing yield quality of crops.

5. Various calcareous soils of Basrah regions have a positive response to addition of sulphur at rate of 80 kg S ha^{-1}.

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