Middle East Research Journal of Agriculture and Food Science
ISSN: **2789-7729 (Print & Open Access)**
Frequency: Bi-Monthly
DOI: 10.36348/merjafs.2021.v01i01.003

Website: http://www.kspublisher.com/
Email: office.kspublisher@gmail.com

Response of Sulphur Fertilizer Application to Bread Wheat (*Triticum aestivum*) Yield and Quality in Kulumsa, Arsi, Ethiopia

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ABSTRACT: A field study was conducted during 2013/14 cropping season with the objectives of to study the response of bread wheat to different rates of sulfur fertilizer, to study the effect of Sulphur fertilization on yield and quality of protein of bread wheat and to suggest some recommendations about the optimal rates of sulfur fertilizer application for bread wheat as well as for further sulfur research works. The treatments applied as one factor of six levels of sulphur (0, 20, 40, 60,80 and 100 kg S ha-1 . The treatments were replicated three times in a Randomized Complete Block Design. The experiment was carried out at the Kulumsa Agricultural Research Center on clay textured soil. Data were collected and statistical analysis was done on various characters of the crop. Soil Samples were also taken before and after the implementation of the experiment and chemically analyzed. The analysis of variance for the results of the study revealed among yield and Quality parameters of wheat; Thousand Grains Weight, Grain protein content and wet Gluten were significantly ($p \leq 0.05$) affected by rates of S. In addition to Grain yield and Hectoliter Weight were highly significant ($p \leq 0.01$) by rates of S. Average over S treatments, each S level brought about significant increase in grain yield and protein over no S. Accordingly, 60 kg S ha-1 further increased yields significantly over control (no N), followed by 40,20, kg S ha-1. Application of 60 kg S/ha increased the grain yield of wheat by 12.64%, 11.39%, 6.44% and 2.52% respectively when compared with the no S application and increased protein contents of wheat by 2.94%, 1.77%, 1.42% and 1.36% respectively when compared with the no S application. However, more systematic investigation should be made based on the detailed analysis of soil fertility, crop characteristics and economic feasibility of recommended treatments in different principal bread wheat growing areas of Ethiopia in order to reach a sound conclusion and recommendation.

Keywords: Bread wheat, Sulphur fertilizer, Yield, protein, Gluten wet.

RESEARCH PAPER

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How to cite this paper:
Almaz Admasu Terefie*;* "Response of Sulphur Fertilizer Application to Bread Wheat (*Triticum aestivum*) Yield and Quality in Kulumsa, Arsi, Ethiopia". Middle East Res J. Agri Food Sci., 2021 Nov-Dec 1(1): 18-24.

Article History:
| Submit: 20.10.2021 |
| Accepted: 22.11.2021 |
| Published: 28.12.2021 |

INTRODUCTION

Crops and cultivars within crops vary considerably in their S requirements. Spencer (1975) has divided crops into three broad groups. Group I includes Crucifers and Brassicas which have high S requirement (20 to 80 kg S ha–1). Group II includes plantation crops, which have moderate S requirements (10 to 50 kg S ha–1). Group III includes cereals, forages, and other field crops and has low S requirement (5 to 25 kg S ha–1). As a rule of thumb, Tandon (1991) gives the following S requirements (kg S Mg–1grain): 3 to 4 kg for cereals, 8 kg for grain legumes (beans), and 12 kg for oilseeds (rapeseed mustard, sunflower, groundnut, soybeans, etc.)

Deficiency of S in agricultural crops, especially wheat, was reported as rare (Withers *et al.*, 1995). This is due largely to the belief that the S requirement of crops is satisfied from S deposited from wet deposition of S compounds and release from organic matter. On average, 10–12 kg ha−1 of sulfate-S is obtained from rainfall, which is slightly less than the wheat crop requirement of 15–20 kg ha−1 (Zhao *et al.*, 1999b). While demand for sulphur depends on plant species, the amount and rate of sulphur uptake from the nutrient solution depends on many factors, including pH, temperature, access to energy, sulphate concentration and the presence of other ions (Siuta and Rejman-Czajkowska 1980).

With the increase in sulphate ions accumulation in the nutrient solution, their uptake by plants increases. Having reached a certain level, various for different plant species, further increase of concentration does not affect the uptake any longer. However, high sulphate concentrations may affect plant development and crop yield (Cerda *et al.*, 1984).

Wheat requires a relatively high amount of supplemental S due to incompatibility of conditions with its period of most rapid growth during early spring, when the rate of S release from soil organic matter is quite slow (Johnson, 1999). Significant yield increases of winter wheat in response to S additions have been reported elsewhere (Randall and Wrigley, 1986; McGrath and Zhao, 1995).

In Pakistan, According to Arshad *et al.*, (2012) studies that Different rates of Sulfur which are 25 kg/ha, 50 kg/ha and 75 kg/ha on saline-sodic soil showed positively influenced on wheat growth and yield. Tillering, plant height, spike length, number of grain spike-1, 1000 grain weight, straw and grain yield were statistically significant. The highest numbers of tillers were recorded in treatment receiving 50 kg S ha-1 followed by treatments receiving 25 and 75 kg S ha-1. Plant height was the highest in treatment receiving 25 kg S ha-1 and spike length was highest in the treatment receiving 50 kg S ha-1.

The highest 1000 grain weight, grain and straw yield were obtained with the application of 50 kg S ha-1 followed by 25 and 75 kg S ha-1, which is 26% higher than control treatment. The treatments receiving 50 kg S ha-1 registered the highest grain yield followed by treatments receiving 75 kg S ha-1 producing 13% higher yield as compared to control treatment. Gupta *et al.*, (2004) reported that S application significantly enhanced wheat yield and yield components. Therefore, this research project was proposed with the objective to study the response of bread wheat yield and quality on different rates of sulfur fertilizer

MATERIALS AND METHODS

Description of the Study Area

The study was undertaken at Kulumsa Agricultural Research Center (KARC), which is located in Tiyo Woreda of Arsi Zone in the Oromia National Regional State, Ethiopia. It is situated 160 km southeast of Addis Ababa and 8 km North of Asella town at an altitude of 2200 meters above sea level (masl) and 8° 01'10" N latitude and 39° 09' 11"E longitude. The study area falls in the moist 2 (tepid to cool moist mid to high altitude) agro-ecological zone (MoA, 2000). The weather data recorded from 1992 to 2013 indicates that the area receives an average annual rainfall of 820 mm. The rainfall pattern is uni-modal with extended rainy season from March to September. However, the peak rainy season is from July to August. The mean annual potential evapotranspiration is about 1300 mm. An average annual minimum and maximum temperatures are 10.5 and 22.8 °C, respectively. The center is located on very gently undulating topography with a gradient of 0 to 10% slope. In some places where the slope is very flat, flooding and water logging occur. The soil moisture regime can be classified as ustic and the soil temperature as Isothermic (Abayneh, 2003). Variations in climatic and vegetation cover with the differences in parent materials and relief led to the occurrence of different soils in the study area. The soils of the study area are largely developed from parent materials of volcanic origin, predominantly basalt. However, in certain parts, there are soils that were developed from alluvial materials. The dominant soil of the area is Luvisol (MoA, 1984) and wheat is the most widely cultivated crop in the area followed by barley.

Table 1: Mean monthly rainfall as well as full and half pan evaporation of the study area in 2013

months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall(mm)	19	67	86	120	82	90	122	135	107	38	11	9
PET	108.5	103.5	117.8	111	117.8	117	93	96	87	108.5	111	105.4

The composite surface soil samples at 0-30cm depth were collected from the experimental field just before planting of the crop and analyzed for some of their physical and chemical properties including texture, pH, organic carbon, total nitrogen, total phosphorus, exchangeable cations, micronutrients and available sulfur.

Table 2: Physical and chemical properties of soils of the experimental site before planting

Soil properties	Sample 1	Sample 2	Sample 3	Mean
Particle size (%)				
Sand	20.72	34.21	27.46	27.46
Silt	30.38	19.38	22.89	24.22
Clay	48.9	46.41	49.65	48.32
Textural class	clay	clay	clay	clay
Total N (%)	0.24	0.11	0.23	0.19
Av.P (ppm)	19	21	21	20.33
Av. S (ppm)	9.42	20.47	12.57	14.13
OC (%)	1.58	1.63	1.54	1.58
pH	6.2	6.3	6.3	6.3
Exchangeable base(cmol/kg)				
Na	1.82	1.5	1.45	1.59

Soil properties	Sample 1	Sample 2	Sample 3	Mean
K	0.75	0.82	0.7	0.76
Ca	45.38	45.18	45.68	45.41
Mg	1.08	1.11	1.18	1.12
Micronutrients(cmol/kg)				
CU	1.87	1.87	1.97	1.9
Fe	26.61	20.03	27.48	24.71
Mn	28.18	25.5	23.99	25.89
Zn	0.68	0.64	0.7	0.68

Experimental Treatments, Design and Procedures

Kakaba' variety bread wheat was used for the experiment which is released in 2010 by EIAR in collaboration with DRRW, CIMMYT and ICARDA and popularized during 2011/12 crop seasons and it is highly adapted at altitude of 1500-2200 meters above sea level (masl).The origin name of Kakaba is called Picaflor #1 and the Pedigree of Kakaba is Kititati//Seri/Rayon. It is Rust resistance spring type bread wheat and early maturing variety with the maturity of 90-120 days (MOA, 2011).

Six different rates of sulfur (0, 20, 40, 60, 80 and 100 kg S/ha) fertilizer applications were the treatments of the present study. Calcium sulphate ($CaSO_4$) was used as the source of sulfur fertilizer. The treatments were laid out in randomized complete block design (RCBD) with three replications. In accordance with the specification of the design, a field layout was prepared and each treatment was assigned randomly to experimental units within a block. Plot size of each replicated treatment was 5m X 5m, consisting 25 rows. The spacing between plots within blocks was 50 cm, while the spacing between blocks was 1m. At the recommended seeding rate, the seeds were drilled manually in 20cm apart open rows and covered with soil on-22/07/2013. Land preparation and other all agronomic practices were done as per their recommendations for wheat.

Data Collection

Apart from yield and quality components of wheat, nitrogen and sulfur uptakes by wheat plants were consider as study parameters of the present experiment. Data from these parameters were collected as per their respective standard sampling and measuring methods and procedures indicated here below.

Thousand Grain Weight

After threshing of plants harvested from each net plot, thousand seeds were taken and counted randomly from each plot and their weight was measured with an electronic balance having a precision of ±0.001 g to obtain thousand grains weight.

Hectoliter Weight

The grain was fallen into the lower chamber of the chondrometer under the restriction of a falling weight. The fallen grain was weighed with the balance and the weight in gram was converted from a balance weight to hectoliter weight via the calibration chart. Hectoliter weight was done by using hectoliter weight tester. The grains passing hectoliter weight tester were measured with an electronic balance and the weight obtained was multiplied by four to obtain hectoliter weight.

Grain Yield per Hectare

Plants from each net plot area were manually harvested and sun dried in the open air. The dried wheat plants were threshed and weighed to determine the grain yield of each plot. Finally, yield per plot was converted and expressed as kg ha-1 basis. Grain yield was adjusted to 12.5% moisture content, indeed.

Protein content (%)

After threshing of sun dried plants from net plots, grain samples were taken for further protein and wet gluten contents analysis. Protein content of wheat grains was analyzed by near Infrared Transmittance based Protein Analyzer (Model: Infratec 1241 grain analyzer).

Wet Gluten (%)

Similarly, Wet Gluten was also analyzed by near Infrared Transmittance based Protein Analyzer (Model: Infratec 1241 grain analyzer).

Soil Sampling and Analysis

For characterization of experimental plot soil as well as to assess the residual effects of sulfur fertilizer applications on some important physicochemical properties of soil, soil samples were taken just before planting and after harvesting. Just before planting, surface soil samples were collected at 0-30cm depth by using auger from 10 spots of the experimental field. These samples were composited to three samples for further laboratory analysis. In the same way, just after harvesting, soil samples were gathered from three spots of three respective plots of each treatment and composited to yield one representative sample per treatment. In both cases, the composite samples were air dried and ground to allow them passed through 2.0 mm sieve before laboratory analysis. The fraction, which passed through the sieve, was used for further soil analysis in the laboratory. Analyses of the important soil physicochemical properties of the composite samples were carried out separately in the soil laboratories of Kulumsa and Debre Zeit Agricultural Research Centers.

Soil particle size distribution was determined by hydrometer method (Bouyoucus, 1951). Soil pH was measured using a glass combination pH meter in the supernatant solution of 1:2.5 soils to solution ratio of water (Van Reeuwijk, 1992). Soil organic carbon was determined by the wet oxidation method as described by Walkley and Black (1934). Determination of total nitrogen of the soil was performed by the Kjeldahl digestion and distillation method (Jackson, 1958). Total P was extracted following the procedure described by Mehlic and content of Available sulphur in solution was estimated by turbidometric method using spectrophotometer at 420 nm (Williams and Steinbergs, 1959).

Plant Chemical Analysis

To estimate the uptakes of nitrogen and sulfur by wheat plants as influenced by the application of different rates of sulfur fertilizer, nitrogen and sulfur contents of sampled wheat plants were analyzed in the laboratory, while the effect of sulfur is much complemented with that of nitrogen. Total N in the sampled plants was determined by Kjeldahl procedure following the treatment of the plant material with H_2SO4 (NSRC, 2000) and expressed in percentage. Total sulphate contents of sampled whole plants at harvest were extracted by wet ashing method. Sulfur content in grain and straw was estimated by turbidometric method (Williams and Steinbergs, 1959).

Data Analysis

All data were subjected to the analysis of variance using General Linear Model procedures of SAS (SAS institute, 2000), and significant mean differences were separated by least significant difference (LSD) at respective level of significance used for ANOVA.

RESULTS AND DISCUSSION

Thousand Grains Weight

There was statistically significant difference ($p \leq 0.05$) on 1000 grains weight due to S application. Among the application of S the highest (42.43 gm) was recorded. From 1000 grains weight under the influence of applied S rates, the result obtained at 60 kg S /ha was the highest (42.43gm) followed by treatments receiving 40,20,80,0 (control) and 100kg S/ha .This result was similar by Gupta *et al.*, (2004) was reported that S application significantly enhanced wheat yield and yield components.

Grain Yield per Hectare

The mean grain yield of wheat was highly significantly ($p \leq 0.01$) affected by S rates. The highest grain yield (5602.7 Kg/ha) was obtained from 60 kg S/ha followed by 40, 20, 80, 0(control), and 100 kg S/ha. This information agreed with results obtained by other authors (FAO, 2004; Reussi Calvo *et al.*, 2006). Furthermore, Anderson *et al.*, (2006) reported similar results, showing very high S grain responses in wheat.

Grain Protein Content and Wet Gluten

The mean grain protein of wheat was significantly ($p \leq 0.05$) affected by S rates. The grain protein content ranged from 10.66% to 5.88%). Whereas the highest protein (l0.66%) was obtained from 60 kg S/ha followed by 40, 20, 80, 0(control), and 100 kg S/ha and the lowest protein (5.88%) was obtained from 100kg S /ha. The mean wet gluten of wheat was significantly ($p \leq 0.05$) affected by S rates. The wet gluten content ranged from 23.40% to 31.06%). Whereas the highest wet gluten (31.06%) was obtained from 60 kg S/ha followed by 40, 20, 80, 0(control), and 100 kg S/ha and the lowest wet gluten (23.40%) was obtained from 100kg S /ha (Table 2).

This results was similar with (Linser *et al.*, 1964., Eppendorfer, 1968 were stated that plants which has insufficient sulphur, has low protein content and it improved the protein quality. This might be due to that sulfur fertilization improved the potential of seed to produce more protein contents as well as increased it efficiency to absorbed water during germination which leads to healthier seedlings. Furthermore, Gupta *et al.*, (2004) and Chaudhary *et al.*, stated that the highest protein ratio was obtained from S application in wheat. This might be due both nitrogen and sulfur application enhanced the protein content and resulted in heavier seedlings.

Table 3: Effect of sulphur fertilizer application at different levels on yield components of wheat

S level Kg/ha	GY(kg/ha)	TKW(gm)	PRO (%)	GLU (%)
0	4339^{cd}	40.15^{b}	7.72^{bc}	25.10^{c}
20	4983^{b}	41.66^{a}	9.14^{ab}	25.66^{bc}
40	5478^{a}	41.98^{a}	9.49^{ab}	29.16^{ab}
60	5603^{a}	42.43^{a}	10.66^{a}	31.06^{a}
80	4592^{cb}	41.26^{ab}	9.08^{ab}	25.40^{c}
100	4123^{d}	40.12^{b}	5.88^{c}	23.40^{c}
LSD	465.93**	1.45*	2.57*	3.79*
CV	5.27	1.93	16.37	7.66

Means within columns followed by the same letter are not significantly different within groups of levels by analysis of variance protected LSD test at (P ≤ 0.05) NS-non significant, *= significant at 0.01 < P≤0.05, ** = highly significant at P≤ 0.01

Lowe and Ries (1973) reported positive correlation of macro and micro nutrients and seedling dry weight. They found that seedlings developed from high protein grain showed increased water absorption and oxygen consumption during germination and produced heavier seedlings.

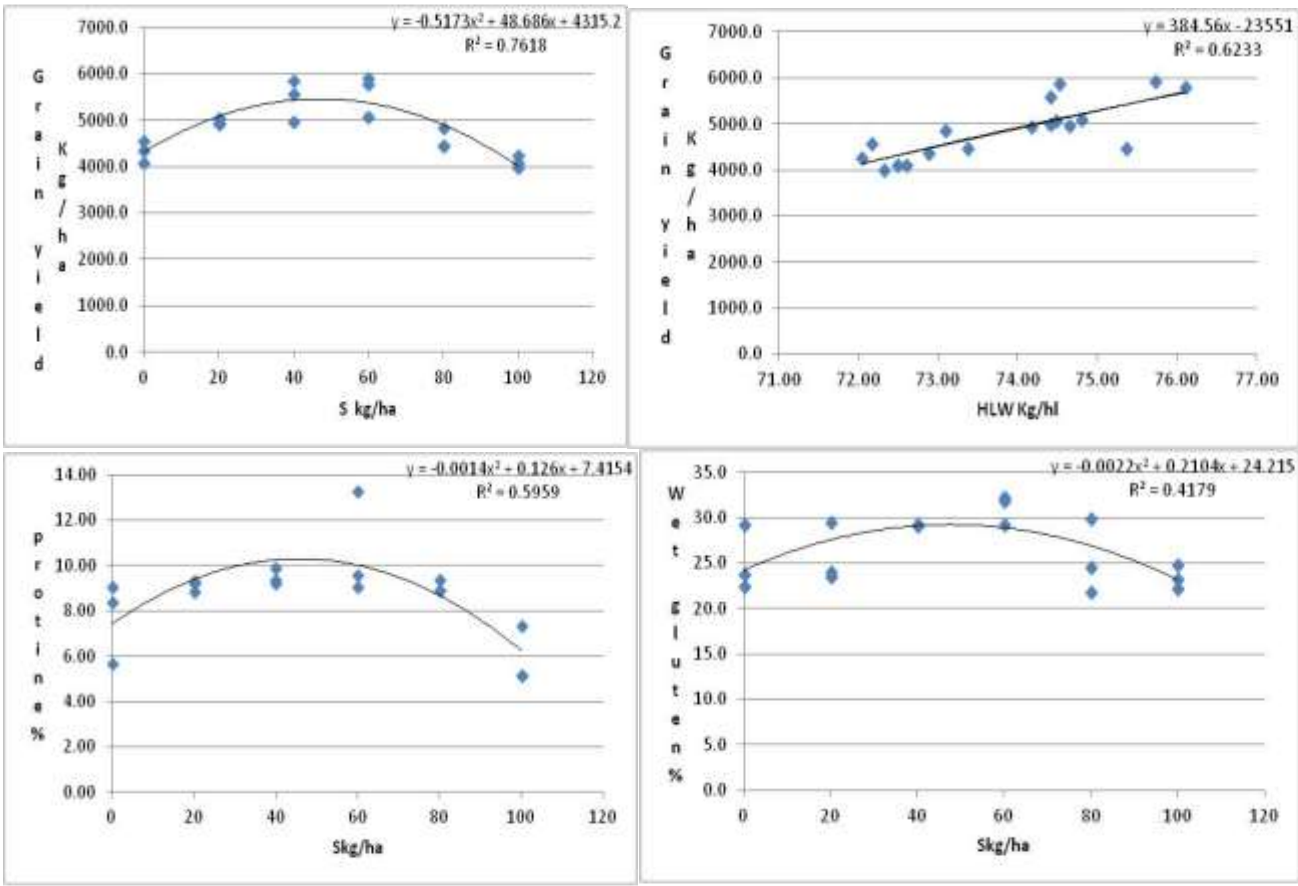

Figure 1: Regression equations showing the relation of sulphur rates with Grain yield, protein and wet gluten and grain yield with Thousand kernel weight and hectoliter weight. (P- Pearson Correlation Coefficients)

Nitrogen Uptake

Nitrogen accumulation in grain, straw and total uptake were significant (p≤ 0.05) influenced by application of different sulphur rates. Grain Nitrogen range from 1.71 to 0.97% whereas the highest nitrogen up take (1.71%) was obtained from 60 kg S/ha followed by 40,20,80,0(control) and100kgS/ha and the lowest (0.97%) was obtained from 100kgS/ha. These results were might be S fertilizer increased the availability of other macro and micro nutrients with in crop production. This information was agreed with results obtained by other authors Mandhata Singh *et al*., (1994) also reported higher nutrient uptake due to sulphur fertilization in crop.

Straw Nitrogen range from 0.563 to 0.33% but, the highest nitrogen up take of straw was obtained from 0(control) followed by 20, 100, 40, 80 and 60 kg S/ha whereas the lowest value was obtained by 60kg S/ha. These results were might be N fertilizer taken by the crop of grain. This result was agreed with Khan *et al*., (2009) reported that nitrogen concentration within the plants increased by increasing nitrogen concentration either in soil or by foliar application of urea.

Sulphur Uptake

Sulphur accumulation in grain and straw and total uptake were non-significantly (P>0.05) by statistically.

Table 4: Effect of sulphur fertilizer application at different levels on nitrogen and sulphur uptakes by bread wheat plants

S rates kg/ha	Grain N content (%)	Straw N content (%)	Grain S content (%)	Straw S content (%)
0	1.233bc	0.563a	0.072	0.072
20	1.476ab	0.493a	0.232	0.048
40	1.516ab	0.436ab	0.312	0.09
60	1.706a	0.333b	0.328	0.08
80	1.463ab	0.333b	0.12	0.048
100	0.970c	0.460ab	0.088	0.095
CV %	15.88	16.61	NS	NS
LSD	0.403*	0.131*	NS	NS

Means within columns followed by the same letter are not significantly different within groups of levels by analysis of variance protected LSD test at ($P \leq 0.05$) NS-non significant, *= significant at $0.01 < P \leq 0.05$

Available Soil Sulphur

The results of soil analysis for available soil S after harvest against treatments are presented in below table. There was non-significantly (P>0.05) by statically in turbid metric blue method available soil S across S rates soil S and straw S uptake (r=0.095). Appendix TableA4) clearly indicates their associations.

Total Soil Nitrogen

There was significantly (p≤ 0.05) by statically in available soil S across S rates. Averaged over all N rates, the initial level of Total soil N which was 0.19% before sowing increased to 0.563,0.493,0.460,0.436,0.33,and 0.33% N Among the six treatment of S application rates, the highest increment in soil total N was obtained from 0 Kg S/ha(control)(0.56%N) and the lowest from 60 Kg S/ha (0.33%N). These results were might be S fertilizer increased the availability of other macro and micro nutrients with in crop production.

Table 5: Effect of Sulphur fertilizer application at different levels on total nitrogen and available sulphur in the soil of bread wheat field just after harvest

S rates kg/ha	Available soil S(ppm)	Total soil N (%)
0	9.423	0.563a
20	9.423	0.493a
40	12.563	0.436ab
60	13.09	0.333b
80	14.587	0.333b
100	17.277	0.460ab
CV	NS	16.61
LSD	8.81	0.131*

Means within columns followed by the same letter are not significantly different within groups of levels by analysis of variance protected LSD test at ($P \leq 0.05$) NS-non significant, *= significant at $0.01 < P \leq 0.05$

RECOMMENDATIONS

The application of 40 kg S/ha would be preferred to grow bread wheat at Kulumsa area for grow better grain yield and quality. Thus, farmers in the area might be advised to 40kg S/ha used to increase the productivity of this crop through increase the efficiency of S uptake. However, it is too early to reach a conclusive recommendation since the experiment was conducted only on one soil type and crop variety in one location for one season. Hence, studies involving more genotypes under various soil types, environmental factors, crop characteristics, methods and time of S application and the economic feasibility of recommended treatments in different principal bread wheat growing areas of Ethiopia and for many seasons should be conducted; otherwise the result could be unreliable.

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