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Effect of Sulphur on Quality and Nutrient Uptake of Bread Wheat (*Triticum aestivum*) on Vertisols, Central Highlands, Ethiopia

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Abstract: Afield experiment was carried out to evaluate the effect of Sulphur fertilizer rates on yield, quality and uptake of bread wheat on Vertic Luvisols. The treatments applied as one factor of six levels of sulphur (0, 20, 40, 60, 80 and 100 kg S ha^{-1}). The experiment was carried out at the Kulumsa Agricultural Research Center on clay textured soil under rainfed condition. The analysis of variance for the results of the study revealed among yield and Quality variables of wheat; Thousand Grains Weight, Grain protein content and wet Gluten were significantly ($p < 0.05$) affected by rates of S. In addition to Grain yield and Hectoliter Weight were highly significant ($p < 0.01$) 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 60 kg/ha of S increased protein contents of wheat by 2.94%, 1.77%, 1.42% and 1.36% respectively when compared with the no S application. While, partial budget analysis result revealed that, 20kg/ha of Sulphur produced the highest MMR (13.3%) and thus, 20 kg/ha S is found to be economically feasible treatment for bread wheat production in study area of the district.

Keywords: Sulphur, Protein, Gluten Wet, Nutrient Uptake

1. Introduction

Bread wheat (*Triticum aesativum* L.) is the most principal vital cereal crops provided and consumed in Ethiopia. It stands third among cereals in respect of cultivated area [16] and second in the perspective of grain production next to maize [16]. Usually, wheat grains are utilized to get local bread, kolo, genfo, kinche, tela, borde, Enjera and other types of food. It is additionally handled in production lines to deliver flour for commercial production of bread for buyers in cities and towns. Inspite of its significance and developing request for bread wheat in Ethiopia, its production and productivity are very low.

The current average yield of wheat is below 3tha^{-1} [16]. In spite of its potential yield greater than 5tha^{-1} [1]. Thus, the nation imports much quantity (30–50% of total yearly request) wheat grains each year from overseas to fulfil home consumption [37]. In Ethiopia the production of bread wheat is very low due to reduction of soil fertility through time [10, 15]. There are many factors for reduction of soil fertility which are erosion, deforestation, unbalanced nutrient management, mono cropping system, abnormal tillage practices are the many problems for whole production and productivity in Ethiopia [1].

Loss of soil fertility is extremely expanded through time that is becoming burning issue and required highly attention [1]. In Ethiopia, most of the time DAP (di ammonium phosphate) and Urea were applying the only fertilizer source for nitrogen and phosphorus. However, unbalanced fertilizer application did not bring significant effect on bread wheat production and cannot assure food security in the country [41]. Nowadays, Sulphur is a most important nutrient for bread wheat production to improve protein content of different cereals. Sulphur is an essential element of grain proteins and amino acids which are important in forming the high-quality glutenins and gliadins [52].

Deficiency of S in agricultural crops, especially wheat, was reported as rare [51]. 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} [51]. 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 [51]. 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 [51]. 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 [29].

Menna A. reported that S application significantly enhanced wheat yield and yield components based on research result from eighteen research experiments were carried out on different area at East shewa, Oromia liyuu zone and Arsi zone of Oromia region in Ethiopia under rainfed condition. East Shewa which has Pellic Vertisol was showed better S response, followed by Oromia liyuu zone which has Nitosol and Arsi zone which has Light Vertisol and Nitosol. On these experiments very low SO_4-S in soils was recorded at B/Lencha in Arsi zone. Indeed, this site is found in the periphery of the rift-valley [36]. Moreover, the soil of this site was sandy clay. This may indicate that, the calcareous soils, low in organic matter (OM) in the peripheries of rift-valley are expected to be much deficient in S. Assefa reported that on 15kg/ha S recommended integrated with 22kg/ha of P on heavy vertisol [5]. In agreement with this [49] reported significant yield responses of wheat to S, particularly in areas of low S deposition and with light-textured or shallow calcareous soils in England. Bavec reported that “Grain yield of cereals is a product of three yield components: the number of ears per unit area, the number of kernels per ear and individual kernel weight” [8]. Any physiological or agronomic variables at a given stage of growth would be of furthers use only when its effect is reflected on yield either way. Grain yield is a function of HI and dry matter production [37].

Gupta A reported that S application significantly enhanced wheat yield and yield components [22]. This experiment was conducted to study the effects of Sulphur application on growth and yield components on bread wheat at Kulumsa.

2. Materials and Methods

2.1. Description of the Study Area

The field experiment was conducted in 2013/14 cropping season 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”Elongitud.

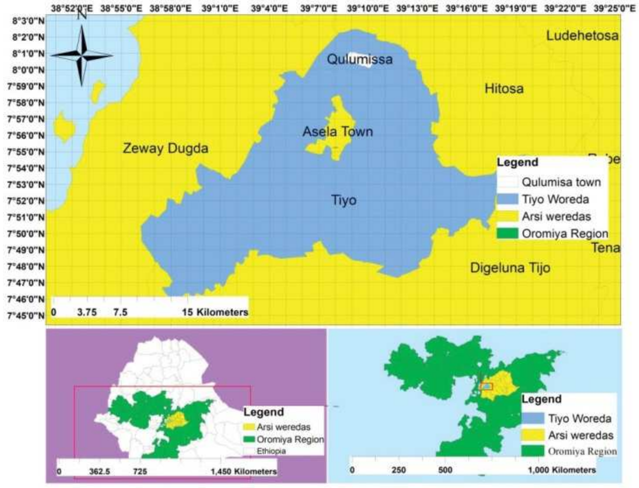


Figure 1. *Location map of the study sites.*

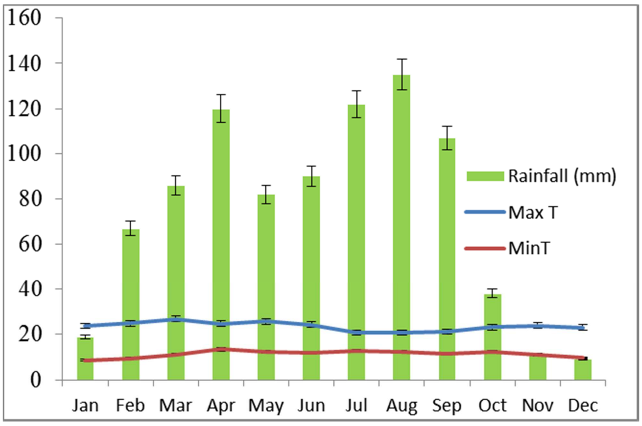


Figure 2. *Monthly total rainfall and average maximum and minimum temperatures.*

The study area falls in the moist 2 (tepid to cool moist mid to high altitude) agro-ecological zone. 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. The 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. 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 and vertisol (MoA, 1984) and wheat is the most widely cultivated crop in the area followed by barley.

2.2. Description of Soil Horizon and Soil Classification of Study District

The soil profile pit was dug on representative site. The soil profile description made according to FAO system was recorded on standard form for soil profile description (FAO, 1999). The soil type of the study area was classified as Vertic Luvisols (FAO-1999). The soil of the study district described as follows.

Profile Description

Ap -horizon (0 - 30 cm depth)- Dark reddish brown (5YR2.5/2) moist and dark brown (7.5YR3/2) dry, clay; strong coarse sub-angular blocky; sticky slightly plastic wet, friable moist, hard dry; many fine interstitial pores; common fine roots; wide closely spaced cracks; clear and smooth boundary.

Bt –horizon (30 - 95 cm depth) - Dark reddish brown (5YR2.5/2) moist, clay; strong coarse angular blocky; sticky plastic wet, firm moist; abundant prominent clay cutans; common fine interstitial pores; common fine roots; clear and wavy boundary.

Bc-horizon (95 - 135 cm depth) - Dark reddish brown (5YR3/2) moist, clay; strong coarse angular blocky; sticky plastic wet, friable moist; abundant prominent clay cutans; few very fine interstitial pores; very few fine rock fragments; clear and smooth boundary.

C-horizon > 135 cm depth- Highly weathered rock.

2.3. Soil Sampling and Analyses

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 [9]. Soil pH was measured using a glass combination pH meter in the supernatant solution of 1:2.5 soils to solution ratio of water [55]. 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 Mehlich III (Mehlich, 1984) and Soil available Sulphur (ava. S) in the soil was determined turbid metrically using a spectrophotometer (Singh et al., 1999).

Table 1. *Pre-planting selected physicochemical properties of experimental soils.*

Physical Properties				**Chemical properties**			
sand	**silt**	**clay**	**texture class**	**pH**	**OC (%)**	**TN (%)**	**Ava. P (ppm)**
27.46	24.22	48.32	Clay	6.3	1.58	0.19	20.33

Table 1. *Continued.*

Chemical properties				
Ava. S (ppm)	**Ex. K (cmol/kg)**	**Ex. Na (cmol/kg)**	**Ex. Ca (cmol/kg)**	**Ex. Mg (cmol/kg)**
14.3	0.76	1.59	45.41	1.12

pH=soil reaction, Oc=soil organic carbon, ava. P=available phosphorus, ava. S=available sulphur, Exch. K=exchangeable potassium, Na=sodium, Ca=calcium, Mg=magnisume,. TN=Total nitrogen.

2.4. Experimental Planting Material

Kakaba' was 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.

2.5. Experimental Treatments, Design and Procedures

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 and incorporated by hand with in the soil at planting but there was difficult to prevent dispersion of powered calcium sulphate by wind. 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 1 m. At the 125kg/ha seeding rate, the seeds were drilled manually in 20 cm apart open rows and covered with soil on-22/07/2013. Recommendation rate for experimental site is 92kg/ha N and 69 kg/ha P_2O_5. Land preparation and other all agronomic practices were done as per their recommendations for wheat.

2.6. Plant Chemical Analysis

At crop maturity, a subsample from each net plot was harvested at ground level and dried at 70°C until constant weight was reached for dry weight determination and partitioned into straw and grain. The dried samples were milled, and the grain and straw Total N in the sampled plants was determined by Kjeldahl procedure following the treatment of the plant material with H_2SO_4 (NSRC, 2000) and expressed in percentage. Total sulphate contents of sampled whole plants at harvest were extracted by wet ashing method. Sulphur content in grain and straw was estimated by turbid metric method (Williams and Steinbergs, 1959). After the determination of N and S concentration, in grain and straw uptake of N and S in the grain and straw of wheat was determined by using the following formula.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content\%*yield (kg/ha)}}{100}$$

2.7. Data Collection

The measured (computed) variables for yield and quality of bread wheat were kernel weight, grain yield, hectoliter weight, protein content and gluten. For grain yields measurements, the entire crop was harvested from a net plot area of 25 m^2 (5 m by 5 m). The air-dried samples were threshed manually, cleaned and weighed for grain yield determination. The moisture contents of the grain samples were measured using a moisture tester device and adjusted to a standard value of 12.5%. The weighed samples of the aboveground biomasses and grains from each plot were converted to kg ha^1 for statistical analyses. Grain samples were collected from each plot and their respective kernel and hectoliter weights were determined using seed counter and hectoliter weighing devices, respectively in the crop physiology laboratory of KARC. All quality parameters such as protein and wet gluten were measured by using Infratec™ 1241 Grain Analyzer.

2.8. Data Analysis

All data were subjected to the analysis of variance using General Linear Model procedures of SAS and significant mean differences were separated by least significant difference (LSD) at respective level of significance used for ANOVA [48]. Relation analysis was carried out to study the nature and degree of relationship between fertilizer rates and yield components and quality variables. Correlation analyses were also carried out for selected variables using the same software.

2.9. Economic Analyses

Based on an economics training manual procedures of CIMMYT the Partial budget analyses were done to determine economic feasibility of Sulphur for bread wheat production around the study areas [11]. The mean grain and straw yield data of wheat was employed in the analyses. Furthermore, the grain yield and straw yield obtained from each treatment were adjusted down by 10% in order to narrow the possible yield gap that may happen due to difference in field management by researcher and farmers. This is because usually, researcher managed field give higher yield than farmer managed field.

3. Results and Discussion

3.1. Effects of Sulphur Fertilizers on Yield and Quality of Bread Wheat

Yield and quality components of bread wheat which are grain yield, hectoliter weight, thousand kernel weight, protein and gluten showed significant respond ($P < 0.05$) (Table 2).

3.1.1. Grain Yield

Grain yield is the important component of plant performance under a set of growing conditions. The mean grain yield of wheat was highly significantly ($p < 0.01$) affected by S rates (Table 4). 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 whereas the lowest grain yield (4122.8 kg/ha) was obtained from 100 kg S/ha (Table 4). In the present study the synergism and antagonism relationship among N, P and S fertilizer levels on wheat yield was observed. Synergism relationship was observed where treatment receiving up to 92 kg N -69 kg P with 20-60 kg S/ha. The beneficial synergism relationship Xie A reported that application of 50kg/ha S fertilizer increased spring bread wheat grain yield by 3.58% on Cambisols in southeastern Poland [52] whereas According to Podleśna (2013) application of 60kg/ha S fertilization increased winter wheat grain yield by 11%. Moreover, Klikocka reported that Maximum yield of grain for ‘Shehan’ and ‘Enkoy’ cultivar were found at the combined application of 180 kg /ha N and 60 kg/ha S on Andisols and Cambisols in northern Ethiopia [30].

The author Menna who reported that the highest rate (20 kg/ha) of S application showed that significantly yield increment on Kekeba bread wheat variety on vertisol of central high land of Ethiopia [36]. Furthermore, the authors Assefa showed that the rate of Sulphur application under balanced fertilization of digelu variety of bread wheat 20-30kg/ha S on cambisol, 30-40kg/ha S on vertisol and 15kg/ha S combined with 22kg/haP of menze bread wheat Varity on vertisol of north central highland of Ethiopia were recommended [5].

Antagonism relationship was also observed in the present study at higher rates of S fertilizer. A finding from this study shows that application of NP and S on vertisol beyond 80-100 kg S with 92 kg N-69 kg P/ha results in reduction of wheat yield. Similarly, Assefa reported that application of P and S at higher rate (44 kg P and 30kg S ha/1) showed reduction in wheat yields [5]. Generally, grain yield was declining after 80-100kg/ha application rate of S. The reason should be imbalanced ratios of macronutrients (S-N-P) have been created in the soil solution. In soil solution, SO_4^{2-} is highly mobile and only weakly held on colloidal particles; it is easily volatilized and leached out of the crop rhizospheres and pastures, and huge losses of up to 100 kg S ha^{-1} per year have been recorded in Southern England [17].

Soil nutrient interaction in different crop species is probably one of the most important factors affecting yields of annual crops (Fageria, 2014). Imbalanced nutrients interaction affects their availability to crops as on overabundance one may result in deficiency of another nutrient [30]. According to Xie, Chapman, Salvagiotti Combination of S and N have also been established in terms of dry matter accumulation and yield in different crop species [52, 10, 45]. In addition to Ali also was observed that Grain yield ha^{-1} can be significantly enhanced by applying N and S [2] while at the whole plant level, the requirement for matching N and S supply to corresponding demand arise from the close link between the uptake of SO_4^{2-} and NO_3^-[12].

3.1.2. Thousand Kernel Weight

There was statistically significant difference ($p<0.05$) on 1000 kernel weight due to S application (Table 4). Among the application of S, the highest (42.43 g) was recorded (Table 4). 1000 kernel weight under the influence of applied S rates, the result obtained at 60 kg S/ha was the highest (42.43 g) followed by treatments receiving 40, 20, 80, 0 (control) and 100 kg S/ha whereas the lowest (40.12 g) was obtained at 100 kg S/ha application. Similar results of increased bread wheat 1000 kernel weight with increased S fertilization rates were also reported by several researchers [47, 25, 52]. A previous study by Zhiqiang reported that S fertilization at 45 kg S/ha, 200 kg N/ha, 183 kg P/ ha, and 163 kg K/ ha significantly ($p < 0.05$) increased kernel weight in both (GY2018 and ZM8) cultivars by 30.2% in GY2018 and 14.2% in ZM8 compared to the control (no S applied) [54]. Moreover, Zhao reported that Application of Sulphur fertilizers may actually decrease 1000-kernel weight of wheat [53].

3.1.3. Hectoliter Weight

The mean hectoliter weight of wheat was highly significantly ($p<0.01$) affected by S rates (Table 2). Hectoliter weight range 72.32-75.54 whereas the highest hectoliter (75.54 Kg/hl) was obtained from 60 kg S/ha followed by 40, 20, 80, 0 (control), and 100 kg S/ha and the lowest hectoliter weight (72.32 kg/hl) was obtained from 100kg S/ha (Table 4). This information agreed with results obtained by other authors [43]. Furthermore [15] reported similar results, showing very high S grain responses in wheat.

3.1.4. Grain Protein Content

The values of grain protein content are presented in Table 2. The mean grain protein of wheat was significantly ($p < 0.05$) affected by S rates. The grain protein content ranged from 10.66% to 5.88%). Whereas the highest protein (10.66%) 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 (Table 2). At optimum level of Sulphur treatments recorded significantly higher grain protein content than the treatment receiving control and high Sulphur. The latter treatment recorded the lowest protein content in grain. Among Sulphur treatments, 60 kg/ha Sulphur as gypsum recorded higher protein content (10.66%). Similar results of increased grain protein content of wheat with increased S fertilization rates were also reported by several researchers including [21, 54, 50, 53, 40].

Results from the present study revealed that Synergism relation among NP with S. The authors [40] who stated that Sulphur is known to play an important role in grain protein formation and nitrogen.

Assimilation in wheat. Furthermore, the authors [26] confirmed that in plants, S and N play a synergistically central role in the synthesis of proteins, and the supplies of N and S nutrients in plants are highly inter-related.

Results from the present study the lowest protein content was obtained from the highest (100 kg S) rate of Sulphur. This result was brought due to un-proportional N: S ratio in plant tissue that leads low protein synthesized. Similar results were also reported by several researchers including [4, 26, 19, 45] reported that N and S have exhibited strong interdependence on effecting significant yield and protein synthesis in wheat, the ratio of total N to total S in plant tissue can reflect the ability of N and S in protein synthesis. Therefore, an altered ratio of reduced N to reduced S, an acceptable way to reflect the amount of amino acids S, may reveal significant protein metabolism alterations that may have important implications for protein quality. S deficiency can reduce the utilization of available soil N, leading to increased nitrate leaching and that N deficiency can also reduce S use efficiency. Furthermore, Assefa also reported that the synergistic effect of S and P on availability of P was increased at lower rate of S but decreased at higher rates [5].

3.1.5. Wet Gluten Content

The values of wet gluten content are presented in Table 2. The mean wet gluten of wheat was significantly ($p < 0.05$) 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. Furthermore [22] stated that the highest protein ratio was obtained from S application in wheat.

Table 2. *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 Kg/ha	GY (kg/ha)	TKW (g)	HLW (kg/hl)	PRO (%)	Wet GLU (%)
0	4339^{cd}	40.15^{b}	72.51^{c}	7.72^{bc}	25.10^{c}
20	4983^{b}	41.66^{a}	74.43^{ab}	9.14^{ab}	25.66^{bc}
40	5478^{a}	41.98^{a}	74.44^{ab}	9.49^{ab}	29.16^{ab}
60	5603^{a}	42.43^{a}	75.54^{a}	10.66^{a}	31.06^{a}
80	4592^{cb}	41.26^{ab}	73.93^{b}	9.08^{ab}	25.40^{c}
100	4123^{d}	40.12^{b}	72.32^{c}	5.88^{c}	23.40^{c}
LSD	465.93**	1.45*	1.12**	2.57*	3.79*
CV	5.27	1.93	0.83	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.

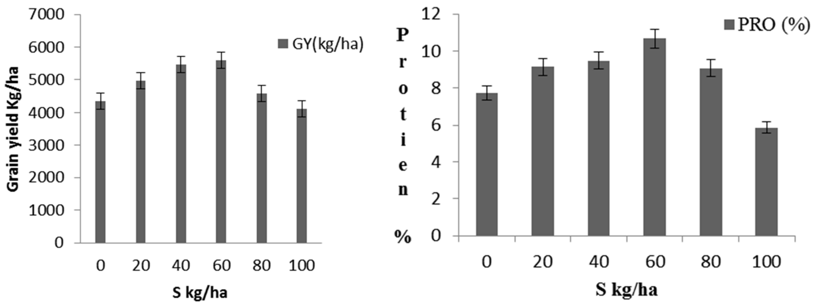


Figure 3. *The relation of Sulphur rates with Grain yield and protein.*

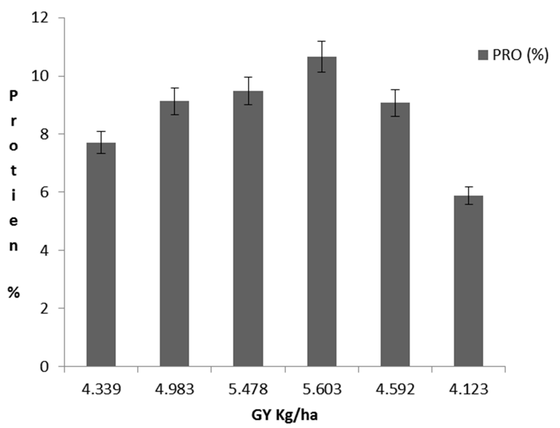
Figure 3 describes the relation of quality and yield variables with Sulphur as expressed by Correlation coefficients (r) computed between each other. As indicated by the correlation Coefficient values, apparent interrelationships with quality components were observed. These values indicated the magnitude and direction of the associations and relationships among yield and quality variables. For instance, among the yield and quality components of wheat, grain yield was directly and highly significantly (p<0.01) correlated with thousand kernel weight (r=0.81), hectoliter weight (r=0.78), harvest index (r=0.77) and wet gluten (r=0.69) while positively and significantly (p<0.05) association with protein (r=0.51).

3.2. The Effect of Sulphur on Nutrient Uptake

3.2.1. 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) and 100kg S/ha and the lowest (0.97%) was obtained from 100kgS/ha. While 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. Similar result reported by Fotyma on fertilization of spring wheat with S showed that the application of 60 kg S ha^{-1} increased N uptake, but did not affect the accumulation of S in the grain [20]. In addition to this application of Sulphur fertilizer enhancing the accumulation of N in grain [39]. Meanwhile, Barczak showed that S fertilization resulted in an increase in the content of total N in spring barley [7]. Also in studies of Martin the increasing level of S increased noticeably the N content in grains of wheat [33, 43]. Moreover, Pourbabaee showed that N uptake was dependent on efficient S fertilization [39]. S and N interact on their concentration in plants and the total accumulation in yields, as the S content in the grain of wheat depends not only on its dose, but also on the availability of N. [43].

Nutrient availability such as N, P, K, S and other micronutrients of Sulphur carried out through the inhibition of microorganisms on rhizosphere for oxidation, Solubilization, mineralization process of nutrients for plant availability in plant root. The rhizosphere is the region of the soil that includes the area immediately around plant roots and a large number of microorganisms [38]. The rhizosphere is a region with a high turnover of nutrients and a high microbial density where biotic and abiotic factors are under the strict control of each other [14]. Examples of microorganisms that can be found in the rhizosphere include Plant Growth-Promoting Rhizobacteria (PGPR) and mycorrhizal fungi [38, 39].



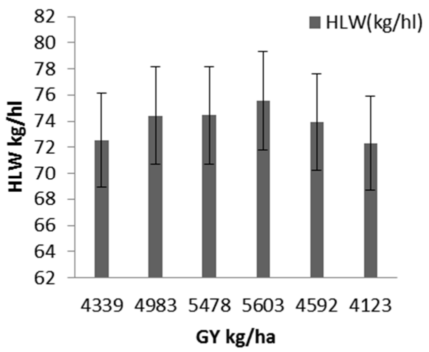


Figure 4. The relation of Grain yield with protein and hectoliter weight.

PGPR (Rhizobium, Bradyrhizobium, Bacillus, Azospirillum, Azotobacter, Acinetobacter, and Pseudomonas) live in close association with plants and plant tissues (bacterial endophytes) and may stimulate plant nutrient uptake, modulate the level of phytohormones in plant tissues, and/or increase plant biotic or abiotic stress tolerance [16, 25].

Current finding showed that the uptake of N decreasing at higher rates S (80-100 S kg/ha). According to Assefa application of 22 kg P with 15 S kg/ha reported the highest N uptake both grain and Straw and decrease at high rate of S kg/ha [5]. This implies that, beyond 60kg S/ha failed to increase in N uptake and it was declined which might be due to inhibition effect of higher doses of S on N uptake [6]. The present study showed that accumulation of N in straw increased at control /or low S rates (0-20kg/ha).

Many species of nitrogen-fixing bacteria like Azospirillum belonging to the family Rhodospirillaceae (A. zeae, A. thiophilum, A. rugosum, A. picis, A. oryzae, A canadense, A. mazonense, and A. melinis) have been found associated with grass rhizospheres [6]. According to Wani reported that Azotobacter and Pseudomonasacter) have the potential to colonize the roots of wheat to increases protein content, promotes plant growth and yield by causing changes in the cell wall elasticity or the morphology of the root, or both through the production of phytohormones (auxin) [32, 49, 4].

The process of sulphur-oxidiation carried out through different microorganisms such as the genera of Xanthobacter, Alcaligenes, Bacillus, and Pseudomonas which have great role for plant growth-promoting activities [23]. Moreover, [39] reported the positive effect of Thiobacillus spp. on maize plants by increasing plant height, yield, and nitrogen uptake. A deficiency of Sulphur in plants results in low nitrogen metabolism, which causes chlorosis, low lipid percentage, and low plant growth and yield [44].

3.2.2. Sulphur Uptake

Sulphur accumulation in grain and straw were non-significantly ($P<0.05$) by statistically.

Table 3. Effect of Sulphur fertilizer application at different levels on nitrogen and Sulphur uptakes by bread wheat plants.

S rates kg/ha	Nutrient uptake			
	Nitrogen (%)		Sulphur (%)	
	Grain	Straw	Grain	Straw
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 ($P <0.05$) NS-non significant, *=significant at $0.01 < P<0.05$.

3.3. Partial Budget Analysis

Partial budget analysis supports to evaluating the effect of a change in the production system on a farmer's net income without knowing all his costs of production. The data related to partial budget analysis is given in Table 4. The maximum net benefit (35047.2 ET Birr) was obtained from application of 60kg/ha Sulphur followed by 40 kg/ha (34756.7 ET Birr.). Minimum net benefit (27808.3ET Birr.) was recorded in control (treatment that did not receive any Sulphur fertilizers). Depend on dominancy analysis, treatments of Sulphur at 80 and 100 kg Sulphur were dominated by the rest four treatments and they were also removed from further economic analysis. The data regarding the marginal rate of return (MRR) revealed that maximum MRR (1333.32%) obtained from 20 kg/ha of Sulphur was applied followed by rate of 40 kg S/ha (865.522%). Minimum MRR was (91.9%) recorded in treatment where application of Sulphur at 60 kg/ha. Therefore, application of 60kg/ha Sulphur rejected due to MRR was below 100%. Data from Table 4 clearly revealed that the non-dominated treatments associated with MRR are greater than 100%. This implies that the two non-dominated treatments are economically feasible alternative to the other dominated treatments. The marginal rate of return, 1333.32% means the producer obtained an additional income of 13.33 Ethiopian birr per a unite cost they have invested. Generally, treatment of 20kg/ha of gave better MRR value relative to another non- dominated treatments and profitability can be optimized by using this treatment.

Table 4. Partial budget Analysis for Sulphur fertilizers studied area.

Treatment	AGY	AST	GBGY	GBSTY	TVC	TGB	NB	MRR%
0	3905	5073	31240	1268	4700	32508	27808.3	-
20	4485	4631	35880	1158	5016	37038	32021.6	1333.32
40	4930	2595	39440	649	5332	40089	34756.7	865.522
60	5043	1405	40344	351	5648	40695	35047.2	91.9462
80	4133	4147	33064	1037	5964	34101	28136.8	D
100	3711	6538	29688	1634	6280	31322	25042.4	D

Adj. GY=Adjusted grain yield (kg /ha), Adj. STY=Adjusted Straw yield (kg/ha) TGB=Total growth benefit, TVC=Total variable cost, NB=Net benefit, MC ¼ marginal cost, MB=marginal benefit, MRR=marginal rate of return, D=dominated, R=rejected.

4. Conclusion and Recommendation

Nutrient application rate determined on soil type, season, climate, and weather, application methods, time of application, crop type, cultivars and source of fertilizer.

The present study demonstrated that application of S fertilizer has significantly increased yield and quality of bread wheat grown in Vertisols of the study district, Arsi zone of Ethiopia compared to that obtained from unfertilized control. Moreover, the current finding presents additional evidence to research claims that S is becoming a limiting nutrient in some Ethiopian soils which is being reported. Maximum yield of wheat was obtained from treatment involving application of 20 kg S ha^{-1} on Vertisols. While, partial budget analysis result revealed that, 20 kg S ha^{-1} produced the highest MMR (1333.33%) and thus, those treatments are found to be economically feasible treatments for bread wheat production in Vertisols of the district of Tiyo.

Declarations

Author Contribution Statement

Almaz Admasu: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Data included in article/supplementary material/referenced in article.

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The authors declare no conflict of interest.

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