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Effect of Sulphur Fertilizer on Yield and Quality Attributes of Bread Wheat (*Triticum aestivum* L.) Varieties

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Abstract

Wheat production and its importance in Arsi Zone and Ethiopian has much contribution to the market and consumption throughout the country's community, but its productivity is still very low due to poor agronomic practices and diminishing soil fertility. Thus, field study was conducted with the objective of evaluating the effect of sulphur fertilizer on yield and quality attributes of bread wheat varieties. The experiment consisted of six levels of sulfur (0, 15, 30, 45, 60, 75 kgha^{-1}) fertilizer and three wheat varieties (Kingbird, Lemu, Hidasse) which were replicated three times in a Randomized Complete Block Design. Grain yield and hectoliter weight were significantly ($p<0.05$) affected by rates of sulphur. Application of 45 kgha^{-1} sulphur increased the grain yield of wheat by 14% as compared to those grown without sulphur application. The results of the correlation analysis showed that the grain yield was positively significantly ($p<0.05$) correlated with total number of tillers(r=0.33), total number of productive tiller(r=0.30), plant height (r=0.32), days to maturity(r=0.10), panicle length(r=0.07), Number of grain per spike(r=0.16), biomass yield(r=0.42), hectoliter weight(r=0.11) and harvest index(r=0.32); while, negatively and significantly ($p<0.05$) associated with protein content (r=0.14). A maximum of 4.45% decrease in soil pH was observed in plot applied with 60 kgha^{-1} sulphur as compared to the control, which is important for soil amendment. In general, the application of 45 kgha^{-1} sulphur would be preferred to produce bread wheat at the study area for better grain yield and quality in addition to the soil physico-chemical properties improvement.

Keywords: Bread wheat, Sulphur fertilizer, yield, wheat protein content

1. Introduction

Wheat is believed to be originated in south western Asia where it has been grown for more than 10,000 years. Related wild species have still grown in Lebanon, Syria, Northern Israel, Iraq, and eastern Turkey the modern hexaploid bread wheat (*T. aestivum L. em. Thell*). Evolved later and became abundant about 8,000 years ago (Curtis, 2002). Wheat can grow under very different temperature and moisture conditions. For example, the optimal temperature range for germination varies between 12^{o}c and 25 °C (Acevedo and Silva, 2002). Today, there is a very wide range of wheat species and varieties. This explains why wheat can adapt to the most different environments. According to (Abu, 2012) indicate that wheat is grown at an altitude ranging from 1500 to 3000 m.a.s.l, between $6\text{-}16^{0}$ N latitude and $35\text{-}42^{0}$ E longitude in our country. The most suitable agro- ecological zones, however, fall between 1900 and 2700m.a.s.l. Wheat is one of the most important cereals grown in the world. In 2011/2012 the global production of wheat is forecasted to be 674 million tons (FAO, 2011) According to (Mollasadeghi and Shahryari, 2011) it is, a self-pollinating annual plant in the true grass family Gramineae (Poaceae), is extensively grown as staple food sources in the world.. Wheat is mostly grown for its grains, and the amount and quality of gluten in wheat grains is an important factor for flour production (Winch, 2006).

Ethiopia is one of the largest wheat producers in SSA (Minot *et al*., 2015) with an estimated area of 1.66 million ha and production of 4.3 million tons (CSA, 2016). The major wheat producing areas in Ethiopia are located in Arsi, Bale, Shewa, Ilubabor, Western Hareghe, Sidamo, Tigray, Northern Gonder and Gojam zones (Bekele *et al*., 2000).It has become one of the most important cereal crops in country ranking 4th in total grain production and 4th in area coverage next to teff, maize and sorghum (CSA, 2014). Despite the long history of wheat cultivation and its importance to the Ethiopian agriculture, its average yield is still very low, not exceeding 2.4 t ha^{-1} (CSA, 2014) as compared to the world average 3.0 t ha^{-1} (FAOSTAT, 2013). Mean wheat yields increased from 1.3 t ha^{-1} in 1994 (CSA, 1995) to 2.54 t ha^{-1} in 2015 (CSA, 2016), which is well below experimental yields of over 5 t ha^{-1} (Tadesse *et al*., 2000; Zeleke *et al*., 2010; Mann and Warner, 2015). The yield gap of over 3t ha^{-1} suggests that there is potential for increasing production through improved soil and crop management practices, particularly increased use of fertilizers and an adequate soil fertility maintenance program. Parameters influencing wheat yields include disease, the tendency to be flattened during storms, soil drainage, and fertiliser use. However, to ensure sustainable crops production including wheat, healthy soils are important, soils with good physical, chemical and biological fertility. In contrast, poor health/quality soils exhibit various functional attributes like deficiencies in nutrients, erosion and various other constraints. Plant nutrients are key components of soil health/quality and are good, if present in adequate, but if not, the means of replenishing them must be weighed against any economic activity (Assefa *et al*., 2015). Sulfur is reported to be a macro-nutrient that is taken-up by crops in amounts similar to and sometimes exceeding those of P, 10-30 kg/ha (Weil, 2011) and considered to be one of the most limiting nutrient element for crop production. It is essential not only for plant growth and quality produce, but also enhances other nutrients use efficiency and ranks second only to N in importance for optimum crop yield/quality (Brown, 2005). In our country according to the soil fertility map made over 150 districts, Ethiopian soil lacks about seven nutrients (N, P, K, S, Cu, Zn and B) (EthioSIS, 2013). For the last three decades, Ethiopian agriculture depended solely on imported fertilizer products, only urea and di-ammonium phosphate (DAP) as sources of N and P. In addition numerous problems that decrease Wheat production in Ethiopia especially in relationship to the fertility of the soil for most crops, of which major causes are salinity and moisture (Bello and Haftom, 2008). However, recently it is perceived that the production of such high protein cereals like wheat and legumes can be limited by the deficiency of S and other nutrients. In Ethiopia, major prone areas of S deficiency are the central highlands (HLs), because of their high crop production, which is driven by high market access in the big towns/cities in the central of the country (Assefa *et al*., 2015). Reasons that lead to S deficiency in soils of central HLs include 1) improved use of high-analysis fertilizers that contain no S, 2) intensive agriculture that leaves behind little organic matter (OM), and/or complete removal of OM for alternative uses, including farm yard manure (FYM), 3) use of high yielding varieties, resulting in more S removal, and 4), intensive cropping-systems that include legumes and oil crops that mine more S. But, in such conditions, failure to supplement S in balanced-fertilizer programmers can rapidly deplete available soil reserve leading to hidden S deficiency. Regardless of its importance, very little research is done on the status of S in soils and crops, and the available information/data are quite scanty. Moreover, unlike NPK and other elements, S is not routinely analyzed in soil and plant tissues at the laboratories in Ethiopia: Thus, the study was intended to evaluate the effect of sulphur fertilizer on yield, yield components and quality attributes of bread wheat varieties.

2. Materials and Methods

2.1. Description of the Study Area

The experiment was conducted at Munessa woreda, Arsi zone of Oromia Regional State, Ethiopia during the 2017 main cropping season. Munessa is located 7^{o} $02^{'}$ 45’’to 7^{o}31’35’’north latitude and 38^{o}47’04’’ to 39^{o}04’36’’ east longitude. It is found at a distance of 232 km SouthEast of Addis Ababa and 57 km South East of Asella town (capital city of the Zone). The site is located at an altitude of 1500 to 3300 masl. The area is characterized by bimodal rainfall pattern. There are two growing season spring and summer based on the time of crop harvest. The main cropping season of the crop growth duration in the district is from Mid-June to mid- December. Temperature ranged from 10^{o}c to 20^{o}c, and the rain fall is from 900mm – 1200mm with the soil type of clay loam.

2.2. Experimental Design and Treatments

Three wheat cultivars (Hidasse, Kingbird and Lemu) and six levels of sulphur fertilizer (0, 15kg/ha, 30kg/ha, 45kg/ha, 60kg/ha and 75 kg/ha) were used for the experiment. Nitrogen and phosphorous were applied as recommended dose of DAP for wheat production in the study area (100 DAP, Kg ha^{-1}) and additional urea (100kg ha^{-1}) were applied for the treatment (variety). Gypsum was used as a source of sulphur fertilizer except the treatment without any of external sulphur fertilizer (control) application. The three varieties and fertilizer rates combinations were replicated three times in factorial randomized complete Block Design (RCBD). The DAP compound fertilizer nutrient components are in the ratio of 46, 0, 18 P, K and N respectively and Gypsum as source of Sulphur in addition to Calcium content ratio of /23, 19/ Calcium , Sulphur respectively utilized as treatments.

2.3. Experimental Procedures

2.3.1. Soil sampling, preparation and soil analysis

An initial soil sample at a depth of 0-30 cm was taken from five randomly selected spots in Zigzag pattern of the experimental field using auger before planting. Similarly, surface soil (0-30 cm depth) samples were collected from every replication of each treatment and bulked to yield a total of 54 composite surface soil samples per treatment, which is one composite soil sample per plot after the crop harvested. Then, the collected soil samples were air dried, grounded under moist covered dried air condition, sieved and analyzed in the soil laboratory of Kulumsa Agricultural Research Center for selected physicochemical properties mainly organic matter, total N, total S, soil pH, available phosphorus, and textural using standard laboratory procedures using their appropriate procedures. The experimental field was prepared following the conventional farmers’ practices. The field was ploughed using 3 times and one time by tractor before sowing. The seed were sown directly in rows with spacing of 20 cm between rows and 5 cm between plants. The entire sulphur levels from Gypsum were drilled within rows and incorporated into soils before seeding. Nitrogen were applied in splits (one third (1/3) at sowing and the other two third (2/3) at tillering) as Urea (46 % N). Unlike nitrogen, the full rate of P was applied at sowing as Triple Supper Phosphate (20% P). Seed rate of bread wheat 100 kgha^{-1} were used in experiment. The total experimental area 556.20 m^{2}and 1.4 m x 4 m plot sizes were used as an experimental unit. The blocks were separated by a 1 m wide space and each plot was separated by 0.5 m spacing. There were 7-rows per plot of which two were borders and the remaining middle rows were used for plant sampling and seed sampling. Each treatment was randomly assigned to the experimental unit within a block.

2.4. Data Collection

2.4.1. Growth parameters

Total number of tiller per plant: were recorded as when the spikes fully extruded out and the average number of productive and none productive tillers were counted.

Plant height: were determined at maturity from 10 randomly tagged representative plants in a plot by measuring from the ground surface to the tip of the spike excluding the awns. i.e. The average height in cm from ground level to the tip of the spike was measured.

Day to maturity (DTM): were recorded when the number of days from sowing to the stage when 90% of the plants in a plot have reached physiological maturity.

2.4.2. Yield parameters

Panicle length (cm): panicle length in each plot from 10 random tagged spikes was obtained by measuring from the base of the spike up to the apex of the terminal spikelet excluding the awns.

Number of grain per spike: were counted from 10 randomly tagged representative plants in a plot of each plot and the average number of grain per spike.

Thousand grain weight (g): thousand grain weights was measured on dockage free basis by taking the mass of carefully counted thousand full sized grains on sensitive electronic balance (+ 0.1g).

Grain yield (ton ha^{-1}): grain yield in ton taken by harvesting and threshing the seed yield from net plot area and converted to ton per hectare. The yield was adjusted to their moisture content.

$$Yield\ (12.5\%, mb) = \frac{yieldobtained\ (100 - 12.5)}{100 - \%mc} x\, 100$$

Biological yield (ton ha^{-1}) was obtained by weighing above ground dry matter of plant (straw and grain) in each plot. After physiological maturity from net plot area and converted to ton per hectare.

Harvest index: was calculated as ratio of grain yield to above ground total biomass

$$HI = \frac{Economic\ yield}{Biological\ yield} x\, 100$$

2.4.3. Quality analysis

At the end of harvesting the yield samples (500g) were taken from each plot fertilized with different rates of sulphur along the three varieties. The samples were taken to Kulumsa Agricultural Research Centre laboratory for analysis of protein content of each treatment.

2.4.3.1. Protein content

The nitrogen content was determined by micro-Kjeldhal method as stated in AACC method 46-11 (AACC, 2000). A conversion factor of 6.25 was used to convert the percent of nitrogen to percent protein**.**

2.4.3.2. Hectoliters weight (HLW*)*

Hectoliter weight was estimated for each experimental unit following standard procedure (AACC, 2000) on dockage free basis using laboratory standard hectoliter and electronic balance.

2.5. Data Analysis

Analysis of variances (ANOVA) was used for the data analysis recorded according to Generalized Linear Model using SAS version 9.0 (SAS, 2004). Correlation analyses were performed to determine simple relationship between quality and yield components of Bread Wheat varieties as affected by rates of sulphur application. Least significant differences (LSD) test at 5% probability were used for mean separation when the analysis of variance indicated the presence of significant difference.

2.6. Partial Budget Analysis

In this study the partial budget analysis were done considering all variable costs and all benefits (grain yield). Variable costs are costs of fertilizers which are used for fertilizer combination, packaging material costs for grain and cost of transport. The fertilizer cost was calculated for the cost of each fertilizers of DAP, Urea and Gypsum. The cost of packaging and transport were Birr/ 100kg of grain yield and the average open market price of wheat grain at kersa town market ETB kg^{-1}.

3. Results and Discussion

3.1. Soil Physico-chemical Properties of the Study Sites before Planting

The physicochemical properties of the study soil before planting were analyzed (Table 1). The soil pH of the site before planting was low indicating weak acidic (5.98). Sulphur (SO_4-S) content of the soil before planting was 6.28 mg/kg which indicated that a critical limit of S deficiency for most crop species range from 10-13 mg kg^{-1} as reported by (Tandon 1991). Similarly, results of (Assefa *et al*., 2015) indicated that critical soil (SO_4-S) level determined using Cate and Nelson procedure, from the first set of experiments as 11.3 mg kg^{-1} and also (Patrick *et al.*, 2013) indicated that below 10 mg SO_4 kg^{-1} as a critical Sulphur deficiency level for crop growth. The total nitrogen (0.19%) content of the study soil was considered to be very low based on (SAS, 2002) for tropical soils. This low total nitrogen can be attributed to the low levels of Sulphur and organic Carbon in the studied soil and this can adversely affect crop yields. The available P extracted by (Olsen method) from the study soil was 8.99 which is below <20 mg P kg^{-1} as categorized as very low (Horneck, 2011). The soil organic carbon content of the studied soil was 2.93% which was considered being very low based (Thiagalingam, 2000). Soil OC is also reported to be a promising indicator for guiding N fertilizer management and soil quality (Patrick *et al*., 2013). Furthermore, soil organic carbon is described as a 'universal keystone indicator' in soil fertility management (Ssali, 2000; Loveland and Webb, 2003) in region with the lowest fertilizer use (Dobberman, 2012).

Table 1 Physico-chemical properties of the soil before planting

Site	Particle size (%)			Textural class	CEC(Cmol(+)/kg	pH	OC (%)	Total N (%)	Available P (mg/kg)	SO4-S (mg/kg)
	sand	silt	clay							
Munesa	31.6	36	32	Clay loam	13.28	5.98	2.9	0.19	8.99	6.28

CEC = cation exchange capacity, OC= organic carbon, N =Nitrogen, P= phosphorus, S= sulphur

3.2. Effect of Sulphur Fertilizer Application on Postharvest Soil Physico-chemical Properties

3.2.1 Soil reaction

The analysis of variance showed not significant ($P < 0.05$) differences in pH due to the effects of Sulfur application (Table 2). It is important chemical property which determines the availability of nutrients to plant. Soil analysis indicates that application of gypsum effective for lowering soil pH this important for soil amendment. All the treatments remained significant statistically in decreasing soil pH when compared with control (Table 2). Maximum decrease in pH was noted in treatment received 60 kg S ha^{-1} where pH was 5.80. However, the value of pH for treatments 45, 30, 15, 75 and 0 kg S ha-1 were 5.86, 5.85, 5.87, 5.91and 6.07, respectively. In this regard, highest pH (6.07) was determined for treatment received 0 Kg S ha $^{-1}$ (control treatment) which is almost similarly to initial soil analysis before planting (Table 1). The pH of the soils after harvest due to interaction effect of Variety and sulphur fertilizer was no significant ($p>0.05$). pH before planting at site of study was 5.98, the average soil pH at harvest varied from 5.50 to 6.40. Application of S at the rate of 0, 15, 30 and 75 kg S ha^{-1} interaction with King Bird variety reduced the pH of the soils at site by 5.78, 5.94, 5.63 and 5.90 as compared to the result before planting. Application of S at the rate of 15, 30 and 60 kg S ha $^{-1}$ with Hidasse variety also reduced pH of soil to 5.61, 5.89 and 5.54; and with variety Lemu 45, 60 and 75 kg S ha $^{-1}$ reduced pH of soil to 5.50, 5.90 and 5.81 as compared to soil result before planting (Table 2) which similarly along the report of Brady and Weil (2005). pH of saline sodic soils is high because of exchangeable Na present on exchange sites. By application of gypsum to such soil pH of soils decreased. Gypsum gave Ca and SO_4 $^{2+}$; Ca replaces Na from exchange site. This Na reacts with SO_4 to form Na_2SO_4 which is soluble and leach out of soil profile. So, in this way pH of the soil is decreased. However, applications of 45 kg S ha $^{-1}$ with Hidasse and King bird Varieties increase pH of soil to 6.02 and 6.05 respectively. Treatments 0, 15 and 30 kg S ha^{-1} with variety Lemu increase pH of soil 6.40, 6.05 and 6.06, respectively.

3.2.2. Sulfur Concentrations in the Soil as Influenced by Fertilizer Applications

The results of soil analysis for available soil S after harvest against treatments are presented in (Table 2). There was not significantly ($P>0.05$) Sulfur application by statically in turbid metric blue method available soil S across S rates. Averaged over all S rates, the initial level of available soil S which was 6.28 ppm before sowing (Table 1) increased to 15.06, 14.44, 14.14, 13.67, 12.38 and 12.04 ppm among the treatment of S application rates, the highest increment in soil available S was obtained from 15 kg S ha $^{-1}$ (15.06 ppm) and the lowest from 30 kg S ha -^{1} (12.04 ppm). This highest level of turbidly Blue soil S resulted due to coincided with the highest grain yield, grain uptake S and plant S uptake.

3.2.3. Total Soil Nitrogen

The results of soil analysis for total soil N after harvest against treatments are presented in (Table 2) were significantly ($p< 0.05$). Averaged over all N rates, the initial level of total soil N which was 0.19% before sowing (Table 1) decreased to 0.184, 0.182, 0.177, 0.175, 0.173, and 0.165% N Among the six treatment of S fertilizer rates, the lowest decreased in soil total N was obtained from 45 Kg S/ha (0.165%N) and the highest from 0 kg S ha^{-1} and 15 kg ha-^{1} (0.182, 0.184%N) respectively (Table 2). Similar "These results suggest that application of S fertilizer, with N, can promote the uptake of N by corn in S-responsive soils," (Chen *et al.*, 2008). Furthermore, positive correlation between total soil N and available soil S(r= 0.22) clearly indicates their associations (Table 2). The total N of the soils after harvest due to interaction effect of Variety and sulphur fertilizer not significant ($p>0.05$) were less than before planting (Table 2). Total N before planting at site of study was 0.19%, the average soil N content at harvest varied from 0.157 to 0.187%. Application of S at the rate of 15 kg S ha^{-1} interaction with King Bird variety increased the total N concentrations of the soils at site by 6.25%

over the control plot (Table 2). However, applications of 30, 45, 60 and 75 kg S ha^{-1} within varieties Hidasse and Lemu reduced the soil N content by 9.58, 5.78, 3.39, 3.29 and 7.65, 16.56, 5.78 and 9.58%, respectively over the control. The facts that the mean total N contents of the soils after harvest were lower than the soil N before planting. The fact that total N in the control plots had no differences from the S treated plots such as 15 kg S ha^{-1} within variety lemu and 30, 60 and 75 kg S ha^{-1} within variety King bird indicates that crop uptake of organic form of N in the soils was less compared with the external N inputs or inorganic N sources. Similarly (Brady and Weil, 2002) reported that plants can absorb very small portion of their N needs as soluble organic compounds. Therefore, more of inorganic form of N have been absorbed by plants or lost through different mechanisms.

3.2.4. Total Soil Phosphorus.

The results of soil analysis for total soil P after harvest against treatments are presented in (Table 2) there was significantly ($p< 0.05$) affected by interaction effects of Variety and Sulfur application. Averaged over all S rates, the initial level of total soil P which was 8.99% before sowing (Table 1) increased to 13.45 – 20.45 P % Among the six treatment of S application rates and bread wheat varieties, the highest increment in soil total P was obtained from 75 kg S ha^{-1} (20.45, 18.26 % of P) variety king bird and lemu respectively and the lowest from 30 kg S ha^{-1} (13.45%P) variety of Hidasse. These results were might be S fertilizer increased the availability of other macro and micro nutrients with in crop production (Salvagoiotti *et al*., 2009; Muhammad *et al*., 2013). Furthermore, positive correlation between total soil P and available soil S(r= 0.10) clearly indicates their associations.

3.2.5. Total Organic Carbon

The results of soil analysis for total organic carbon after harvest against treatments are presented in (Table 2) there was significantly ($p< 0.05$) affected by interaction effects of Variety and Sulfur application. Averaged over all S rates, the initial level of total organic carbon which was 2.90% before sowing (Table 1) and after harvest range to 2.57 – 3.14 % among the six treatment of S application rates and bread wheat varieties, the highest increment in soil total organic carbon was obtained from 60 kg S ha^{-1} (3.14 %) variety lemu and the lowest from 15 kg S ha^{-1} (2.57%) variety of lemu. Treatments 0, 15, 30, 45, 60 and 75 kg S ha^{-1} with varieties of Hidasse and King Bird almost show similarly results when compared to variety lemu. These results were might be S fertilizer increased the availability of other macro and micro nutrients with in crop production (Salvagoiotti *et al*., 2009; Muhammad *et al*., 2013). Furthermore, positive correlation between total organic carbon and available soil S(r= 0.23) clearly indicates their associations.

Table 2. Physico-chemical properties of the study soil after harvested

Varieties	Sulphur Rates (Kg ha $^{-1}$)	Parameters				
		pH	AV.S	Av.P	Total N	Total OC
Hidasse	0	5.78^{ab}	12.16^{a}	19.35^{ab}	0.183^{a}	2.73^{abc}
	15	5.94^{ab}	17.75^{a}	16.76^{abcd}	0.183^{a}	2.99^{abc}
	30	5.63^{ab}	11.98^{a}	13.45^{e}	0.167^{ab}	2.96^{abc}
	45	6.02^{ab}	17.31^{a}	17.18^{abcde}	0.173^{ab}	2.93^{abc}
	60	5.98^{ab}	17.48^{a}	15.32^{bcde}	0.177^{ab}	2.63^{bc}
	75	5.9^{ab}	14.82^{a}	13.81^{e}	0.177^{ab}	2.92^{abc}
King bird	0	6.03^{ab}	15.09^{a}	19.18^{abc}	0.183^{a}	2.95^{abc}
	15	5.61^{ab}	10.65^{a}	13.283^{e}	0.187^{a}	2.95^{abc}
	30	5.89^{ab}	10.39^{a}	16.65^{abcde}	0.183^{a}	2.95^{abc}
	45	6.05^{ab}	15.88^{a}	15.76^{bcde}	0.167^{ab}	3.05^{abc}
	60	5.54^{b}	14.73^{a}	14.78^{de}	0.183^{a}	2.76^{abc}
	75	6.01^{ab}	16.69^{a}	20.45^{a}	0.183^{a}	2.97^{abc}
Lemu	0	6.4^{a}	9.85^{a}	14.40^{de}	0.18^{a}	2.62^{bc}
	15	6.05^{ab}	16.78^{a}	15.17^{cde}	0.183^{a}	2.57^{c}
	30	6.06^{ab}	13.75^{a}	16.10^{bcde}	0.170^{ab}	2.74^{abc}
	45	5.5^{b}	10.12^{a}	15.25^{bcde}	0.157^{b}	2.82^{abc}
	60	5.9^{ab}	8.79^{a}	16.07^{bcde}	0.173^{ab}	3.14^{a}
	75	5.81^{ab}	10.92^{a}	18.26^{abcd}	0.167^{ab}	3.10^{ab}
Mean		5.89	13.62	16.18	0.176	2.88
CV (%)		8.67	38.1	15.46	7.95	10.5

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant CV= coefficient of variation, Av,S = available sulphur, Av.p= available phosphorus, N =nitrogen, OC= organic carbon

3.3. Effect of Sulphur Fertilizer on Phinology and Growth Parameters

3.3.1. Days to physiological maturity

The number of days required to reach physiological maturity of bread wheat was significantly ($P < 0.05$) influenced by interaction effect of variety and Sulphur fertilizer (Table 3). Hidasse (157) and Lemu (157) variety were late maturing varieties at higher rates of sulfur fertilizer application (45 kg S ha^{-1}) while King Bird were early maturing variety (146.67). Mean days to physiological maturity of three varieties higher due to the interaction effects of varieties and sulphur fertilizer rates was recorded. Enhanced days to matured by (5.33, 7.67 and 4.67) days compared to the control Hidasse, King bird and Lemu respectively. While without S fertilizer (control) three varieties resulted lowest number of days to physiological maturity (151.67, 139.00 and 152.33) Hidasse, King bird and Lemu respectively (Table 3). Delayed maturity was observed along the increased sulphur levels and the differences between maturities at a given rate were due to their genotype. This result is in line with the findings of (Suleiman *et al.*, 2014) on their work on effect of varieties on yield and yield components of wheat that showed significant difference among five varieties on days to maturity.

Table 3. Interaction effect of varieties and sulphur fertilizer rates on day to maturity.

	Day to Maturity					
	Sulphur Fertilizer Rates Kg ha $^{-1}$					
Varieties	**0**	**15**	**30**	**45**	**60**	**75**
Hidasse	151.67^{g}	153.67^{de}	154.67^{bc}	157.00^{a}	155.33^{b}	152.00^{g}
King bird	139.00^{k}	139.67^{k}	143.67^{i}	146.67^{h}	142.00^{j}	141.33^{j}
Lemu	152.33^{fg}	153.00^{ef}	154.00^{cd}	157.00^{a}	156.33^{a}	153.00^{ef}
Mean			150.13			
CV (%)			0.31			

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv= coefficient of variation

3.3.2. Plant height

The analysis of variance showed highly significant ($P < 0.05$) differences in plant height due interaction effect of variety and sulphur fertilizer (Table 4). Hidasse (109.10cm) was the tallest variety, while Lemu (102.33cm) and King bird (96.93 cm) were the shortest varieties (Table 4). The Variety Hidasse showed better performance of plant height at the highest rate of sulphur fertilizer (60 kg ha^{-1}) application which may be due to the highest response variety to S and use efficiency. The rest of the variety Lemu and Kind Bird obtained the maximum plant height at the S rate application of (15, 45 kg ha^{-1}) respectively. Similarly (Muhammad *et al*., 2013) reported significant effect of Sulphur application on plant height of wheat. (Bello, 2012) also reported that increased of sulphur application was increased plant height, but higher sulphur fertilizer plant height was decreased. This result was agreeing with those reported by (Matsi *et al*., 2003) who contributed that best plant height of wheat was due to more availability of Sulfur and More over similar results were presented by (Jarvan *et al*., 2008) who stated that S fertilization during the growing season considerably enables an increase in plant height.

Table 4. Interaction effect of varieties and sulphur fertilizer rates on plant height

	Plant Height					
	Sulphur Fertilizer Rates Kg ha $^{-1}$					
Varieties	**0**	**15**	**30**	**45**	**60**	**75**
Hidasse	101.20^{bcd}	102.07^{bc}	105.13^{ab}	108.57^{a}	109.10^{a}	101.87^{bc}
King bird	90.67^{g}	91.30^{g}	96.07^{defg}	96.93^{cdef}	94.80^{efg}	92.87^{fg}
Lemu	94.77^{efg}	102.33^{bc}	98.77^{cde}	101.30^{bcd}	101.27^{bcd}	100.80^{bcd}
Mean	99.43					
CV (%)	3.01					

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv= coefficient of variation

3.3.3. Number of tillers per plant and productive tillers per plant

The analysis of variance for total number of tillers per plant and productive tillers per plant was significantly ($P<0.05$) influenced by the interaction effect of variety and sulphur fertilizer rates (Table 5). The variety lemu had the highest number of total tillers per plant (23.53) and productive tillers (15) without statistical difference from king Bird variety at 75 kg ha^{-1} sulphur applied (Tables 5). While Variety Hidasse had low number of total tillers per plant (12.70) and productive tillers (8) as compared to the two varieties on plot planted without any external fertilizer application. Highest number of total tillers obtained from Lemu variety at 60 kg S ha^{-1} applied was significantly improved by 26.51% and 18% respectively as compared to Kingbird and Hidasse varieties, respectively. This was also in agreement with that of (Suleiman *et al*., 2014) who reported significant difference among varieties for tillering.

Table 5. Interaction effect of varieties and Sulphur fertilizer rates on total tillers per plant and total productive tillers per plant

Varieties	Sulphur Rates kg ha^{-1}	Parameters: Total tillers per plant	Parameters: Total productive tillers per plant
Hidasse	0	12.7^{h}	8.00^{g}
	15	17.27^{defg}	11.30^{def}
	30	16.30^{efg}	10.70^{efg}
	45	17.60^{def}	12.43^{bcde}
	60	18.60^{cde}	13.30^{abcd}
	75	16.70^{efgh}	10.70^{fg}
King bird	0	13.30^{gh}	8.70^{g}
	15	16.70^{efg}	11.30^{cdef}
	30	21.00^{abcd}	14.30^{ab}
	45	20.00^{abcde}	13.30^{abcd}
	60	19.87^{abcde}	13.30^{abcd}
	75	19.30^{bcde}	12.70^{abcde}
Lemu	0	14.30^{fgh}	8.00^{g}
	15	16.93^{efg}	10.70^{fg}
	30	22.00^{abc}	14.30^{ab}
	45	22.87^{ab}	13.03^{abcde}
	60	23.53^{a}	13.70^{abc}
	75	21.70^{abc}	15.00^{a}
Mean		18.43	12.01
CV (%)		11.53	10.24

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv=coefficient of variation

3.4. Yield and Yield Attributes

3.4.1. Panicle length

The analysis of variance showed highly significant (P< 0.05) differences in panicle length due to the interaction effects of variety and sulfur application (Table 6). Lemu (11.65cm) variety gave highest panicle length and followed by Hidasse variety (10.88cm). The variety Lemu showed better performance panicle length growth at the highest rate of sulphur (30, 45 and 60 kg ha^{-1}) application as compared to no sulphur fertilizer application (10.25cm). While King bird (9.27 cm) were the Low Panicle Length variety at higher application of sulphur fertilizer (Table 6). Panicle Length of wheat increased with increasing S level. Similarly (Almaz, 2014) reported the result obtained at 60 kg S ha ^{1} was the highest (6.2cm) whereas the lowest (5.4cm) was obtained at no S application. This result is similarly to Muhammad *et al.* (2013) as they reported significant effect of Sulfur application on panicle length of wheat and Bello (2012) as reported that increased of sulfur application was increased Panicle Length, but higher sulfur fertilizer Panicle Length was decreased.

Table 6. Interaction effect of varieties and Sulphur fertilizer rates on panicle length

	Panicle length					
	Sulphur Fertilizer Rates Kg ha $^{-1}$					
Varieties	**0**	**15**	**30**	**45**	**60**	**75**
Hidasse	9.04^{hi}	9.90^{efg}	10.40^{de}	10.51^{cde}	10.88^{bcd}	9.43^{ghi}
King bird	8.85^{i}	9.37^{ghi}	9.21^{ghi}	9.57^{gh}	9.60^{fgh}	8.99^{hi}
Lemu	10.25^{def}	10.80^{bcd}	11.27^{ab}	11.65^{a}	11.10^{abc}	10.37^{de}
Mean	10.07					
CV (%)	3.75					

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv= coefficient of variation

3.4.2. Number of grains per spike

The analysis of variance showed significant ($P < 0.05$) differences in number of grains per spike due to the interaction effects of variety and sulfur application (Table 7). Hidasse (70.73) gave the higher number of grains per spike as compared to King Bird Variety which gave low number of grains per spike at higher application of sulphur fertilizer (Table 7). This result was in agreement with that of. (Ghulama *et al.*, 2010) who reported significant difference among three varieties of wheat on number of grains per spike. Similar result was reported also by (Muhammad *et al.*, (2013) that S treatments as a significant improvement the number of grains per spike showing a range of 46.73 to 60.86.

Table 7. Interaction effect of varieties and sulphur rates on number of grains per spike.

	Number of Grains per Spike					
	Sulphur Fertilizer Rates Kg ha $^{-1}$					
Varieties	**0**	**15**	**30**	**45**	**60**	**75**
Hidasse	56.13^{efg}	64.13^{bcd}	69.13^{ab}	70.53^{a}	70.73^{a}	60.20^{cdef}
King bird	58.57^{defg}	60.73^{cdef}	65.13^{abc}	68.47^{ab}	64.20^{bcd}	60.20^{cdef}
Lemu	53.13^{g}	56.53^{efg}	64.13^{bcd}	60.93^{cde}	67.20^{ab}	54.93^{fg}
Mean	62.5					
CV (%)	5.01					

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv= coefficient of variation

3.4.3. Thousand Kernel weight

The analysis of variance showed significant (P< 0.05) differences in thousand grain weight due to the interaction effects of Variety and Sulfur application (Table 8). Hidasse (48.86gm) gave higher thousand grain weight at any application of sulphur fertilizer including those grown on the control. While King Bird (43.87gm) and Lemu (42.60gm) varieties gave lower thousand grain weights at higher application of sulphur fertilizer (Table 8). Also (Almaz, 2014) result obtained at 60 kg S ha^{-1} was the highest (42.43gm) and 100 kg S ha^{-1} whereas the lowest (40.12gm) of thousand grains weight. Similarly (Muhammad *et al*., 2013) reported significant effect of Sulfur application on thousand kernels weight of wheat. This research result was similar with that of (Gupta *et al*., 2004) who reported that S application significantly enhanced wheat 1000 grain weight. More over results have also been reported by (Ali *et al*., 2008).

Table 8.Interaction effect of varieties and Sulphur fertilizer rates on thousand grain weight.

	Thousand kernel Weight					
	Sulphur Fertilizer Rates Kg ha $^{-1}$					
Varieties	**0**	**15**	**30**	**45**	**60**	**75**
Hidasse	47.70^{a}	47.17^{a}	47.50^{a}	48.87^{a}	47.40^{a}	47.97^{a}
King bird	42.40^{bcd}	43.27^{bc}	43.60^{bc}	43.87^{b}	43.307^{bc}	42.80^{bcd}
Lemu	41.17^{de}	42.03^{bcd}	41.83^{cd}	42.60^{bcd}	41.93^{bcd}	39.73^{e}
Mean	44.18					
CV (%)	2.29					

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv= coefficient of variation

3.4.4. Grain yield

The mean grain yield of wheat was significantly (p< 0.05) affected by S rates but not by variety and their interaction (Table 9). The highest grain yield (7.89 tha^{-1}) was obtained from the plant fertilized with 45 kg S ha^{-1} followed by 60 kg ha^{1} whereas the lowest grain yield (6.69 t ha^{-1}) was obtained from the control plot (Table 9). Highest grain yield produced at 45 kg ha^{-1} sulphur application was improved by 14% as compared to those produced on the control plot. Similar results reported by (Almaz, 2014) showed that the highest grain yield (5.60 t ha^{-1}) was obtained from 60 kg S ha^{1} application. Significant yield increment of winter wheat in response to S and Ca additions have been reported also by (Mahmood *et al*., 2010). Deficiency of S and Ca significantly affected the production and quality of wheat (McGrath, 2003; Gyori, 2005). According to (De Ruiter and Martin 2001) depending upon available S levels, the wheat yield can increase from 0 to 42% and according to (Järvan *et al*., 2008) also due to sulphur addition the yield of winter wheat was increased, depending on the weather and soil conditions, in field trials 7.7–43.0% and in production trials 39.8–45.5% with compare to control treatment.

3.4.5. Biological yield

Total biological yield was significantly (0.05) affected by the main effect of variety only; King Bird variety produced higher total biological yield (16.76) than lemu (14.73) variety (Table10). Such a high total biological yield was obtained as a result of higher yield and low harvest index than lemu variety. Main effects of Sulphur fertilizer rates as well as the interaction effect of variety by sulphur fertilizer rates were not significant in affecting the total biomass yield of Bread Wheat.

Table 9. Effect of varieties and sulphur fertilizer rates on grain yield and biomass yield

Treatments	Parameters	
Variety	Grain yield(Kg ha $^{-1}$)	Biological Yield (Kg ha $^{-1}$)
Hidasse	7.15	15.70ab
King bird	7.32	16.76a
Lemu	7.3	14.73b
Mean	7.25	15.73
LSD	NS	1.56
CV (%)	10.8	14.6
Sulphur Fertilizer rates Kg ha $^{-1}$		
0	6.69c	15.56
15	7.19bc	16.17
30	7.14bc	14.37
45	7.79a	16.01
60	7.53ab	15.87
75	7.00bc	16.41
Mean	7.25	15.73
LSD	0.76	NS
CV (%)	10.8	14.6

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv= coefficient of variation

3.4.6. Harvest Index

The analysis of variance showed significant (P<0.05) differences in harvest index due to the interaction effects of variety and sulfur application (Table11). The range of HI was ranged from 41.47%- 59.81% from kingbird at 60 kg ha^{-1} and Lemu at 45 kg ha^{-1} respectively. Lemu gave the highest harvest index (59.81%) at Sulphur fertilizer rate (45kg S ha^{-1}). While King Bird and Hidasse showed the lowest harvest index (41.47, 49.30%) application of 60 kg S ha^{-1} (Table 10) respectively. This indicated that variation of varieties in terms of nutrient requirement and yield performances. This information was agreed with results obtained by other authors (FAO. 2004; Reussi *et al*., 2006).

Table 10. Interaction effect of varieties and Sulphur fertilizer rates on harvest index

	Harvest Index					
	Sulphur Fertilizer Rates Kg ha $^{-1}$					
Varieties	**0**	**15**	**30**	**45**	**60**	**75**
Hidasse	43.04^{c}	45.21^{bc}	46.61^{bc}	47.64^{bc}	49.30^{bc}	43.08^{c}
King bird	41.73^{c}	44.38^{c}	48.96^{bc}	46.29^{bc}	41.47^{c}	44.95^{bc}
Lemu	46.22^{bc}	64.59^{bc}	55.14^{ab}	59.81^{a}	52.52^{abc}	42.13^{c}
Mean	46.95					
CV (%)	12.13					

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv= coefficient of variation

3.5. Quality Parameters as Affected by Sulphur Fertilizer Applications

3.5.1. Grain protein content

The results showed that when S rates become increased the grain protein contents decreased up to a certain level. The values of grain protein content are presented in (Table 11). The mean grain protein of wheat was significantly ($p< 0.05$) affected by interaction effects of Variety and Sulfur application. The protein content increased from 9.28 % to 12.87 %. The highest grain protein content was scored from lemu (12.87 %) and Hidasse (12.74 %) varieties at higher sulphur fertilizer and control and lowest from King Bird (9.28 %) variety. The highest protein (12.87%) was obtain from 75 kg S ha^{1} and the lowest protein (9.28%) was obtained from 60kg S ha ^{1}. Lemu variety gave lowest protein contents at 30, 45 and 60 kg S ha ^{1} rates applied. This result was agreed with results obtained by other authors (Ron and Loewy, 2007) who stated that Protein and wet gluten content in grain of winter wheat may decrease when crop yield responds to sulfur, likely due to a dilution of nitrogen in the grain and the weather conditions during the grain ripening period had the greatest effect on the winter wheat.

Table 11. Interaction effect of varieties and sulphur fertilizer rates on grain protein content.

	Protein Content					
	Sulphur Fertilizer Rates Kg ha $^{-1}$					
Varieties	**0**	**15**	**30**	**45**	**60**	**75**
Hidasse	12.04^{ab}	12.74^{a}	12.56^{ab}	11.04^{bcd}	12.24^{ab}	12.54^{ab}
King bird	10.23^{de}	11.85^{abc}	10.16^{de}	10.49^{cde}	9.28^{e}	11.79^{abc}
Lemu	12.59^{a}	12.24^{ab}	11.43^{abcd}	12.48^{ab}	12.80^{a}	12.87^{a}
Mean	11.74					
CV (%)	7.87					

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv= coefficient of variation

4.5.2. Hectoliter weight

Test weight provided a rough estimate of flour yield potential in wheat. It is important to millers just as grain yield is important to wheat producer. The mean hectoliter weight of wheat was significantly ($p< 0.05$) affected by variety. Lemu (77.66 kg/hl) and King Bird (77.96 Kg/hl) scored the highest hectoliter weight whereas Hidasse (75.95 kg/hl) scored the lowest hectoliter weight (Table 12). The mean hectoliter weight of wheat was significantly ($p< 0.05$) affected by S rates (Table 12). The highest hectoliter weight (77.52 Kg/hl) was obtained from the control and the lowest hectoliter weight (76.12 kg/hl) was obtained from 60kg S ha $^{-1}$ (Table 12). This result was in agreed with results obtained by other authors (FAO, 2004; Reussi *et al*., 2006).

Table 12. Effect of varieties and sulphur fertilizer rates on hectoliter weight

Treatments	**Parameters**
Variety	**HLW**
Hidasse	75.95b
King bird	76.96a
Lemu	77.66a
Mean	76.86
LSD	0.77
Sulphur Fertilizer rates	
0	77.52a
15	77.29ab
30	76.39bc
45	77.02abc
60	76.12c
75	76.8abc
Mean	76.86
CV	1.48
LSD	0.77

Means followed by the same letter(s) within a column are not significantly different from each other at 5% level of significance, ns: Not significant Cv= coefficient of variation

4.6. Associations between Growth, Yield and Quality Parameters as Influenced by Fertilizer Applications

Table 13 describes the association of agronomic and yield parameters as expressed by Correlation coefficients (r) computed between each other. As indicated by the correlation Coefficient values, apparent interrelationships with agronomic components were observed. These values indicated the magnitude and direction of the associations and relationships among agronomic and quality parameters. For instance, among the agronomic, yield and quality components of wheat, grain yield was directly significantly ($p<0.05$) correlated with total number of tillers (r=0.33), total number of productive tillers(r=0.30), plant height(r=0.32), day to maturity(r=0.10) panicle length(r=0.07), Number of grain per spikes(r=0.16), biomass yield (r=0.42), harvest index(r=0.32) and hectoliter weight (r=0.11). However, it was negatively and significantly ($p<0.05$) associated with protein (r=0.14). This implied that increased protein percentage result in reduction of grain yield. Moreover, there was a positive significant and negative ($p<0.05$) associations among total number of tillers per plant positive associations with total number of productive tillers per plant height(r= 0.43), day to maturity(r=18), panicle length(r=36), number of grain per spike(r=23), harvest index(r=0.35) and hectoliter weight. Whereas there were a negative significant ($p<0.05$) associations with thousand grain weight(r=0.29), biomass yield(r=0.08) and grain protein percentage(r=0.02). Total number of productive tillers per plant were positive significant ($p<0.05$) associations with plant height(r=0.04), day to maturity(r=0.18), panicle length(r=0.37), biomass yield(r=0.33), and harvest index(r=0.35). Whereas there were a negative significant ($p<0.05$) associations with thousand grain weight(r=-0.29), hectoliter weight(r=-0.36) and grain protein percentage(r=-0.02). Plant height were positive significant ($p<0.05$) associations with biomass yield(r=0.12), harvest index(r=0.04) and grain protein percentage(r=0.31).

Whereas a negative significant ($p<0.05$) associations with hectoliter weight(r=-0.36). Day to maturity were positive significant ($p<0.05$) associations with harvest index(r=0.31). Whereas there were a negative significant ($p<0.05$) associations with hectoliter weight(r=-0.10) and biomass yield(r=-0.27). Number of grain per spike were positive significant ($p<0.05$) associations with biomass yield(r=0.05) and harvest index(r=0.02). Whereas a negative significant ($p<0.05$) association with grain protein percentage(r=-0.15). Thousand grain weight were positive significant ($p<0.05$) associations with harvest index(r=0.04). Whereas a negative significant ($p<0.05$) associations with biomass yield(r=-0.07) and hectoliter weight(r=-0.35). Biomass yield were positive significant ($p<0.05$) associations with hectoliter weight(r=0.11); while negative association with grain protein percentage(r=-0.14). In general, the highest and positive correlation values were observed between total number of tillers per plant and total productive tillers per plant (0.82). The association of grain yield with hectoliter weight in this experiment agree with Leilah and Al-Khateeb (2005) and Sen and Toms (2007).

Table 13. Coefficients of correlation of growth parameters yield and yield components and quality of Bread Wheat crop as influenced by sulphur fertilizer rates.

	TNT	TNPT	PH	DTM	PL	NG	TGW	GY	BY	HI	PPP.	HLW
TNT.	0.000											
TNPT	0.820*	0.000										
PH	0.043*	0.204*	0.000									
DTM	0.179 *	0.113*	0.763	0.000								
PL	0.365*	0.345*	0.514	0.731	0.000							
NG	0.227*	0.439	0.454	0.182	0.290.	0.000						
TGW	-0.292*	-0.261*	0.439	0.254	-0.184	0.355	0.000					
GY	0.330*	0.304*	0.321*	0.104*	0.073*	0.163	0.003*.	0.000				
BY	-0.075*	0.077*	0.121*	-0.266*	-0.268	0.051*	-0.069	0.416*.	0.000			
HI	0.353*	0.153*	0.042 *	0.310*	0.331	0.018 *	0.040	0.317*	-0.710.	0.000		
PPP	-0.018*	-0.101*	0.309*	0.524	0.324	-0.147*	0.061	-0.144*	-0.210 *	0.120.	0.000	
HLW	0.131	-0.128*	-0.355*	-0.099*	-0.081	-0.492	-0.350	0.107*	-0.133*	0.208	0.079	0.000

**= significant, TNT= total number of tiller, TNPT= total number of productive tiller, DTM= day to maturity, PL= panicle length, TGW=thousand grain weight, GY= grain yield, BY=biological yield, HI= harvest index, PPP= protein percentage, HLW= hectoliter weight*

4.7. Partial Budget Analysis

In this study the partial budget analysis was done considering all variable costs and all benefits (Table 14). Variable costs are costs of fertilizers which are used for fertilizer combination, bagging material costs for grain and cost of transport. The fertilizer cost was calculated for the cost of each fertilizers of DAP (10.85 ETB kg^{-1}), Urea (9.46 Birr kg^{-1}), Sulphur fertilizer or Gypsum (3.20 ETB kg^{-1}). The cost of bagging and transport was 25 ETB for 100kg of grain yield and the average open market price of wheat grain at Kersa town market were 12.00 ETB kg^{-1}. Economic analysis for using Sulphur fertilizers on wheat varieties (Table 14) indicated that significant marginal rate of return (2,139 and 1,404%) which was recorded from variety Hidasse due to 45 and 60 S kg ha^{-1} respectively when compared to the control , King bird variety with 30, 45, 15, 60 and 75 S kg ha^{-1} fertilizer application (2977, 2787, 1722, 1562 and 1190 %) respectively as compared to the control; and Lemu variety with 15, 45, 60, 30 and 75 S $kgha^{-1}$ marginal rate of return

(3686, 3294, 2855, 2661 and 2318 %) respectively as compared to the control which have the lowest total variable cost. The higher marginal rate of return with least cost was obtained from Lemu variety 15 S kg ha^{-1} (MRR= 3686%). Using 15, 30, 45, 60 and 75 kg S ha^{-1} application with varieties has economic advantage compared to control treatment. While 15, 30 and 75 kg S ha^{-1} with Hidasse variety was negative. Marginal rate of return values obtained was considered dominated. Treatment 45 and 60 Kg S ha $^{-1}$ recommendation for three varieties with net benefit (ETB ha^{-1}) of Hidasse (81,724 and 79,461), King bird (83, 8334 and 76,612) and Lemu (86,683 and 81,683), respectively.

Table14. Partial budget analysis for variety and fertilizer treatments

Varieties	**S kg ha^{-1}**	**GY kg ha^{-1}**	**A.GY (10%)**	**GB ETB ha^{-1}**	**TC**	**NB ETB ha -1**	**MC ETB ha^{-1}**	**MB ETB ha^{-1}**	**MRR (%)**
Hidasse	0	71.4	64.26	77112	1785.0	75,327	0.00	0	0
	15	71.4	64.26	77112	1833.0	75,297	48.00	-30	-63
	30	68.7	61.83	74196	1813.5	72,383	28.50	-2944	-10330
	45	77.6	69.84	83808	2084.0	81,724	299.00	6397	2,139
	60	75.5	67.95	81540	2079.5	79,461	294.50	4134	1,404
	75	64.6	58.14	69768	1855.0	67,913	70.00	-7414	-10591
King bird	0	68	61.2	73440	1700.0	71,740	0.00	0	0
	15	69.4	62.46	74952	1783.0	73,169	83.00	1429	1,722
	30	77.5	69.75	83700	2033.5	81,667	333.50	9927	2977
	45	79.6	71.64	85968	2134.0	83,834	434.00	12094	2787
	60	72.8	65.52	78624	2012.0	76,612	312.00	4872	1562
	75	72.1	64.89	77868	2042.5	75,826	343.50	4086	1190
Lemu	0	61.2	55.08	66096	1530.0	64,566	0.00	0	0
	15	74.8	67.32	80784	1918.0	78,866	388.00	14300	3686
	30	68	61.2	73440	1796.0	71,644	266.00	7078	2661
	45	82.3	74.07	88884	2201.5	86,683	671.50	22117	3294
	60	77.5	69.75	83700	2129.5	81,683	599.50	17117	2855
	75	73.4	66.06	79272	2075.0	77,197	545.00	12631	2318

S= Sulphur, GY= grain yield, A.GY= adjusted grain yield, GB=gross benefit, NB=net benefit, MC=marginal cost, MB= marginal benefit, MRR= marginal rate of return, ETB =Ethiopian birr Where GB = A.GY 1200ETB, NB= GB of each treatments- GB of control treatment, MC= TC each treatments – TC control, MRR%= MB/MC *100*

5. Conclusion and Recommendations

The application of 45 kg S ha $^{-1}$ would be preferred to grow bread wheat in Munessa, Arsi Zone area for grow better grain yield and quality. Thus, the finding in this MSc. thesis work is a benchmark for future works in bread wheat agronomy and fertility research in which the maximum yield response for increased levels of S has to be further studied even more levels than studied here. However, it is too early to reach a conclusive recommendation since the experiment was conducted only on one soil type and 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 it is important to repeat the study using additional rate of sulphur and including other parameters of growth factors and at different growth stage.

The economical feasibility of recommended treatments in different principal bread wheat growing areas of Ethiopia and for many seasons should be conducted. Also gypsum important to be effective on sodium affected soils, poor sub surface drainage therefore, suggested that for optimum performance of Wheat production, gypsum could be used by the subsistence farmers to improve the nutrient uptake of the plant on saline and alkaline soils.

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