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Effects of Blended NPSB Fertilizer Rates on Yield and Grain Quality of Durum Wheat (*Triticum turgidum* L.) Varieties in Minijar Shenkora District, Central Ethiopia

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የዱረም ስንዴን ምርታማነትን እና ጥራትን ለማሻሻል ተስማሚ ዝርያዎችን ከተመጣጠነ የአፈር ማዳበሪያ ጋር መጠቀም አስፈላጊ ነዉ፡፡ ስለሆነም የተቀላቀለ ናይትሮጂን፣ ፎስፈረስ፣ ሰልፈር እና የቦሮን (NPSB) ማዳበሪያ መጠን በተመረጡ የዱረም ስንዴ ዝርያዎች ምርት እና ጥራት ላይ ያለውን ውጤት ለማወቅ የመስክ ሙከራ ተደርጓል፡፡ አራት የNPSB ድብልቅ የማዳበሪያ መጠኖች (0፣ 61፣122፣ 183 ኪ.ግ. በሄክታር) እና አራት የተሻሻሉ ዱረም ስንዴ ዝርያዎች (አለምጤና፣ ማንጉዶ፣ ኡዴ እና ኡቱባ) በጥምረት ሙከራ ተደርጓል፡፡ በሁሉም መደቦች ላይ 46 ኪ.ግ. የናይትሮጂን ማዳበሪያ በሄክታር ተጨምሯል፡፡ ከተሞከሩ ዝርያዎች መካከል ማንጉዶ ከፍተኛውን የእህል ምርት (2682 ኪ.ግ./ሄ)፣ የአንድ ሺህ ዘር ክብደት (44.7 ግራም)፣ የፕሮቲን ይዘት (11.5%) እና ከፍተኛ የአንፀባራቂነት ባህርይ (71.8%) አስመዘግቧል፡፡ የNPSB ማዳበሪያ ውጤትን በተመለከተ ከፍተኛ የአንድ ሺህ ዘር ክብደት (44.8 ግ)፣ የእህል ምርት (3640 ኪ.ግ./ሄ)፣ ከፍተኛ የፕሮቲን ይዘት (11.7%) እና ከፍተኛ የአንፀባራቂነት ባህርይ (81.5%) በከፍተኛው የNPSB መጠን (183 ኪ.ግ./ሄ) ተመዝግቧል፡፡ በኢኮኖሚያዊ አዋጭነት ስሌት መሠረት ሁለተኛ ከፍተኛ ገቢ (44614.25 ብር/ሄ) ያስገኘው ማንጉዶ ዝርያ 183 ኪ.ግ/ሄ NPSB በመጠቀም ነዉ፡፡ በመሆኑም በምንጃር ሸንኮራ ወረዳ እና ተመሳሳይ ስነ ምህዳር ላላቸው አካባቢዎች ማንጉዶ ዝርያ ከ183 ኪ.ግ./ሄ NPSB ማዳበሪያ በመጠቀም ቢዘራ ይመከራል፡፡

Abstract

Use of appropriate varieties and balanced fertilizer application are major agronomic practices to improve the productivity and quality of durum wheat. Hence, a field experiment was carried out to determine the effect of blended nitrogen, phosphorus, sulfur, and boron (NPSB) fertilizer rates on yield and yield components, and grain quality of selected durum wheat varieties. Factorial combinations of four NPSB rates (0, 61, 122, 183 kg ha^{-1}) and four durum wheat varieties (Alemtena, Mangudo, Ude, Utuba) were laid out in a randomized complete block design with three replications. All the plots were supplemented uniformly with 46 kg N ha^{-1}. Among the varieties, variety Mangudo recorded the highest grain yield (2682 kg ha^{-1}), thousand kernels weight (44.7 g), grain protein content (11.5%), and vitreousness (71.8%). The main effect of NPSB fertilizer showed significantly the highest number of kernels per spike (42.7), thousand kernels weight (44.8 g), aboveground dry biomass yield (11772 kg ha^{-1}), and grain yield (3640 kg ha^{-1}), the highest hectoliter weight (80.2 kg hl^{-1}), grain protein content (11.7%) and vitreousness (81.5%) at the highest NPSB rate (183 kg ha^{-1}). The partial budget analysis also revealed that variety Mangudo gave the second highest economic benefit of 44614.25 Birr ha^{-1} at 183 kg NPSB ha^{-1}. Thus, variety Mangudo with application of 183 kg NPSB ha^{-1} can be recommended for durum wheat production in Minijar Shenkora District and in areas with similar agro-ecological conditions.

Keywords: Blended fertilizer, Durum wheat, Gluten content, Protein content, Virtuousness

Introduction

Wheat is one of the major cereal crops grown in Ethiopia which covered about 1.696 million ha with about 4.54 million tons of grain yield in 2016/17 cropping season (CSA, 2017). It is mainly grown in the highlands of Ethiopia, which lie between 6 and 16° N latitude, and 35 and 42° E longitude, at altitudes ranging from 1500 to 2800 meters above sea level (Bekele *et al.*, 2000). It is produced across a wide range of soil conditions, although it is best adapted to fertile, well-drained silt and clay loam soils (Bekele *et al.*, 2000).

In Ethiopia, durum wheat (*Triticum turgidum* L. var. durum) accounts for 40% of production, and bread wheat (*Tritícum aestívum* L.) the remaining 60% (Bergh *et al.*, 2012). Durum wheat is predominantly grown in central, southeastern, northwestern and northeastern parts of Ethiopia and it is mainly used to make semolina for macaroni, spaghetti and a variety of local food recipes (Badebo *et al.*, 2009).

Ethiopia is endowed with huge amounts of genetic variation for durum wheat, which is recognized as its center of diversity. However, due to various reasons, locally produced durum wheat grains are censured to be poor quality and do not meet the quality standard of pasta production (Badebo *et al.*, 2009). Some of the factors contributing to lower yield and quality of durum wheat are poor fertilizer application practices, diseases, soil moisture stress, waterlogging, etc. Hence, in spite of the large volume of local production, some processing industries import durum wheat grain for pasta production from abroad (Badebo *et al.*, 2009). Therefore, it is important to improve durum wheat productivity and grain quality to satisfy the demands of the processing industries, durum wheat producing farmers and consumers.

The quality of durum wheat is highly dependent on the protein content of the grain, which is largely dependent on genotypes and influenced by environment and crop management, especially nitrogen (N) availability of the soil. Nitrogen fertilization management, therefore, offers the opportunity for increasing wheat protein content and other related quality traits. The protein content of the grain is of high value for defining the end-use quality of both bread wheat and durum wheat (Gooding and Davies, 1997).

Nutrient mining due to sub optimal and unbalanced fertilizer uses have favored the emergence of multi-nutrient deficiency in Ethiopian soils (Agegnehu *et al.*, 2013; Zeleke *et al.*, 2010). Di-ammonium phosphate (DAP) and urea have been the only chemical fertilizers used for crop production with initial understanding that nitrogen and phosphorus are the major limiting nutrients of Ethiopian soils

(Bekabil and Hassan, 2006). However, in addition to N and phosphorus (P), sulfur (S), boron (B) and zinc (Zn) deficiencies are widespread in Ethiopian soils, while some soils are also deficient in potassium (K), copper (Cu), manganese (Mn) and iron (Fe) which all potentially limit crop productivity (EthioSIS, 2013). Therefore, different fertilizer materials would be required to ensure balanced fertilizer use involving all or most of the nutrients required by crops. Sulfur is required for the synthesis of S containing amino acids such as cystine, cysteine and methionine. Sulfur addition showed increased N uptake when S was applied at the highest N rate, indicating a synergism between both nutrients (Fernando *et al.,* 2009). Boron is also an essential element for better utilization of macro-nutrients by plants and thereby for greater translocation of photo-assimilates from source to sink during growth period (Ali *et al.,* 2013).

Currently, with the emerging agro-industries using wheat as a raw material, there is a high demand for durum wheat cultivars with higher grain yield and better end-use quality. Moreover, several combinations of blended fertilizers which include vital elements such as N, P, S, B, K, Zn, Cu, Fe, etc. are developed for different agro-ecologies of the country (EthioSIS, 2013). However, there is limited information on the effect of blended fertilizer application rate on yield and grain quality of durum wheat varieties grown in Ethiopia. Moreover, the response of a crop to application of fertilizer varies with varieties, climatic conditions, soils, and agronomic practices. There is also a need to develop location and agro-ecology based recommendation on the fertilizer rates to increase the productivity and quality of especially recently released durum wheat varieties. Therefore, this study was undertaken to determine the effect of blended NPSB fertilizer rates on yield and yield components, and grain quality of selected durum wheat varieties.

Materials and Methods

Description of the Experimental Site

The experiment was conducted on a Farmers' Training Center (FTC) in Sama Senbet *kebele*, in Minijar Shenkora District, Central Ethiopia, from July to October 2017 during the main cropping season. The site is located at a distance of about 100 km from Addis Ababa in the South East direction at latitude of 08^{o} 83' 33''N and longitude of 39^{o} 40'00''E with an elevation of 1850 m.a.s.l. The area is characterized by mono-modal rainfall pattern occurring mainly from June to September. The average annual rainfall of the study area for five years was 930.6 mm with mean annual maximum temperature of 27.3 ^{o}C and mean minimum temperature of 13 ^{o}C (Figure 1).

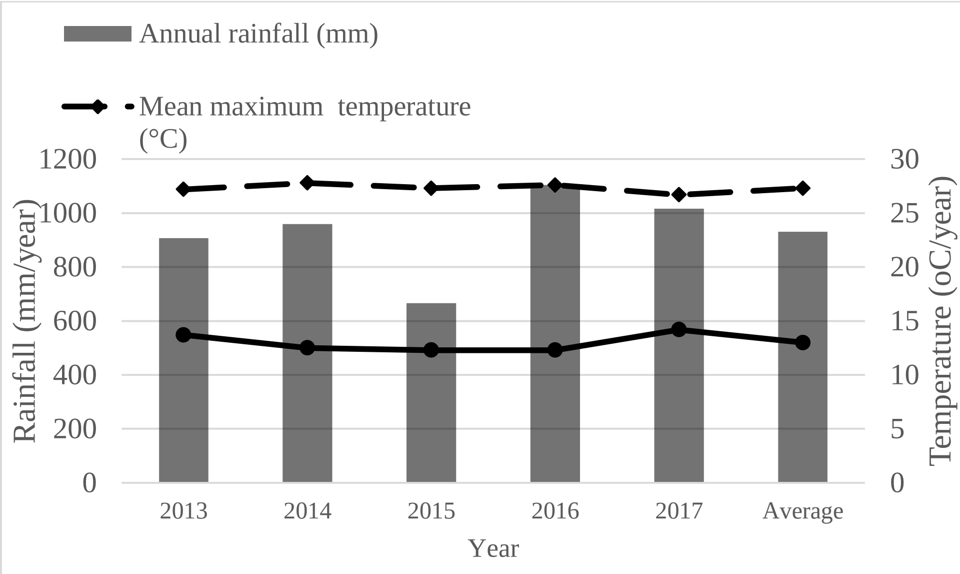

Figure 1. Annual rainfall (mm), mean maximum and minimum temperatures (°C) of the experimental site over five years
Source: National Meteorological Agency, Ethiopia

Tef [*Eragrostis tef (*Zucc.)Trotter] crop was grown in the preceding year of the experiment. The soil physic-chemical properties of the study site before sowing of wheat were analyzed and was clay in texture, moderately alkaline (pH of 7.8), low in available P (10.3 mg kg^{-1}), poor in total N (0.12%), low in organic carbon (1.4%), medium in cations exchange capacity (24.5 cmol (+) kg^{-1} soil), medium in available sulfur (24 mg kg^{-1}), and deficient in boron (0.2 mg kg^{-1}). Thus, the soil needed application of inorganic and organic nutrient sources.

Treatments and Experimental Design

Four improved durum wheat varieties (Alemtena, Mangudo, Ude, and Utuba) developed and released by Debrezeit Agricultural Research Center (DZARC) were used for the study. The varieties were selected based on their wide scale production by the farmers and the potential of the varieties in the study area. The varieties Udie and Utuba were released in 2002 and 2012, respectively, and both are adapted to areas with annual rainfall of 1800-2400 mm and altitudes of 800-1200 m. On the other hand, varieties Mangudo and Alemtena were released in 2012 and 2016, respectively, and are adapted to areas with annual rainfall of 1800-2700 mm and altitudes of 700-1000 m (MoANR, 2016). Blended NPSB fertilizer that contains 19% N, 38% P_2O_5, 7% S and 0.1% B and urea (46% N) were used as source of fertilizers.

The experiment had four rates of NPSB (0, 61,122 and 183 kg ha^{-1}) which was derived on basis of national blanket recommendation of nitrogen and phosphorus for wheat to the area and four durum wheat varieties (Alemtena, Mangudo, Ude, and Utuba). In addition, nitrogen fertilizer at the rate of 46 kg ha^{-1} was applied in the form of urea to all plots uniformly. The experiment was laid out in 4 by 4 (4×4) factorial arrangement in randomized complete block design (RCBD) with three replications. The gross size of each plot was 2 m × 3 m (6 m^2) consisting of ten rows in spacing of 20 cm and with row length of 3m. The outermost one row on both sides of each plot and 20 cm on both ends of each row were considered as border plants, and were not used for data collection to avoid border effects. Thus, the net plot was 1.6 m × 2.6 m (4.16 m^2), consisting of eight rows of 2.6 m length.

The experimental field was ploughed with oxen to a fine tilth four times and the plots were leveled manually. According to the design, a field layout was made and each treatment was assigned randomly to the experimental units within a block**.** After seed beds were leveled, durum wheat varieties were sown on July 12, 2017 at the recommended seed rate of 125 kg ha^{-1} in row spacing of 20 cm by drilling manually. All the blended NPSB fertilizer and 1/3 of urea were applied at sowing and the remaining 2/3 of urea was top-dressed at mid-tillering growth stage of wheat. Weeding, harvesting and threshing were carried out manually.

Data collection

Yield and yield components

The total and effective numbers of tillers were determined at physiological maturity of the crop by counting from two rows of 0.5 m length from the net plot randomly selected and converted to m^2. The number of kernels per spike was determined by counting from randomly taken 10 spikes per plot at maturity and averaged to per spike. Thousand kernels weight (g) was determined by counting 1000 kernels sampled from each net plot using electronic seed counter from the net plot and weighed using a sensitive balance. The aboveground biomass (kg ha^{-1}) and grain yield (kg ha^{-1}) recorded on a plot basis were converted into kg ha^{-1} for statistical analysis. The grain yield was adjusted to 12.5% moisture content.

Grain quality parameters

Hectoliter weight which measures the weight of flour density produced in a hectoliter of the seed was determined for each net plot following standard procedure (AACC, 2000) on dockage free basis using hectoliter weight apparatus. Grain protein content was determined by NIR (Near-infrared reflectance) as stated in AACC (2000) method for whole grain wheat. After calibrating the equipment for durum wheat, cleaned samples of 300 g seeds were added to the equipment and the reading for protein (%) content was taken after one minute.

Wet gluten content was determined by hand washing using 2% sodium chloride solution for the washing according to AACC (2000) Method 38-10. In the process, starch, water-soluble pentonsans, water and dilute salt soluble proteins were washed out. Then the gluten was press dried between hands, rolled in to ball and the remaining mass was determined as wet gluten content of the sample. The percentage of wet gluten was calculated as:

$$\text{Wet gluten content, \% (14\% moisture basis)} = \frac{\text{total wet gluten (g)} \times 860}{100 - \text{\% sample moisture}}$$

To determine the dry gluten content (%), the total wet gluten obtained by the above method was weighed and dried at 150°C for four minutes in air draught oven to get the dried gluten mass (Perten Instrument, Glutork 2002, France). According to AACC (2000) Method 38-12A, the percentage of dry gluten was calculated as:

$$\text{Dry gluten content, \% (14\% moisture basis)} = \frac{\text{total dry gluten (g)} \times 860}{100 - \text{\% sample moisture}}$$

The gluten index (%) was determined by using automatic Glutomatic system (Perten, 1995; Perten instrument AB, Huddings, Sweden). After completion of hand washing, the gluten ball was gently kept in the gluten index sieve cassette (88 µm screen). Then, after centrifugation (6000 rpm for 1 min) the gluten index sieve cassette was removed and the gluten portion was passed through and measured to the nearest 0.01 g. The gluten index was calculated as the ratio of the wet gluten remaining on the sieve (after centrifugation) to the total wet gluten as:

$$\text{Gluten index (\%)} = \frac{\text{Gluten remaining on the seive (g)}}{\text{Total gluten (g)}} \times 100$$

Vitreousness (%) was estimated according to ICC standard number 129 (ICC, 2000). The total number of vitreous kernels was recorded from a partial sample of 50 g taken from cleaned and sieved 250 g average samples was observed under a transmitted light. The percent vitreousness was calculated as:

Vitreousness (%) = $\frac{F1}{F2+F3} \times 100$; where, F1 was weight of fully vitreous kernels (g), F2 was weight of kernels which were not fully vitreous (g) and F3 was the weight of kernels which were not vitreous including the damaged ones (g).

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) as per the experimental design using GenStat 18th edition software (GenStat, 2015). Fisher's protected Least Significance Difference (LSD) test at 5% level of significance was used for the treatment mean separation.

The partial budget analysis was also carried out according to CIMMYT (1988). The market costs for inputs at sowing and prices of outputs at harvesting were used. All costs and benefits were calculated on hectare basis in Ethiopian birr. The variable costs considered in the economic analysis included the cost of blended NPSB (birr 10.58 kg^{-1}) and application cost of NPSB of 200 birr ha^{-1}. The straw and grain yields were adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. The average open market price of durum wheat grain and straw were estimated to be birr 12 kg^{-1} and birr 0.70 kg^{-1}, respectively, at the nearest local market during harvesting time (October 2017). The net benefit (NB) was calculated as the difference between the gross benefit and the total cost that varied (TCV). Then, marginal rate of return (MRR) was calculated as: MRR (%) = $\frac{\Delta NI}{\Delta TVC} \times 100$, where ΔNI = change in net income; ΔTVC= change in the total cost that varied. A treatment having marginal rate of return (MRR) greater than 100% and with the highest net benefit was considered to be economically best as per the procedure described by CIMMYT (1988).

Results and Discussion

Yield and Yield Components

The grain yield of small cereals such as wheat can be described as the product of three yield components; number of spikes per unit area, number of kernels per spike and mean kernel weight (Ramos *et al.,* 1995). The summary of the analysis of variance showing the effect of blended NPSB fertilizer rates on yield and yield components of durum wheat varieties is shown in Table 1.

Table 1. Means squares of the analysis of variance showing the effect of blended NPSB fertilizer rates on yield components and yield of durum wheat varieties

Parameter#	Replication (d.f.=2)	NPSB rates (d.f.=3)	Varieties (V) (d.f.=3)	NPSB ×V (d.f.=9)	Error (d.f.= 30)
NTT	543.9	27077**	2709.9**	951.9**	316.4
NPT	385.9	24732**	3822.5**	1651.4**	199
NKS	45	377.54**	251.069**	45 ns	4.52
TKW	8	144.79**	162.63**	9.6ns	2.7
GY	113122	12596327.8**	77224.3ns	261882.2 ns	389.01
AGDBM	3498181	139346535.5**	1029620.5ns	665062 ns	1648

d.f. = degrees of freedom; ns and ** = non-significant, and significantly different at 1% level of probability, respectively; NTT= Number of total tillers, NPT= Numbers of productive tillers, NKS = Number of kernels per spike, TKW = thousand kernels weight, GY= Grain yield, and AGDBM = Aboveground dry biomass.

The main effects of blended NPSB fertilizer rate and varieties as well as their interaction were highly significant ($P < 0.01$) on total and effective numbers of tillers (Table 1). The highest numbers of total tillers (301.7 m^{-2}) and productive tillers (245.6 m^{-2}) were recorded for variety Mangudo at 183 kg NPSB ha^{-1} followed by variety Utuba with the total tiller number of 256.8 m^{-2} and productive tiller number of 227.2 m^{-2} at 122 kg NPSB ha^{-1} (Table 2 and 3). On the other hand, the lowest total number of tillers (142.4 m^{-2}) and productive number of tillers (102.4 m^{-2}) were recorded for varieties Ude and Alemtena, respectively, without NPSB fertilizer application. The differences in the number of tillers produced by the wheat varieties could be attributed to genetic differences (Alam *et al.*, 2007).

The increase in the numbers of tillers in response to increasing rate of blended NPSB fertilizer indicated the importance of availability of balanced nutrients for better growth and development of wheat. The more availability of N at the highest rates of NPSB might have played a positive role in cytokinin synthesis and cell division and thereby accelerated the vegetative growth of plants. It might also be due to the positive role of P found in NPSB in emerging radicle and seminal roots during seedling establishment in wheat (Cook and Veseth, 1991). In agreement with this result, Brhan (2012) reported that application of blended fertilizer (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) resulted in significant increase in the number of total tillers (15 tillers per plant) of *tef* as compared to 5 tillers per plant of unfertilized plot. Similarly, Fayera *et al.* (2014) obtained the highest number of productive tillers of *tef* (26 tillers per plant) with the application of 200 kg ha^{-1} blended NPKSZnB fertilizer. Seyoum (2017) also reported the highest number of tillers per plant of bread what due to the combined application of 200 kg NPS + 92 kg N ha^{-1} indicating the positive role of high rate of nitrogen for tillering.

Table 2. **Interaction effect of variety and blended NPSB fertilizer rate on number of total tillers per m^2 of durum wheat**

	NPSB rate (kg ha^{-1})			
Varieties	0	61	122	183
Alemtena	147.2^{f}	166.5^{ef}	201.5^{f}	204.8^{cd}
Mangudo	154.8^{f}	167.2^{ef}	252^{b}	301.7^{a}
Ude	142.4^{f}	165.6^{ef}	189.6^{de}	237.7^{b}
Utuba	147.6^{f}	171.2^{ef}	256.8^{b}	228.8^{bc}
LSD (0.05)		14.6		
CV (%)		9.0		

Means in the table followed by the same letter are not significantly different at 5% level of significance; NPSB= Nitrogen, Phosphorus, Sulfur and Boron blended fertilizer, CV (%) = Coefficient of variation; LSD (0.05) = Least Significant Difference at 5% level of significance

Table 3. Interaction effect of variety and blended NPSB fertilizer rate on number of productive tillers per m^2 of durum wheat

	NPSB rate (kg ha^{-1})			
Varieties	0	61	122	183
Alemtena	102.4^{hi}	131.2^{gh}	168.8^{ef}	172^{de}
Mangudo	108.8^{hi}	146.4^{fg}	219.2^{bc}	245.6^{a}
Ude	109.1^{hi}	141.6^{fg}	180.8^{de}	206.4^{bc}
Utuba	110.4^{hi}	127.8gh	227.2ab	194.3cd
LSD $_{(0.05)}$		11.7		
CV (%)		8.7		

Means in the table followed by the same letter are not significantly different at 5% level of significance; NPSB= Nitrogen, Phosphorus, Sulfur and Boron blended fertilizer, CV (%) = Coefficient of variation; LSD (0.05) = Least Significant Difference at 5% level of significance

The number of kernels per spike was significantly ($P < 0.01$) affected by the main effects of variety and NPSB fertilizer while the interaction of two factors was not significant (Table 1). Variety Alemtena produced the maximum numbers of kernels per spike (49.5) followed by variety Mangudo whereas the minimum number of kernels per spike (35.27) was recorded from variety Ude (Table 4). The highest number of kernels per spike from variety Alemtena might be due to the lowest number of productive tillers resulting in less competition among the plants. Similarly, Esayas (2015) reported significant differences among the varieties of durum wheat in the number of kernels per spike which ranged from 30.07 to 39.75. Increasing the rates of NPSB fertilizer increased the number of kernels per spike. The highest number of kernels per spike (42.7) was produced from the highest rate of NPSB fertilizers (183 kg ha^{-1}) whereas the minimum number of kernels per spike (30.3) was produced at nil NPSB rate (Table 4). The increase in the number of kernels per spike with the increase in NPSB fertilizer rate might be due to the fact that P is essential nutrient in the development of grains. Moreover, boron plays a vital role in grain setting of wheat as the supply of boron containing fertilizer helps in grain filling and ultimately sterility is reduced and number of grains per spike is increased (Mengel and Kirkby, 2001). Seyoum (2017) also reported that increasing the rates of NPS increased the number of kernels per spike in bread wheat where the maximum number of kernels per spike (49.5) was produced at the highest rate of NPS fertilizers (200 kg ha^{-1}). Similarly, Yasir *et al.* (2015) reported the maximum numbers of wheat kernels per spike (56.4) with the application of 140 kg N ha^{-1} and 20 kg S ha^{-1}.

Main effect of NPSB rate and varieties showed highly significantly ($P < 0.01$) effect on thousand kernels weight, while the interaction effect was not significant (Table 1). Among the varieties, Mangudo had the highest thousand kernels weight (44.7 g) with non-significant difference with varieties Ude and Utuba while variety Alemtena recorded significantly the lowest thousand kernels weight of 36.6 g (Table 4). According to Abaye *et al.* (2009) all varieties evaluated were bold-kernelled and fulfilled the minimum acceptable kernel size (35 g at 14% moisture content) to be certified for pasta processing. In agreement with this result, Esayas (2015) reported significant difference in thousand kernels weight among durum wheat varieties that ranged from 36.14 to 44.08 g. Similarly, Abdo *et al.* (2012) reported thousand kernels weight that ranged from 42.5 - 49.5 g for durum wheat varieties.

In general, as the rate of NPSB fertilizer increased, the thousand kernels weight was increased. The maximum thousand kernels weight (44.8 g) was recorded at the NPSB rate of 183 kg ha^{-1} and it was statistically at par with the NPSB rate of 122 kg ha^{-1} (44.3 g) while the lowest thousand kernels weight (37.2 g) was recorded for no application of NPSB fertilizer (Table 4). The increase in thousand kernels weight with increased rates of NPSB might be due to the provision of adequate and balanced nutrients which enhanced accumulation of assimilate in the grains, resulting in good grain filling and development of bigger kernels. In line with this result, Rahman *et al.* (2011) reported maximum 1000 kernels weights of 49.4 g and 46.6 g for wheat in two consecutive years with the application of 120 kg N ha^{-1}. Similarly, Tilahun *et al.* (2017) reported the highest durum wheat thousand kernels weight of 59.99 g with the highest N rate of 92 kg ha^{-1}.

Table 4. Main effects of variety and blended NPSB fertilizer rate on number of kernels per spike (NKS), thousand kernels weight (TKW), aboveground dry biomass (AGDB), and grain yield (GY) of durum wheat

Treatments	NKS	TKW (g)	AGDB (kg ha^{-1})	GY (kg ha^{-1})
Varieties				
Alemtena	43.9^{a}	36.6^{b}	7813.3	2492.8
Mangudo	37.5^{b}	44.7^{a}	8366.6	2682.0
Ude	33.0^{c}	43.5^{a}	8466.0	2609.1
Utuba	36.0^{bc}	43.6^{a}	8331.3	2632.7
LSD (0.05)	3.7	2.2	Ns	ns
NPSB rate (kg ha^{1})				
0	30.3^{c}	37.2^{c}	3756.0^{d}	1230.3^{d}
61	36.6^{b}	42.2^{b}	7779.7^{c}	2282.5^{c}
122	41.3^{a}	44.3^{ab}	9669.5^{b}	3173.8^{b}
183	42.7^{a}	44.8^{a}	11772^{a}	3640^{a}
LSD (0.05)	0.9	2.2	1374.1	324.3
CV (%)	11.9	6.4	19.9	14.9

Means followed by the same letter(s) or no letter in columns are not significantly different at 5% level of significance; NPSB= Nitrogen, Phosphorus, Sulfur and Boron blended fertilizer, CV (%) = Coefficient of variation; ns= Non-significant; LSD (0.05) = Least Significant Difference at 5% level of significance

The aboveground dry biomass was highly significantly ($P < 0.01$) affected by the main effects of blended NPSB fertilizer rates while varieties and the interaction of the two factors did not significantly affect biomass yield (Table 1).

The highest aboveground dry biomass (11772 kg ha^{-1}) was obtained at the application of the highest rate of 183 kg ha^{-1} NPSB whereas the lowest aboveground dry biomass (3756 kg ha^{-1}) was recorded from the control (Table 7). In general, the aboveground dry biomass was increased with the increase in NPSB rate which might be due to improved root growth and increased uptake of nutrients favoring better growth, tillering and delayed senescence of leaves of the crop due to synergetic effect of the applied NPSB fertilizer. Fageria *et al.* (2011) also indicated that application of S enhanced the photosynthetic assimilation of N in crops which in turn increased the dry matter accumulation. In conformity with this result, Salvagiotti and Miralles (2008) reported that wheat yield is known to respond to N and S fertilization, associated with an increase in aboveground biomass.

The main effect of blended NPSB fertilizer rates had highly significant ($P < 0.01$) influence on grain yield. However, the main effect of the varieties and the interaction of the two factors were not significant (Table 1). With increasing the rates of NPSB fertilizer from 0 to 183 kg ha^{-1}, the grain yield showed significant increase. The highest grain yield of 3640 kg ha^{-1} was obtained from the application of 183 kg ha^{-1} blended NPSB fertilizer while the lowest grain yield of 1230.3 kg ha^{-1} was obtained without application of NPSB (Table 4). The highest grain yield at the highest NPSB rate might have resulted from improved root growth and increased uptake of nutrients and better growth due to the synergistic effect of the four nutrients which enhanced yield components and yield. Nitrogen enhances the vegetative growth as well as yield whereas phosphorus plays a fundamental role in metabolism and energy producing reaction thus resulting in enhanced grain yield (Mengel and Kirby, 2001).

Jarvan *et al.* (2012) reported that the addition of 100 kg N ha^{-1} with 10 kg S ha^{-1} to wheat gave the highest grain yield of 5.88 t ha^{-1} indicating the synergistic effect of the two nutrients. Similarly, Brhan (2012) reported that the treatments that received blended fertilizers (69 kg N ha^{-1} + 46 kg P_2O_5 + 22 kg S ha^{-1} + 0.3 kg Zn ha^{-1}) increased grain yield of *tef* by 30% as compared to N and P treatments only. Tilahun (2017) also reported the highest durum wheat grain yield of 5274 kg ha^{-1} in response to the application of 200 kg ha^{-1} NPS.

Grain Quality Parameters

The analysis of variance showing the effect of blended NPSB fertilizer rates on grain quality parameters of durum wheat varieties is indicated in Table 5.

Table 5. Mean squares of the analysis of variance showing the effect of blended NPSB fertilizer rates on grain quality parameters of durum wheat varieties

Parameter¥	Replication (d.f.=2)	NPSB rates (d.f.=3)	Varieties (d.f.=3)	NPSB × Variety (d.f.=9)	Error (d.f.= 30)
HLW	11.5	115.98**	10.6 ns	3.6 ns	5.31
GPC	1.2	5.103**	2.21**	0.5 ns	0.62
DGC	21.5	9.7 ns	28.7**	12.8 ns	2.89
WGC	63.9	10.3ns	21.5 ns	171.3**	5.23
GI	41.8	24ns	900.1**	184.2ns	10.68
VT	17.7	1921.6**	110.4 ns	35.5 ns	58.1

¥d.f. = degrees of freedom; ns, and ** = non-significant, and significantly different at 1% level of probability, respectively; HLW = Hectoliter weight, GPC = Grain protein content, DGC= Dry gluten content, WGC=Wet Gluten content GI= Gluten Index, VT= Virtuousness

Hectoliter weight is a measure of the density of the sample and is an indicator of milling yield and it is used as a criterion in grading of grains, especially wheat. The main effect of NPSB fertilizer rates was significant ($P < 0.01$) on hectoliter weight while the main effect of the varieties and the interaction with NPSB rates were not significant (Table 5). The highest hectoliter weight (80.2 kg hL^{-1}) was recorded from the highest NPSB rate of 183 kg ha^{-1} which was statistically at par with 61 and 122 kg ha^{-1} while the lowest hectoliter weight (73.3 kg hl^{-1}) was recorded from the control treatment (Table 6). Significantly higher hectoliter weight with the application of NPSB fertilizer might be due to the role of balanced nutrients on quality of wheat such as flour yield and protein content as N increases the plumpness and protein content of the cereal grains (Agegnehu *et al.*, 2014; Fageria *et al.*, 2011). In agreement with this result, Abdo *et al.* (2012) reported hectoliter weight range of 78.5-81.6 kg hL^{-1} and Girma *et al.* (2012) found hectoliter weight ranging between 81.36 - 83.43 kg hL^{-1} for durum wheat varieties. The variation in hectoliter weight reported by different authors might be due to differences in varieties, soil type, climate and agronomic practices as these factors affect hectoliter weight. Atwell (2001) indicated that hectoliter weight ranged from about 57.9 kg hL^{-1} for poor wheat to about 82.4 kg hL^{-1} for sound wheat. The current result indicated hectoliter weight range of 73.3 to 80.2 kg hL^{-1}. Thus, except the treatment without NPSB, all of the NPSB rates fulfill the minimum requirement of Kaliti Foods Share Company (KFSC) quality standard for hectoliter weight (>75 kg hL^{-1}) for durum wheat.

Results showed highly significant ($P < 0.01$) differences among blended NPSB fertilizer rate and varieties for grain protein content while the interaction effect of the two factors was not significant (Table 5). Variety Mangudo had the highest protein content of 11.5% while variety Alemtena recorded the lowest protein content of 9.9%. The variation in grain protein content among the varieties may be attributed to their variation in nutrient uptake and translocation capacities to the sink. In contrast, Karim *et al.* (1999) reported higher flour protein range of 10.9% - 16.8% for durum wheat varieties.

The highest grain protein content (11.7%) was recorded from the highest NPSB rate of 183 kg ha^{-1} while the lowest protein content (9.7%) was recorded from the control treatment with no NPSB application (Table 6). The increase in protein content with increasing rates of NPSB might be due to the presence of higher amounts of N and S which are the major components of grain protein. In contrast, Tilahun (2017) reported higher grain protein content ranging from 11.34% without nil rate of nitrogen application to 14.19% with the application of 92 kg N ha^{-1}. Turnbull (2001) reported typical values for protein content in durum semolina ranging from 11-16%. However, according to Kaliti Foods Share Company (KFSC), the expected protein content requirement of 13% was not achieved in this study which could be attributed to different factors including the low amount of nitrogen fertilizer used, above average amount of rainfall during the season that might have caused leaching of the applied nitrogen and other soil related factors.

Table 6. Grain quality parameters of durum wheat as influenced by the main effects of varieties and blended NPSB fertilizer rate

Treatments	HLW (kg hL^{-1})	GPC (%)	DGC (%)	GI (%)	VT (%)
Varieties					
Alemtena	77.3	9.9^{c}	7.7^{b}	88.1^{a}	74.8
Mangudo	79.0	11.5^{a}	8.6^{ab}	68.1^{c}	71.4
Ude	76.9	10.00^{bc}	6.6^{b}	81^{ab}	68.4
Utuba	77.5	10.8^{b}	9.5^{a}	73.9^{bc}	68.5
LSD (0.05)	ns	1.3	2.4	8.9	Ns
NPSB rate (kg ha^{-1})					
0	73.3^{b}	9.7^{c}	6.7	8	54.5^{c}
61	79.5^{a}	10.4^{bc}	7.9	77.5	67^{b}
122	77.7^{a}	10.8^{b}	7.6	78.8	80^{a}
183	80.3^{a}	11.7^{a}	9.7	75.8	81.5^{a}
LSD (0.05)	6.1	1.3	Ns	Ns	6.3
CV (%)	6.8	5.9	35.3	13.7	10.7

Means followed by the same letter (s) or no letter in columns are not significantly different at 5% level of significance; NPSB= Nitrogen, Phosphorus, Sulfur and Boron blended fertilizer, CV (%) = Coefficient of variation; ns= non-significant; LSD (0.05) = Least Significant Difference at 5% level; HLW=hectoliter weight, GPC = Grain protein content; DGC = Dry gluten content; GI= gluten index, VT = Vitreousness

The interaction effect of varieties and NPSB rate was highly significant ($P < 0.01$) on wet gluten, but the main effects of both factors were not significant (Table 5). The highest wet gluten content (38.9%) was recorded for variety Utuba at 183 kg NPSB ha^{-1} which was statistically at par with variety Ude (34.5%) at 61 kg NPSB ha^{-1} (Table 7). On the other hand, significantly lowest wet gluten contents were recorded for variety Alemtena at 61 kg NPSB ha^{-1} and for variety Ude at no application of NPSB. The highest wet gluten content for variety Utuba at 183 kg NPSB ha^{-1} might be due to an increased N application which is positively associated with wet gluten content. In line with this result, Lelley (1997) found an increasing trend in wet gluten content of wheat from 29.4% to 41.4% as the level of nitrogen increased from 0 to 180 kg ha^{-1}. Similarly, Leta *et al.* (2013) reported the highest wet gluten contents of 54.5% at application of 240 kg N ha^{-1} at Debre Zeit and 34% at application of 180 kg N ha^{-1} at Akaki for durum wheat. The low amount of wet gluten recorded in this study might be partly due to the low amount of nitrogen tested (highest 80.8 kg ha^{-1}).

Generally, pasta made from strong gluten wheat has greater cooked firmness and cooking stability, whereas pasta made with weak gluten is prone to rapid deterioration and become soft with overcooking (Dexter and Matsuo, 1978). Greenaway and Watson (1975) reported hand-washing methods of wet gluten content ranging from 32.1% - 40.7% for durum wheat varieties. Similarly, Kulkarni *et al.* (1987) reported wet gluten ranges between 20.9% - 42.1% for hard red winter and hard red spring wheat flours. The result indicated wide difference in wet gluten content among the treatments ranging from 17.5% to 38.9%. Among the treatments, variety Utuba combined with 183 kg NPSB ha^{-1} (38.9%) and variety Ude combined within 61 kg NPSB ha^{-1} (34.5%) met the minimum Kality Food Share Company (KFSCs) standard for wet gluten.

Table 7. Interaction effect of varieties with NPSB rate on wet gluten content (%) of durum wheat

	NPSB rate (kg ha^{-1})			
Varieties	0	61	122	183
Alemtena	32.3^{ab}	17.5^{d}	30.3^{abc}	18.5^{d}
Mangudo	24.7^{bcd}	22^{cd}	25.3^{bcd}	24.2b^{bcd}
Ude	17.8^{d}	34.5^{a}	25^{bcd}	22.4^{cd}
Utuba	22.2^{cd}	24^{bcd}	23.3^{cd}	38.9^{a}
LSD (0.05)			8.7	
CV (%)			20.8	

Means in the table followed by the same letter/s are not significantly different at 5% level of significance; NPSB= Nitrogen, Phosphorus, Sulfur and Boron blended fertilizer, CV (%) = Coefficient of variation; LSD (0.05) = Least Significant Difference at 5% level of probability

Highly significant ($P < 0.01$) difference was obtained among the varieties on dry gluten content while the main effect of NPSB fertilizer rate and the interaction of the factors were not significant (Table 5). Variety Utuba had the highest dry gluten content of 9.5% which was statistically at par with variety Mangudo (8.6%) while variety Ude recorded the lowest dry gluten content of 6.6% (Table 6). This result was in line with the finding of Payne *et al.* (1983) who reported that the gluten quality is to a large extent genetically controlled. Accordingly, Efrem *et al*. (2000) reported dry gluten content of 4.2 to 17% for the durum wheat cultivars tested in Ethiopia. Similarly, Humphreys *et al*. (2010) reported dry gluten content that ranged between 11.9% - 13.2% for durum wheat varieties. The dry gluten content obtained in this study (6.6% to 9.5%) for the varieties is below the requirement of Kaliti Foods Share Company (10-12%) which could be attributed to different factors including the low nitrogen fertilizer rate used and related climatic and soil factors.

Gluten index (%) is a measure of gluten strength regardless of the quantity of gluten present and is used commercially to select durum samples with strong gluten characteristics. Analysis of variance showed highly significant differences ($P < 0.01$) among the varieties on gluten index whereas the main effect of NPSB fertilizer and the interaction of variety and the NPSB fertilizer were not significant (Table 5). The mean values of the gluten index ranged from 74.3% for variety Mangudo to 88% for variety Alemtena (Table 6). Such a wide varietal difference could indicate a very strong association of gluten index with genetic difference and subtle influence by the environment. In line with this result, Kaushik *et al*. (2015) reported gluten index of 66.25% - 75.96%, and Mengistu (2015) reported gluten index of 36.1% to 71% among the durum wheat varieties. Collar *et al*. (2007) described gluten index values between 60 and 90% to be appropriate quality of gluten for pasta making. Hence, all varieties studied were considered as appropriate for pasta making in terms of gluten index with varieties Alemtena and Ude being superior.

Vitreousness (%) is an important international grading attribute in assessing the quality of durum wheat. Higher vitreousness indicates higher protein content, a harder kernel, and coarser granulation, higher yield of semolina, superior pasta color, improved cooking quality, and opportunity for premium sales pricing (Dowell, 2000). The effect of NPSB fertilizer rate was highly significant ($P < 0.01$) on grain vitreousness while the effects of varieties and their interaction with NPSB were not significant (Table 5). Vitreousness increased in response to the increased rate of NPSB fertilizer rates. The highest vitreousness (81.5%) was recorded from the application of 183 kg ha^{-1} NPSB, which was statistically at par with 122 kg ha^{-1} NPSB (80%) while the lowest vitreousness (54.5%) was recorded with no NPSB application (Table 6). The increased amount of N with increased rate of NPSB might have resulted in vigorous vegetative growth and adequate partitioning of nitrogen to kernels for protein accumulation thereby increased the vitreousness. In agreement with this result, Makowska *et al.* (2008) reported increased vitreousness of durum wheat from 33% to 87% as the nitrogen application rate increased from 0 to 150 kg ha^{-1}. Similarly, Tilahun (2017) reported the lowest vitreousness (76.53%) from 0 kg N ha^{-1} and the highest vitreousness (93.64%) from the addition of 92 kg N ha^{-1}. In this study, mean kernel vitreousness values ranged from 68.4% to 74.8% for varieties and from 54.5% to 81.5% for NPSB fertilizer rates (Table 6). Hence, application of only the highest NPSB rate (183 kg ha^{-1}) fulfills the minimum acceptable vitreousness standard for Kaliti Foods Share Company (KFSCs) which requires kernel vitreousness of over 80% for pasta processing.

Partial Budget Analysis

The partial budget analysis showed that varieties Ude and Mangudo at the application of 183 kg NPSB ha^{-1} gave the maximum economic benefit of 44625.51 and 44614.25 birr ha^{-1} with marginal rate of return of 1354.61% and 1321.21%, respectively, while the lowest net benefit (13552.44 birr ha^{-1}) was obtained from variety Mangudo with no application of NPSB fertilizer (Table 8). The highest economic benefit for the above treatments might be due to the highest grain and straw yields produced by the varieties at the rate of 183 kg NPSB ha^{-1}. Similarly, Tilahun (2017) reported the highest net benefit of 31,782 birr ha^{-1} with the marginal rate of return of 1818% with the applications of 100 kg ha^{-1} NPS and 69 kg ha^{-1} N indicating the economic feasibility of the application of balanced fertilizer.

Table 8. Summary of partial budget analysis of the effects of blended NPSB fertilizer rate on durum wheat varieties

Variety	NPSB rate (kg ha^{-1})	AGY (kg ha^{-1})	ASY (kg ha^{-1})	Gross benefit (Birr ha^{-1})	TVC (Birr ha^{-1})	Net benefit (Birr ha^{-1})	MRR (%)
Alemtena	0	1244.8	2374.2	16599.54	0	16599.54	
Alemtena	61	1945.4	4184.4	26273.88	845.4	25428.48	1044.35
Alemtena	122	2675.7	5800.8	36168.96	1490.7	34678.26	1433.41
Alemtena	183	3121.36	6794.5	42212.47	2136.1	40076.37	836.40
Mangudo	0	987.13	2438.4	13552.44	0	13552.44	
Mangudo	61	2391.76	5000.2	32201.26	845.4	31355.86	2105.92
Mangudo	122	2766.7	6253.5	37577.85	1490.7	36087.15	733.19
Mangudo	183	3500.8	6772.5	46750.35	2136.1	44614.25	1321.21
Ude	0	1410.1	1903.8	18253.86	0	18253.86	
Ude	61	1738.05	5979	25041.9	845.4	24196.5	702.94
Ude	122	2770.6	5894.8	37373.56	1490.7	35882.86	1811.00
Ude	183	3474.1	7246.3	46761.61	2136.1	44625.51	1354.61
Utuba	0	1124.5	1940.4	14852.28	0	14852.28	
Utuba	61	2141.9	4951.5	29168.85	845.4	28323.45	1593.47
Utuba	122	3212.9	5440.9	42363.43	1490.7	40872.73	1944.72
Utuba	183	2998.6	8182.1	41710.67	2136.1	39574.57	D

Where, NPSB cost = 10.58 birr kg^{-1}, NPSB application cost = 200 birr ha^{-1}, sale price of durum wheat grain 12 birr kg^{-1}, sale price of durum wheat straw = 0.70 birr kg^{-1}, AGY = Adjusted grain yield by 10% down ward, ASY = Adjusted straw yield by 10% down ward, TVC = Total variable cost, MRR = Marginal rate of return, D= Dominated treatment

Conclusion

Varieties showed significant differences for major agronomic and quality parameters recorded. Variety Mangudo recorded the highest thousand kernel weight, the highest grain protein content and vitreousness while variety Alemtena scored the highest number of kernels per spike, and maximum gluten index. Similarly, the application of blended NPSB fertilizer at the highest rate of 183 kg ha^{-1} resulted in the highest grain yield, total biomass, number of kernels per spike, thousand kernels weight, hectoliter weight and vitreousness. The partial budget analysis also indicated that variety Mangudo at 183 kg ha^{-1} NPSB gave the second highest net economic benefit. Thus, from the grain yield and quality aspect, variety Mangudo at 183 kg ha^{-1} NPSB can be recommended for Minijar Shenkora District and other areas with similar agro-ecological conditions. However, to reach at a conclusive recommendation, the experiment has to be repeated with increased nitrogen application rates on more varieties and locations to achieve the grain quality requirements especially of grain protein content and dry gluten content of some prominent food factories and also for future export demands.

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