Scientific Papers. Series A. Agronomy, Vol. LXIV, No. 2, 2021
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

RESPONSE OF BREAD WHEAT (*Triticum aestivum* L.) VARIETIES TO NITROGEN FERTILIZER RATES AT MEKDELA DISTRICT, SOUTH WOLLO, ETHIOPIA

Nuru SEID TEHULIE

Mekdela Amba University, Mekdela District, Tulu Awulia, Ethiopia

Corresponding author email: befikrnuru@gmail.com

Abstract

This study was initiated to assess the effect of N fertilizer rates on growth, yield, and quality of newly released bread wheat (Triticum aestivum L.) varieties and identify the optimum N fertilizer rates and appropriate bread wheat variety. A field experiment was carried out in 2019 main cropping season at Mekdela, South Wollo, Ethiopia. Factorial combinations of two wheat cultivars Lemu (ETBW 6861) and Wane (ETBW 6130) and five rates of N (0, 46, 92,138 and 184 kg N ha^{-1}), were laid out in a Randomized Complete Block Design with three replications. Pre planting soil analyses results revealed that soil textural class was clay, medium in total N (0.2%), slightly acidic reaction and medium in organic matter (4.3%). Though the interaction of N rate and variety exhibited fewer effects, the soil analyses after harvest showed that N rate had residual effect on the soil. The variety Lemu had higher values for effective tillers, spike length, plant height, number of seeds spike^{-1}, grain and straw yield, hectoliter weight and grain N uptake. On the other hand, Wane variety exhibited greater values for thousand seed weight, dry and wet gluten, and with short phenological period. Although the difference was non-significant in HI, straw and total N uptake agronomic and physiological efficiency and grain protein content between varieties, Wane had greater agronomic and physiological efficiency, straw N uptake and HI. However, Lemu variety had higher total N uptake and protein content than Wane variety. Days to maturity, effective tillers, plant height and straw yield were consistently increased in response to N rates. The highest values of seed spike^{-1}(57.4), thousand seed weight (44.5 g), grain yield (7415 kg ha^{-1}), HI (36.3%), hectoliter weight (82.53 kg hl^{-1}) and physiological efficiency (45.48 kg kg^{-1}) were recorded at 92 kg N ha^{-1}; whereas the highest agronomic efficiency (48.65 kg kg^{-1}) was obtained from 46 kg N ha^{-1}. Though inconsistent increments of grain and straw N uptake, dry and wet gluten increased with increased N rates, the highest values recorded from 184 kg N ha^{-1}. The longest spike length was obtained from 92 kg N ha^{-1} for Lemu (9.33 cm) and138 kg ha^{-1} for Wane (7.13 cm). The longest days to grain filling and highest grain protein was recorded from 184 kg ha^{-1} for both varieties. The partial budget analysis results revealed that the highest marginal rate of return was 980% at 92 kg N ha^{-1}.In nutshell, based on grain yield, net benefit, MRR, better quality traits, N rate of 92 kg ha^{-1}could be recommended for both Lemu and Wane variety production around Mekdela area. However, as the experiment was conducted only for a single season, we suggest the repeat of the study for more seasons around Mekdela area and similar agroecology.

***Key words**: agronomic efficiency, bread wheat varieties, nitrogen fertilizer, nutrient uptake.*

INTRODUCTION

Wheat is the world's leading cereal grain and more than one-third of the population of the world uses it as a staple food (Curtis, 2002). It is one of the most important cereals cultivated in Ethiopia. It ranks third after sorghum (Sorghum bicolor) and maize (*Zea mays*) in area coverage, while second in total production after maize (CSA, 2015). Despite the large area coverage under wheat, the national average yield in Ethiopia is about 2.2 t ha^{-1} which is below Kenya, Africa and the world's average of about 2.9, 2.4 and 3.2 t ha^{-1}, respectively (CSA, 2013; FAO, 2014). This is attributed to cultivation of unimproved and low yielding varieties, inadequate and erratic rainfall, poor agronomic practices, diseases and insect pests which are among the principal limitations to wheat production in Ethiopia (Gorfu and Hiskias, 2000).

Ethiopia is the second largest wheat producer in Sub-Saharan Africa next to South Africa (White et al., 2001). Wheat is one of the major staple crops in the country in terms of both production and consumption. In terms of caloric intake, it is the second most important food in the country behind maize (FAO, 2014). Wheat is mainly grown in the highlands of Ethiopia, which lies between 6 and 16° N and

35 and 42° E, at altitude ranging from 1500 to 2800 meters above sea level and with mean minimum temperatures of 6°C to 11°C (MOA, 2012). There are two types of wheat grown in Ethiopia: durum wheat, accounting for 60 percent of production, and bread wheat, accounting for the remaining 40 percent (Bergh et al., 2012). Oromia Regional State accounts for over half of national wheat production (54 percent), followed by Amhara (32 percent); Southern Nations, Nationalities and Peoples (9 percent); and Tigray (7 percent) (CSA, 2013).

Nitrogen is subjected to more transformations than any other essential elements. The ultimate source of nitrogen is N_2 gas, which comprises approximately 78 percent of the earth's atmosphere. Inert N_2 gas, however; is unavailable to plants and must be transformed by biological or industrial processes into forms which are plant-available. As a result, modern agriculture is heavily dependent on commercial nitrogen fertilizer (USDA, 2011). Low soil fertility, especially nitrogen (N) deficiency, is one of the major constraints limiting wheat production in Ethiopian highlands (Teklu and Hailemariam, 2009). Thus, increased usage of N fertilizer is considered to be a primary means of increasing wheat grain yield and protein content in these areas.

Wheat productivity of the country in terms of yield per unit area of land is very low due to poor agronomic and soil management practices. Furthermore, inadequate level of technology is also among the constraints to increased wheat production in the highlands and mid highlands of Ethiopia (Demeke and Marcantonio, 2013). As a result of this, the Ethiopian government is forced to import wheat every year because of higher demand than supply. To increase and sustain wheat production and to narrow down the gap between supply and demand, adoption of proper soil fertility managements is of paramount importance. For the improvement of soil fertility, uses of both chemical and organic fertilizer become very vital. Although there is potential for further crop yield improvement, the use of chemical fertilizers has made a significant contribution to crop yield increases so far (Asnakew et al., 1991).

Nevertheless, fertilizers are applied by less than 45%of farmers, on about 40% of the cultivated land for crop production, most likely below optimal dosage levels are applied (Dercon and Hill, 2009). Nitrogen (N) is often the most deficient of all the plant nutrients in Ethiopia. Wheat is very sensitive to insufficient nitrogen and very responsive to nitrogen fertilization. Variety based fertilizer recommendation is unusual in Ethiopia. Diammonium phosphate (DAP) and Urea are the only fertilizers applied to all soil types in the country for soil fertility management. The blanket recommendation rate for these fertilizers is 150 kg DAP ha^{-1} and 100-150 kg Urea ha^{-1} for wheat production. These rates vary as per the agro-ecological domains of the country, but farmers apply below the recommended rate. The increase of agricultural food production worldwide over the past four decades has been associated with a 7-fold increase in the use of N fertilizers (Hirel et al., 2007). Therefore, application of nitrogen fertilizer at the right rate and time is vital for the enhancement of soil fertility and crop productivity.

Cropping system, soil and water management, use of appropriate N fertilizer and application rate based on crop variety and soil type are among the main management options to increase N fertilizer use efficiency (USDA, 2011). In addition, use of slow N releasing fertilizers, nitrification inhibitor, N efficient species or genotypes, and disease, insects and weeds control are also important factors to be considered to improve N use efficiency (Fageria, 2009). Excess N application rate leads to acidity and susceptibility to other biotic and abiotic factors. Therefore, optimum nitrogen fertilizer application rate should be studied to determine its effect on yield, yield components and quality of bread wheat varieties based on agro-ecologies and fertility status of the soil. Therefore, the objectives of this study were to evaluate the effect of N fertilizer rates, varieties and their interaction on yield, yield components of bread wheat varieties and to identify economically optimum N fertilizer rates and appropriate bread wheat variety for the study area.

MATERIALS AND METHODS

Description of the Study Areas

The study was conducted in Northern high land Ethiopia, of Amhara Regional State, Mekdela district. The area is located at 11 29' 59.99"N latitude and 38º 44' 59.99" E longitudes and an altitude of 2953 masl. The study was conducted in 2019 crop season Mekdela District. It is found in South Wollo zone of Amhara Regional State and 550 km away from Addis Ababa. The main agricultural activities are carried out mixed crop livestock production system is found in both high and low land areas of South Wollo zone. The highland mixed crop livestock production system is largely based on intensive cultivation of cereals, pulses, tubers, vegetables and same oil crops. According to Ethiopian agro-ecological classification the area is grouped under dega with the major soil type Vertisols and the most dominate land cover taken by cultivated land.

Experimental Design, Treatments and Procedures

The experiment consisted of 10 treatments as factorial combination of two improved bread wheat varieties *Lemu* (ETBW 6861) and *Wane* (ETBW 6130), and five rates of nitrogen (0, 46, 92, 138 and 184 kg ha^{-1}) arranged in a randomized complete block design (RCBD) with three replications. Replications were folded into two blocks of five plots each to reduce heterogeneity within replications. Following the history of preceding production season, farmlands that were covered with wheat or barley in the preceding year were selected for planting. The gross plot size of the experiment was 4 m long and 2.6 m wide with 20 cm row spacing. The net harvestable plot size of the experiment was 3.20 m long and 2 m wide with 16central rows. The spacing between plots and replications were 1 and 1.5 m, respectively.

Data collected

Agronomic parameters

Data on the phenological, growth yield and yield component parameters were taken from the 16 central rows of harvestable area of the experimental plot as follows:

Days to 50% heading: numbers of days from date of sowing to the stage where 50% of the spikes have fully emerged were recorded.

Days to 90% physiological maturity: number of days from date of sowing to the stage where 90% of the plants in the plot reached physiological maturity was recorded.

Days to grain filling: it was obtained by the number of days to maturity minus the number of days to heading.

Number of effective tillers: it was recorded from randomly selected 10 plants in each experimental plot at physiological maturity.

Plant height (cm): it was measured from the ground level to the tip of spike excluding the awn at physiological maturity.

Spike length (cm): it was the length of the spike from the node where the spike emerges to the tip of the spike, excluding the awn.

Grains per spike: it was taken from ten randomly selected spikes per net plot at harvest and averaged per plant basis.

Above ground dry bio-mass yields (kg ha^{-1}): it was recorded from 16 central rows after sun drying to a constant weight for each plot.

Grain yield (kg ha^{-1}): grain yield was recorded from 16 central rows and then adjusted to 12.5% moisture level for each plot.

Thousand grain weight (g): it was the weight of 1000 seeds determined by carefully counting the grains harvest of each experimental plot by seed counter and weighing them using sensitive balance.

Straw yield (kg ha^{-1}): was measured by subtracting the grain yield from the total above ground biomass yield (after threshing).

Harvest index (HI %): it was the ratio of dried grain weight to the dried total above ground biomass weight per plot multiplied by100.

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS software program (SAS 9.0, 2002). Significant difference among treatment means were assessed using the Duncan Multiple Range Test (DMRT) at 0.05 level of probability (Gomez and Gomez, 1984).

RESULTS AND DISCUSSIONS

Effects of Nitrogen Rate and Variety on Crop Phenology

Days to 50% heading

Days to 50% heading was highly significantly ($p<0.001$) affected by variety and N-fertilizer rate, but not for their interaction. The bread wheat variety *Wane* (64.2 days) was 5 days earlier than *Lemu* (69.3 days). This difference could be attributed to the genetic makeup. In line with this, bread wheat varietal differences with respect to heading were reported by (Jemal et al., 2015).

Increasing N-fertilizer rates from 0 to 184 kg ha^{-1} extended the number of days to 50% heading from 55 to 81 days (Table 1). The use of low N-fertilizer rate in wheat shortens the intervals between the growth phases by facilitating the physiological activities of crops due to the accessibility of inadequate resource. Short number of days to heading was recorded for plots which received zero rates of nitrogen while the longest days to heading was recorded for plots that received 184 kg N ha^{-1}. However, the two varieties did show a consistent increasing trend with increasing N-fertilizer rates. Getachew (2004) and Mekonen (2005) reported that days to heading were significantly delayed when N fertilizer was applied at the highest rate for wheat and barley production compared to the lowest rate. This could be due to the fact that higher N rates enhance more vegetative growth and larger photosynthesis than reproductive parts. Rashid et al. (2007) also reported that NP application significantly affected days to heading of barley.

Days to 90% maturity

The results showed that the main effects of variety and N-fertilizer rate were highly significant ($p<0.001$) on days to 90% physiological maturity. Conversely, the interaction effect of N-fertilizer rates and variety did not show any significant effect on days to 90% physiological maturity. Variety *Wane* took shorter time to mature compared to variety *Lemu* (Table 1). It is also important to note that the differences in maturity can be caused by the combined effect of genetic and environmental factors during the growth stage of the crops. Days to maturity consistently increased with increasing N rate.

The shortest and longest days to maturity were recorded from 0 and 184 kg ha^{-1} N rates, respectively. This might be attributed to the role of N, which increases vegetative growth of crops whereby it delays maturity time. Similar result was reported by Woinshet (2007) in which N-fertilizer supply delayed maturity in malt barley. These results were in line with Bekalu and Mamo (2016) who reported that, N fertilizer rate significantly affected days to maturity on wheat.

Table 1. Main effect of variety and N- rate on days to heading, days to maturity, number of effective tillers per plant and plant height in 2019 cropping season at Mekdela

Variety	DH	DM	ETL	PH(cm)
Lemu	72.33a	146.00a	5.08a	98.60a
Wane	67.40b	134.70b	4.76b	96.70b
SE ±	0.19	0.23	0.04	0.20
LSD (%)	0.55	0.69	0.12	0.61
N (Kg^{-1}ha)				
0	65.00e	132.80e	4.30d	95.00d
46	67.67d	136.70d	4.66c	96.80c
92	70.00c	140.20c	5.73a	98.20b
138	72.00b	144.00b	5.13b	99.00ab
184	74.67a	148.20a	4.76c	99.30a
SE ±	0.29	0.37	0.06	0.32
LSD (%)	0.88	1.10	0.18	0.96
CV (%)	1.03	0.65	3.11	1.14

DH = Days to heading, DM = Days to maturity, ETL = Number of effective tillers per plant, PH = Plant height. 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.

Days to grain filling period

Days to grain filling period were significantly ($p < 0.001$) influenced by the main effects of N rate, variety and their interaction. The longest days to grain filling period were at higher N rates, 138 and 184 kg ha^{-1} for variety *Lemu* than *Wane* (Table 2). Despite small variability, both varieties showed a consistent increasing trend in days to grain filling with increasing nitrogen fertilizer rates. About seven more days were required for the 184 kg N ha^{-1} treatment, which took 77 days to grain filling for *Lemu* variety; while five days difference was noted for *Wane* variety with similar treatment compared to the control (Table 2) . The result was in line with that of Sofonyas (2016) who stated that a steady increasing trend in grain filling period with rates of N in wheat was observed. Wakene et al. (2014) also reported that application of N significantly prolonged number of days to heading and maturity and grain filling period in barley.

Effects of Nitrogen Rate and Variety on Growth Parameters

Plant height

Plant height was highly ($p<0.001$) affected by N-rate and variety, but their interaction was non-significant. Variety *Lemu* (98.6 cm) had higher plant height than *Wane* (96.7 cm). This variation could be related to the inherent character of the variety. Though inconsistent, their heights increased with increasing N rate. The highest plant height (99.3 cm) was recorded from the treatment with the highest N rate of 184 kg ha^{-1}, while the shortest plant height was recorded on plots with 0 kg N ha^{-1}. Tayebeh et al. (2011) and Sofonyas (2016) reported significant increments in plant height due to application of high nitrogen rate.

Spike length

Spike length was significantly influenced by the main effects of N rate, and variety. It was also highly significantly ($p < 0.001$) affected by the interactions of both N rate and variety. Results of N rates and variety interaction effects indicated that the longest spike length (9.33 cm) was obtained from 92 kg N ha^{-1} for *Lemu* whereas 138 kg N ha^{-1} resulted in the longest spike (7.13 cm) for *Wane*. The spike length of *Lemu* increased with increasing N supply from 0 to 92 kg ha^{-1} and then decreased from 138 to 184 kg N ha^{-1}while for *Wane* variety it increased from 0 to 138 kg ha^{-1} N rates. But no statistical difference was observed between 92 and 138 kg ha^{-1} N rates for *Lemu* variety (Table 2). These findings justified that N fertilizer application by itself does not have significant effect on spike length of wheat. In line with these results, Bekalu and Mamo (2016) reported that optimum amount of fertilizer application has significant effect on spike length growth. Similarly, Smith and Hamel (1999) reported that excessive application of N fertilizer has toxic effect on wheat growth and results in stunted growth and reduced spike length.

Number of effective tillers

Number of effective tillers were highly ($p<0.001$) significantly influenced by N-rate and variety, but their interaction was non-significant. Corresponding to this growth parameter, variety *Lemu* had better performance than variety *Wane* (Tables 1). The response of the crop in terms of number of effective tillers was higher at 92 kg N ha^{-1}, but the trend was inconsistent for the remaining N rates. The lowest numbers of effective tillers were recorded from the control plots; which might be due to the role of N in accelerating vegetative growth of plants. The results were in agreement with that of Abdullatif et al. (2010) who reported that increasing in the number of effective tillers with nitrogen fertilization. Bereket et al. (2014) and Abdollahi et al. (2012) also reported that nitrogen fertilization have significant effect on effective number of tillers of wheat.

Table 2. The effects of N rates and bread wheat variety interactions on days to grain filling and spike length in 2019 cropping season at Mekdela

	Days to grain filling		**Spike Length(Cm)**	
		Variety		
N (Kg^{-1}ha)	**Lemu**	**Wane**	**Lemu**	**Wane**
0	70.67cd	65.00g	6.27e	6.01e
46	71.67bc	66.33fg	7.13c	6.46de
92	72.67b	67.67f	9.33a	6.93cd
138	76.00a	68.00ef	9.27a	7.13c
184	77.33a	69.67de	8.47b	6.87cd
SE ±	0.56		0.16	
LSD (%)	1.67		0.47	
CV (%)	1.38		3.75	

Means followed by the same letter(s) within columns of days to grain filling and spike length are not significantly different from each other at 5% level of significance.

Effects of Nitrogen Rate and Variety on Yield and Yield Components

Number of seeds per spike

The analysis of variance showed significant difference ($p<0.01$) on number of seeds per spike due to the main effects of variety and rates of nitrogen, but their interactions were no significant. Higher number of seeds per spike (54.6) was recorded in variety *Lemu* than *Wane* (53.4) (Table 3). Lower number of seeds per spike was recorded in control plot than fertilized plots. Number of seed per spike increased from 0 to 92 kg N ha^{-1}and then decreased from 138 to 184 kg N ha^{-1}. Despite this difference, the highest seed per spike (57.4) obtained from the plots fertilized with 92 kg ha^{-1} N rate was statistically at par with that of 138 kg ha^{-1} N rate (Table 3). The results were in conformity with that of Tayebeh et al. (2010) who stated that increasing N rates up to optimum level significantly increased number of seed spike^{-1}.

Table 3. Main effect of variety and N- rate on SPS, TSW (g), GY (kg ha^{-1}), SY (kg ha^{-1}) HI (%) and NHI (%) at Mekdela in 2019 main cropping season

Variety	SPS	TSW(g)	SY	HI (%)	NHI (%)
Lemu	54.6a	38.3a	13274.2a	32.5	65.7
Wane	53.4b	42.4b	12575.5b	33.0	63.5
SE ±	0.3	0.6 0	171	0.25	1.3
LSD (5%)	0.81	1.69	506.9	NS	NS
N (Kg^{-1}ha)					
0	48.5d	37.4c	11648.0d	26.5d	61.6b
46	52.6c	39.5bc	12305.0cd	34.3b	68.7a
92	57.4a	44.5a	12948.0bc	36.3a	70.0a
138	56.5a	40.4b	13350.0b	34.5b	62.1b
184	39.9bc	14373.0a	14373.0a	32.0c	60.0b
SE ±	0.9	0.9	269.7	7 0.4	2.1
LSD (5%)	1.3	2.68	801.4	1.2	6.2
CV (%)	1.9	5.5	5.1	2.9	7.9

SPS = No. of seed spike-1, TSW = Thousand seed weight, SY = Straw yield and HI = Grain harvest index, NHI = Nitrogen harvest index. Means followed by the same letter(s) within column are not significantly different from each other at 5% level of significance, ns: not significant.

Thousand Seed weight

The results revealed that the main effect of varieties and N rates showed highly significant ($p < 0.001$) difference with respect to thousand seed weight, but not for their interaction (Table 3). Variety *Wane* exceeded variety *Lemu* by 10.7 % in thousand seed weight. This could be due to the late maturity of variety *Lemu* which might have suffered from unfavorable environmental condition lately in the growing season.

The highest thousand seed weight (44.5 g) was produced by the application of 92 kg N ha^{-1}, while there was inconsistent trend of thousand seed weight in the remaining N rates. That is why; the result was in contrary to Tayebeh et al. (2011) who reported number seeds spike^{-1} and 1000 grain weight were significantly enhanced by increasing nitrogen levels. However, the results were aligned with Abdollahi et al. (2012) and Khan et al. (2013) whereby nitrogen rates and sources significantly influence thousand seed weight.

Grain yield

The results revealed that main effect of varieties and N rates showed highly significant ($p<0.001$) difference with respect to grain yield, but their interaction was not significant.

Lemu variety was more productive than *Wane*. The relative advantage in grain yield of *Lemu* (6445 kg ha^{-1}, +2.3%) of this variety might be largely attributed to its higher number of seeds per spike, number of effective tillers and spike length. This result is in agreement with Solomon et al. (2000) who reported a notably superior performance of between bread wheat varieties. Irrespective of N rate, more grain yield (7415 kg ha^{-1}) was obtained by the application of 92 kg N ha^{-1}. Nitrogen fertilizer applied at rate of 138 kg ha^{-1} had 6.2 % less and 66.4 % more grain yield than fertilizer rate applied at 92 kg ha-1 and control, respectively. In line with the result of this study, Bereket et al. (2014) reported that increasing rate of nitrogen fertilization increased grain yield of wheat. There were significant decreases in grain yield when the rate of N increased from 92 to 184 kg ha^{-1}. This is because, balanced supply of N at optimal amount results in higher net assimilation rate and increased grain yield. The present study showed, maximum grain yield of wheat could be obtained by applying of 92 kg ha^{-1} and beyond this rate; applied N becomes in excess of the crop need and consequently the yield decreased.

Straw yield

The main effect of N fertilizer rate and variety exhibited highly ($p<0.001$) differential responses in straw yield, but their interaction was not significant. *Wane* variety was less productive than *Lemu* variety. *Lemu* variety gave 699 kg ha^{-1} more straw yield advantage than *Wane* variety (Table 3). This difference might be attributed to the higher productivity of yield and yield components of *Lemu* variety. Straw yield increased with increasing N rates, whereby the lowest and highest straw yields were obtained from control plots (11648 kg ha^{-1}) and from plots that received 184 kg N ha^{-1} (14373 kg ha^{-1}), respectively (Table 3). Nitrogen increases vegetative growth of plants, especially at higher doses. Besides, the significant increase in plant height, spike length and number of fertile tillers by N rate contributed to the significant increase in straw yield. In agreement with this result, Abebe (2012) and Bereket et al. (2014) reported that wheat straw yield increased with N rates.

Harvest index and Nitrogen harvest index

Harvest Index (HI) and nitrogen harvest index (NHI) were highly ($p<0.01$) significantly influenced by N rate, but the main effect of varieties and the interaction between the two factors were non-significant. Even if the two varieties were not significantly different from each other, variety *Wane* gave 0.5% more HI than variety *Lemu* whereas variety *Lemu* 2.2% more NHI than variety *Wane* (Table 3). This could be due to increasing in biological yield which is inversely proportional to HI and the lower total N uptake in *Wane* variety which is inversely proportional to NHI. Significant varietal differences on harvest index in bread wheat varieties were also reported by Jemal et al. (2015) and cultivars differ for nitrogen harvest index (Metho et al., 1997). With increasing N rates from 0 to 92 kg N ha^{-1}, there were increasing trends of yield and yield components. However, HI and NHI significantly decreased with increasing N rates above 92 kg N ha^{-1}(Table 3).It might be due to nitrogen harvest index and grain harvest index were used to indicate the physiological adaptations of crops to soil N availability, as they expressed by the allocation of N and biomass, respectively, to grain in relation to the whole aboveground plant. A mean harvest index of about 50% with a positive trend due to increasing N rate was previously reported in Ethiopia (Taye et al., 2002). In contrast, Marcelo et al. (2013) reported that rates and sources of N did not affect harvest index of wheat.

CONCLUSIONS

Ethiopia is the second largest wheat producer in Sub-Saharan Africa next to South Africa. Wheat productivity in the country in terms of yield per unit area of land is very low due to poor agronomic and soil management practices. Low soil fertility is particularly one of the factors limiting crops productivity in the highlands of Ethiopia. To this effect, the N fertilizer rates and its interaction, on nitrogen use efficiency, yield, yield components of newly released improved bread wheat varieties was conducted at Mekdela District during the 2019 cropping season. Two improved bread wheat varieties namely *Lemu* (ETBW 6861) and *Wane* (ETBW 6130) were planted using five levels of nitrogen (0, 46, 92, 138 and 184 kg ha-1) in randomized complete block design with factorial arrangement in three replications. Urea was used as source of N in two split forms, at planting and at flowering times. Days to 50% heading, days to 90% physiological maturity, plant height, number of effective tillers, number of seeds per spike, thousand seed weight, grain yield, and straw yield were significantly affected by main effects of variety and N fertilizer rate, but not by their interactions. Grain harvest index and nitrogen harvest index were highly and significantly affected by N fertilizer, but the main effect of varieties and the interaction between N and variety were non-significant. Corresponding to growth parameters, variety *Lemu* had better performance than variety *Wane*. *Lemu* (6445 kg ha^{-1}) variety was more productive than the early maturing *Wane* (6259 kg ha^{-1}) variety at N rate of 92 kg N ha^{-1}. With respect to quality, *Lemu* variety had the highest score for hectoliter weight (79.99) than the variety *Wane* (79.43), whereas variety *Wane* had 6.57 % wet gluten and 2.24% dry gluten higher than variety *Lemu*. Grain N uptake was significantly different for varieties, but not for N rate and their interaction. The main effect of N rates showed significant ($p<0.05$) difference for agronomic efficiency. No significant difference was observed in agronomic, recovery and physiological efficiencies between varieties and their interaction. Agronomic, recovery and physiological efficiencies decreased with increasing N rates. The highest values were recorded at 46 kg N ha^{-1} for three agronomic, recovery and physiological efficiencies. Analytical results of the soil sample after harvesting revealed that total N was higher and the highest value was obtained from application of 92 kg N ha^{-1}. Partial budget analysis indicated that nitrogen rate of 92 kg N ha^{-1} economically beneficial with MRR of 980% compared to the other treatments in this study. Generally, based on grain yield, net benefit, MRR, better quality traits, N rate of 92 kg ha^{-1} could be recommended for both Lemu and Wane variety production around Mekdela area.

REFERENCES

Abdollahi Gharekand, J., Hashemi-majd, K. (2012). Effects of fall nitrogen rates on rainfed bread wheat yield and yield components in drought condition. *International Research Journal of Applied and Basic Science, 3(11)*, 2195–2204.

Abdullatif, M., Asmat U.M., Sattar, A. (2010). Response of growth and yield of wheat to NPK fertilizer. *Science international (lahore), 24(2)*, 185–189.

Abebe, G. (2012). Soil characterization and evaluation of slow release urea fertilizer rates on yield components and grain yields of wheat and teff on Vertisols of jamma district of south wollo zone, amhara region. MSc Thesis, Haramaya University, Haramaya, Ethiopia.

Asnakew, W., Tekalign, M., Mengesha, B., Tefera, A. (1991). Soil fertility management studies on wheat in Ethiopia. pp.137–172. In: Hailu Gebre Mariam,Tanner D.G. and Mengistu Hulluka (eds.) Wheat Research in Ethiopia: A historical perspective. Addis Ababa, IAR/CIMMYT.

Bekalu, A., Mamo, M. (2016). Effect of the rate of N fertilizer application on growth and yield of wheat (*Triticum aestivum* L.) at Chencha, Southern Ethiopia. *International Journal of Plant, Animal and Environmental Sciences, 6*.

Bereket, H., Dawit, H., Mehretab, H., Gebremedhin, G. (2014). Effects of mineral nitrogen and phosphorus fertilizers on yield and nutrient utilization of bread wheat (Tritcum aestivum) on the sandy soils of Hawzen District,Northern Ethiopia. *Agriculture, Forestry and Fisheries 3(3)*, 189–198.

Bergh, K., Chew, A., Gugerty, M.K., Anderson, C.L. (2012). Wheat value chain: Ethiopia.EPAR Brief No. 204.

CSA (Central Statistical Agency). (2013). Agricultural sample survey: area and production of major crops, meher season. Vol. I. Addis Ababa, Ethiopia.

CSA (Central Statistics Agency) (2015). Statistical bulletin for area and production of crops, and farm management practices sample survey. Vol. III. Addis Ababa, Ethiopia

Curtis, B.C. (2002). Wheat in the World. In: Bread Wheat: Improvement and Production, Curtis, B.C., S. Rajaram and H. Gomez Macpherson (Eds.). Food and Agriculture Organization, Rome, pp: 1-18.

Demeke, M., Marcantonio, Di.F. (2013). Analysis of incentives and disincentives for wheat in Ethiopia. Technical notes series, MAFAP, FAO, Rome.

Dercon, S., Hill, R.V. (2009). Growth from agriculture in Ethiopia. Identifying key Constraints. Paper prepared as part of a study on agriculture and growth in Ethiopia.DFID, UK.

Fageria, N.K. (2009). The use of nutrients in crop plants. Taylor and Francis Group, LLC CRCPress.

FAO (Food and Agricultural Organization). (2014). World reference base for soil resources.United nations, Rome.

Getachew, F. (2004). Soil characterization and bread wheat (*Triticum aestivum* L.) response to N and P fertilizatoin. MSc Thesis, Alemaya University, Alemaya,Ethiopia.

Gomez and Gomez H. (1984). Statistical analysis for agricultural research. John Willy and SonsInc. pp. 120–55.

Gorfu, D., Hiskias, Y. (2000). Yield loss of crops due to diseases in Ethiopia. *Ethiopian J.Pest Manage., 5*. 55–67.

Green, R.E. (1981). Placement of nitrogen fertilizer. In: Proc., 14th Hawaii Fertilizer Conf.,College of Tropical Agriculture and Human Resources, Univ. of Hawaii at Manoa,Honolulu. p. 89–104.

Hailu, G.M. (1991). Wheat production and research in Ethiopia. pp.1-15. In: HailuGebre-Mariam, Tanner, D.G. and Mengistu Hulluka (eds.). Wheat Research inEthiopia: A Historical Perspective. IAR/CIMMYT, Addis Ababa, Ethiopia.

Hirel, B., Le Gouis, J., Ney, B., Gallais, A. (2007). The challenge of improving nitrogen use efficiency in crop plants: toward a more central role for genetic variability and quantitative genetics within integrated approaches. *Journal of Experimental Botany, 58(9)*, 2369–2387.

Jemal, A., Tamado, T., Firdissa, E. (2015). Response of Bread Wheat (*Triticum aestivum* L.) Varieties to Seeding Rates. *Asian Journal of Plant Sciences, 14(2),* 50–58.

Khan, M.A., Shah, Z., Rab, A, Arif, M., Shah, T. (2013). Effect of urease and nitrificationinhibitors on wheat yield. *Sarhad Journal of Agriculture, 29(3)*, 371–378.

Marcelo Curitiba Espindula, Valterley Soares Rocha, Moacil Alves de Souza, MarcelaCampanharo, and Guilherme de Sousa Paula. (2013). Rates of urea with or withouturease inhibitor for topdressing wheat. Chilean Journal of Agricultural Research, 73(2).

Mekonnen, A. (2005). Response and uptake of barley (*Hordem vulgarae* L.) to different rates of ORG- P and N fertilizer. MSc Thesis, Alemaya University, Alemaya,Ethiopia.

Metho, A.L., Hammes, P.S., De Beer, J.M. (1997). Effect of cultivar and soil fertility ongrain yield, yield components and grain nitrogen content of wheat. *African Crop Sci. J.,.3(2),* 695–706.

Ministry of Agriculture (MoA). (2012). Ministry of Agriculture. Animal and Plant Health Regulatory Directorate. Crop variety register, Issue No. 15. Addis Ababa, Ethiopia.

Rashid, A., Khan, U.K., Khan, D.J. (2007). Comparative Effect of Varieties and Fertilizer Levels on Barley (*Hordeum vulgare* L.). ISSN Online: 1814–9596, Pakistan.

Smith, D.L., Hamel, C. (1999). Crop Yield: Physiological Processes. Spring-Verlag, Germany.

Sofonyas, D. (2016). Response of bread wheat (*Triticum aestivum* L.) to application of slow releasing nitrogen fertilizer in Tigray, Northern Ethiopia, a thesis (M.Sc.), The School of Graduate Studies, Alemaya University, and Ethiopia.45pp.

Solomon, G., Desalegn, D., Bedada, G., Payne, T., Zewdie, A., Balcha, Y. (2000). Milling and baking quality of Ethiopian bread wheat cultivars. Pp.238. In: The Tenth Regional Wheat Workshop for Eastern, Central and Southern Africa. Addis Ababa, Ethiopia: CIMMYT.

Taye, B., Yesuf, A., Sahlemedhin, S., Amanuel, G., Mohammed, H., Tanner, D.G., Tesfaye, T., Takele, G. (2002). Optimizing fertilizer use in Ethiopia: Correlation of soil analysis with fertilizer response in Hetosa Wereda, ArsiZone. Addis Ababa: Sasakawa-Global 2000.

Tayebeh, A., Abass, A., Seyed, A.K. (2010). Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. *A.J.C.S., 4(6),*384–389.

Tayebeh, A., Abbas, A., Seyed, A.K. (2011). Wheat yield and grain protein response to nitrogen amount and timing. *A.J.C.S., 5(3)*, 330–336.

Teklu, E., Hailemariam, T. (2009). Agronomic and Economic Efficiency of Manure and UreaFertilizers Use on Vertisols in Ethiopian Highlands. *Agricultural Science in China, 8(3),* 352–360.

USDA (United States Department of Agriculture). (2011). National agronomy manual. 190–V–NAM, 4th Ed.59pp.

Wakene, T., Walelign, W., Wassie, H. (2014). Effects of nitrogen and phosphorus fertilizer levels on growth and development of barley (*Hordeum vulgare* L.) at BoreDistrict, Southern Oromia, Ethiopia. *American Journal of Life Sciences, 2(5),* 260–266.

Woinshet, T. (2007). Effect of nitrogen fertilizer levels on grain yield and malt quality of different malt barley (*Hordeum vulgare* L.) varieties in Shashemane woreda. MSc.thesis, Hawassa University, Hawassa, Ethiopia.

White, J.W., Tanner, D.G., Corbett, J.D. (2001). An agro-climatologically characterization of bread wheat production areas in Ethiopia. NRG-GIS Series 01-01. Mexico, D.F.:CIMMYT.