International Journal of Agricultural and Natural Sciences
E-ISSN: 2651-3617 16(3): 255-271, 2023
doi: 10.5281/zenodo.10204225
Research Article

RESPONSE OF BREAD WHEAT (*Triticum aestivum* L.) VARIETIES TO NPS FERTILIZER LEVELS IN WOLMERA DISTRICT, ETHIOPIA

Ketema Berecha[1], Habtamu Ashagre[2*], Girma Chala[3]

[1] *Ethiopian Agricultural Transformation Agency, Addis Ababa, Ethiopia*
[2]*Ambo University, School of Agriculture, Department of Plant Sciences, Ethiopia*
[3]*Ethiopian Institute of Agricultural Research, Holeta Agricultural Research Center, Ethiopia*

**Corresponding author email:*
ashagrehabtamu@gmail.com

(Received 23rd October 2023; accepted 22nd November 2023)

ABSTRACT. Bread wheat production and productivity are constrained by poor soil fertility and the unavailability of improved varieties in the Wolmera district. Hence, a field experiment was conducted to determine the effect of NPS fertilizer levels on yield and yield components of bread wheat varieties. The treatments consisted of four bread wheat varieties (Alidoro, Wane, Lemu, and Shorima) and five levels of NPS fertilizer (0, 100, 150, 200, and 250 kg ha^{-1}). The experiment was laid out in a Randomized Complete Block Design in a factorial arrangement with three replications. The main effects of varieties and NPS level significantly ($p \leq 0.05$) affected phenology, growth, yield, and yield components of bread wheat varieties. The interaction of varieties and NPS levels significantly influenced spike length, leaf area, productive tillers, kernel per spike, above-ground biomass, grain and straw yields, and harvest index of bread wheat. The highest number of productive tillers (6), kernel per spike (62.06), and grain yield (6.3t ha^{-1}) were obtained from the Lemu variety with the application of 200 kg NPS ha^{-1}. The grain yield response index showed that the Lemu variety has more potential in grain yield and exceeded the Alidoro, Shorima, and Wane varieties by 53.4, 36.8, and 15.4%, respectively. The highest net benefit of ETB 89,102.5 with a marginal rate of return 840.9% was recorded from the Lemu variety with the application of 200 kg NPS ha^{-1}. Therefore, the Lemu variety with 200 kg NPS ha^{-1} is economically optimal for bread wheat production in the Wolmera area.

Keywords: *Phenology, response index, variety, yield*

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the most important food security crop and accounts for 95% of all the wheat produced worldwide [1]. Ethiopia is the second largest producer of wheat in sub-Saharan Africa next to South Africa [2]. Oromia accounts for more than half of domestic production in Ethiopian wheat production (51 percent), Amhara 32.65 percent, SNNP 8.67 percent, and Tigray 6.84 percent, while the remaining is by other regions and private companies [3]. Wheat yield increased from 1.3 t ha^{-1} in 1994 [4] to 2.76 t ha^{-1} in 2018/2019 [3], but still below experimental yields (5 t ha^{-1}) [5]. The low yield per hectare is attributed to many factors, such as the unavailability of improved varieties, the use of poor-quality farmer-saved seeds, and poor crop nutrition [6].

Fertilizer is the most important input which contributes significantly towards improving the final grain yield of wheat and exploiting the genetic potential of a cultivar [7]. Plant nutrients like Nitrogen, Phosphorus, and Sulfur play a vital role in plant metabolism and all plant processes. If there are not enough amounts of these nutrients in the soil, the yield and quality of wheat will become worse [8]. Adequate nitrogen and phosphorus nutrients enhance many aspects of plant physiological processes like photosynthesis, flowering, seed maturity, and seed development. Moreover, sulfur is an essential nutrient required to build yield and achieve grain quality. It has also a great role for synthesis of S-containing amino acids like cystine, cysteine, and methionine. When sulfur was added at the maximum rate it increased N uptake, revealing a synergistic effect between the two nutrients [9]. Hence, nitrogen fertilizer may not be fully utilized if S is deficient [10].

Bread wheat production in the country is adversely affected by low soil fertility, suboptimal use of mineral fertilizers, lack of improved seed, and other factors [11]. Diagnostic studies with farmers in the Ethiopian highlands have identified declining soil fertility as a key driver of low yields of crops [12]. According to Elias [13] in Ethiopia, only 30 to 40% of Ethiopian smallholder farmers use fertilizer and those only apply 37 to 40 kg of DAPs and Urea on average per hectare, which is significantly below even the blanket recommended rates (100kg DAP and 100kg Urea) [14]. Such unbalanced and blanket application of plant nutrients may aggravate the depletion of other important nutrient elements in the soils [15]. According to Agegnehu et al. [16] multi-nutrient deficiencies have become more prevalent in Ethiopian soils as a result of nutrient mining brought by improper and uneven fertilizer application. In earlier years, nitrogen and phosphorus were considered as the main limiting nutrients of Ethiopian soils, and the only chemical fertilizers employed for crop development were di-ammonium phosphate (DAP) and urea. However, Ethiopian soils are low in many other elements than nitrogen (N) and phosphorus (P), including sulfur (S) [17], which impair crop yield.

It is perceived that the production of such high-protein cereals like wheat can be limited by the deficiency of S and other nutrients [18]. To overcome this, the Ministry of Agriculture has recently introduced a new fertilizer (NPS) containing N, P, and S with a ratio of 19% N, 38% P_2O_5, and 7% S as the main source of phosphorous [19]. In the study area, there is a lack of information on the effects of different levels of NPS fertilizer on the production and productivity of recently released bread wheat varieties under Nitisols. Therefore, the objective of the study was to determine the effect of NPS fertilizer level on yield and yield components of improved bread wheat varieties in the Central Highlands of Ethiopia.

MATERIALS AND METHODS

Description of the Study Area

The experiment was conducted in Holeta, Walmera district, during the 2019/2020 main cropping season. Holeta is located in the Central Highlands of Ethiopia, in Oromia National Regional State, 29 Km West of Addis Ababa. Geographically it is situated at the latitude of 09^o 03' N, longitude of 38^o 30'E, and an altitude of 2400 meters above sea level. During the 2019 crop-growing season, the area received a cumulative annual rainfall of 1239.5 mm. The maximum and minimum temperatures were 22.2 and 6.1 ^{O}C, respectively, with a mean relative humidity of 62 percent [20]. The major soil type of the study area was Eutric Nitisols. Nitisols was deep, well-drained, red soil with diffuse horizon boundaries [21].

Treatments, Experimental Design, and Procedures

Treatments consisted of four bread wheat varieties (Alidoro, Shorima, Wane, and Lemu) and five levels of NPS fertilizer (0, 100, 150, 200, and 250 kg ha^{-1}) were factorially arranged in randomized complete block design with three replications. The size of each plot was 2m x3m ($6m^2$) with plots and blocks of 0.5m and 1m apart, respectively. Each plot consists of 15 rows with a spacing of 20cm between rows in the plots. Wheat seed at a rate of 150 kg ha^{-1} was drilled evenly in the rows. Treatment-based NPS fertilizer rate and half of the recommended Nitrogen fertilizer (30 kg N ha^{-1}) in the form of Urea [22] were applied for all treatments except for the control treatment at the time of sowing, while the remaining fertilizer was top-dressed at the mid-tillering stage after first weeding. All other agronomic practices have been applied properly as recommended to produce bread wheat.

Soil Sampling and Analysis

Soil samples were taken randomly in a diagonal pattern at a depth of 0-20cm across the experimental field using an auger before planting. A representative composite soil sample was prepared by mixing ten samples taken before planting from the experimental field. The sample was air-dried at room temperature under shade and submitted to the Holeta Agricultural Research Center soil laboratory for analysis of physicochemical properties. Soil texture was determined following hydrometer methods [23]. Soil Organic carbon (OC) was determined by the wet oxidation method [24]. Organic matter was determined by multiplying OC by 1.724 [25]. The pH was determined at a 1:2.5 soil-to-water dilution ratio using a glass electrode method [26]. Similarly, CEC was determined following ammonium acetate (NH_4OAC) extraction method [26]. Total N was determined by the Kjeldhal method [27], while available P and S were determined using the Bray II method [28] and turbid metric method [29], respectively.

Data Collection

Days to 50% heading were determined by counting days from sowing to date when 50% heading of the plants observed from each plot by visual observation. Days to grain filling were calculated by subtracting the number of days to heading from the number of days to physiological maturity. Days to 90% physiological maturity was determined as the number of days from sowing to 90% of the peduncle turned to yellow straw color. Leaf area was measured from the leaves of ten randomly selected plants in each plot at the flowering stage using a leaf area meter. Plant height was determined from the soil surface to the tip of the spike (excluding awns) of ten randomly selected pre-tagged plants. The total number of tillers per plant was computed from the average value of ten pre-tagged plants. In comparison, effective tillers per plant were determined by the average value of all spikes-bearing tillers from ten randomly selected pre-tagged plants at physiological maturity.

Spike length was measured from the bottom to the tip of the spike, excluding the awns from ten randomly pre-tagged spikes per plot at physiological maturity. The number of kernels per spike was taken as an average number of kernels per spike of ten randomly selected pre-tagged plants and expressed as the average number per plant. Above ground, dry biomass yield was taken after harvesting and air-dried for two weeks from the whole plant parts from the net plot. Grain yield was taken from the net plot area and the grain yield of each treatment was adjusted to the standard moisture level (12.5%). The straw yield was obtained by subtracting grain yield from the total above-ground biomass yield. The Harvest index was calculated as the ratio of grain yield per plot to total above-ground dry biomass yield per plot expressed as a percent.

The grain yield response index is an indication of the efficiency of the varieties in producing higher grain yield at a low NPS level as well as the potential of the variety that produces the highest yield with the highest level NPS fertilizer. Accordingly, Bread wheat variety is classified into four groups (i) efficient and responsive (ER), (ii) efficient and not responsive (ENR), (iii) not efficient but responsive (NER), and (iv) neither efficient nor responsive (NENR) based on the formula of Nemat *et al.* [30]. The grain yield response index (GYRI) was calculated for each cultivar using the following equation [31].

$$GYRI = \frac{\text{Grain yield at high NPS} - \text{Grain yield at low NPS}}{\text{High NPS level} - \text{Low NPS level}}$$

Data Analysis

All measured data were subjected to ANOVA by using statistical analysis software (SAS) version 9.3 [32], and interpretation was made following the procedure of Gomez and Gomez [33]. The mean values were compared and separated using the Least Significant Difference test (LSD) to evaluate the difference of treatments at alpha ($P < 0.05$).

Economic Analysis

The economic analysis was performed to investigate the economic feasibility of the treatments based on the procedure recommended for partial budget analysis [34]. All costs and benefits were calculated based on the Ethiopian Birr (ETB). The actual yield for grain was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment.

RESULTS AND DISCUSSION

Soil Physico-chemical Properties Before Sowing

The particle size distribution of soil was categorized by clay textural class (72.5% clay, 11.25% silt, and 16.25 % sand) (Table 1). The pH (H_2O) value was 4.69, which shows strongly acidic soil [35]. The optimum pH range for wheat production is 4.1 to 7.4 [36]. Thus, the pH of the experimental soil was within the range for production, but it needs amendment to increase nutrient availability and soil productivity. The soil organic carbon and organic matter content were found 0.92 and 1.59, which is classified under the low category as rated by Tekalign [35]. Total nitrogen and available phosphorus value were 0.11 and 7.09, respectively which is low [35]. The cation exchange capacity was 15.22 cmol (+) kg^{-1}, which was found in the medium range according to Hazelton and Murphy's [37] rating. The sulfur content of the experimental field was 0.023 mg kg^{-1}, which is very low based on EthioSIS [38] rating. This may be associated with poor farm management practices and continuous cropping with little or no fertilizers input which resulted in a decline in soil fertility of the area.

Table 1. *Soil physicochemical properties of the experimental site before sowing*

Soil depth (cm)	Physical properties			Chemical Properties						
	Clay (%)	Silt (%)	Sand (%)	pH (H_20)	TN (%)	CEC (cmol (+) kg^{-1})	OC (%)	OM (%)	Av.P (*mg kg*$^{-1}$)	Av.S (*mg kg*$^{-1}$)
0-20cm	72.5	11.25	16.25	4.69	0.11	15.22	0.92	1.59	7.09	0.023

TN= Total nitrogen, Av.P= Available phosphorus, Av.S= Available Sulfur, CEC= Cation Exchange Capacity, Cmol(+)kg^{-1}*= Centimole cation per kilogram of soil,* OC *= Organic carbon, OM= Organic Matter, mg kg*$^{-1}$*=milligram per kilogram.*

Phenological Parameters

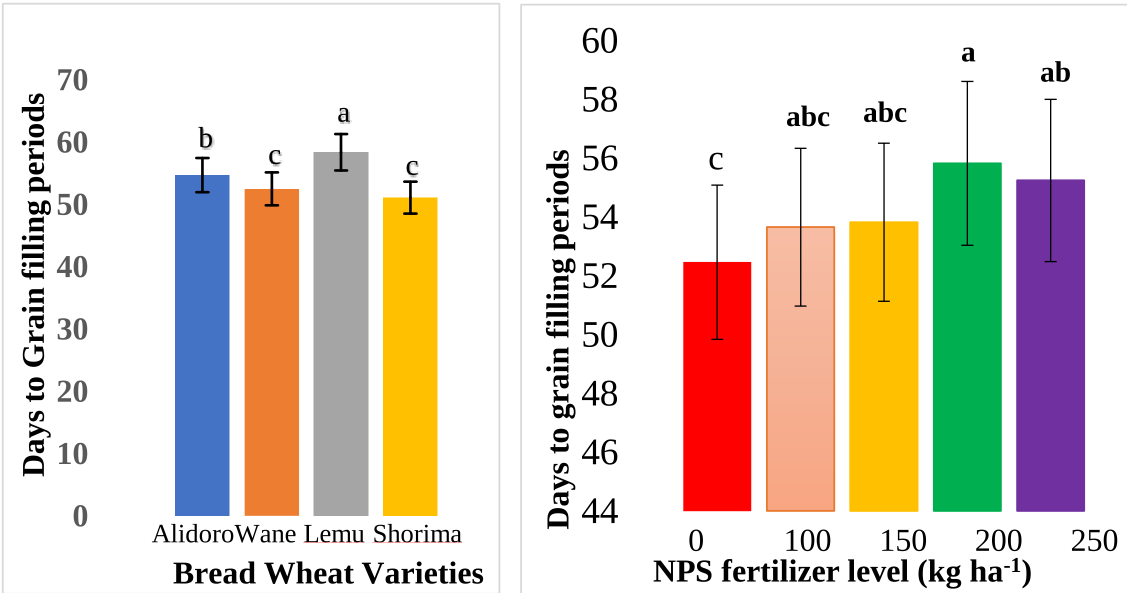
Days to heading

Days to 50% heading of bread wheat was highly significantly (P<0.01) affected by the main effect of varieties and NPS fertilizer level, while their interaction was not significant (Table 2). The delay in days to 50% heading (78.33 days) was recorded from the Alidoro variety, while the Wane variety exhibited earliness (60.33 days) to attain heading. This difference could be attributed to the genetic makeup of the varieties. The result was in agreement with Kifle *et al.*[39] who reported a significant difference in days to 50% headings among bread wheat varieties. An increase in the level of NPS fertilizer application significantly hastened the days to 50% heading of the wheat plants across all NPS fertilizer treatments. The highest level of 250 kg NPS ha^{-1} hastened days to heading (63.66) compared to the control (75.08). This is due to the availability of sufficient nutrients, which results in rapid growth and accelerated days to heading. Similarly, Anwar *et al.*[40] reported that easily available nutrients from fertilizers ultimately produced early heading.

Days to grain filling

The grain filling period of bread wheat was highly significantly (P<0.01) affected by the main effect of varieties and NPS fertilizer level but the interaction effect of main factors was not significant. The longest days to grain filling period (58.4 days) was recorded from the Lemu variety, while the shortest days (51.13 days) were recorded from the Shorima variety which was statistically at par with the Wane variety (Fig.1). This difference may be due to genotypic variability of bread wheat varieties. Likewise, Kifle *et al.* [39] reported that there is a difference in grain filling period among bread wheat varieties due to their inherent variability.

The highest number of days required for the grain filling period (56) was recorded with the application of 200 kg NPS ha^{-1}, however it is statistically at par with all treatments except the control; while the shortest (52 days) was recorded from the control (Fig.1). Application of 200 kg NPS ha^{-1} fertilizer increased the grain filling period by 7.14% over the negative control, this might be due to the optimum amount of nutrient from NPS fertilizer which plays a vital role in the storage and transfer of energy within the cells that contribute to extend grain filling period. The result was in agreement with Tagesse *et al.* [41], who reported that of the NPS rate had a significant effect on the grain filling period.



Values with different letter(s) in a figure are significantly different at a 5% probability level.

Fig.1. *Main effects of varieties and NPS fertilizer level on days to grain filling period of bread wheat*

Days to physiological maturity

Days to 90% physiological maturity of bread wheat was highly significantly ($P<0.01$) affected by the main varieties and NPS fertilizer level, while their interaction effect was not significant (Table 2). Delayed in days to 90% physiological maturity of bread wheat was recorded from Alidoro (134 days), while the earliness to attain maturity was recorded in the Wane variety (129 days). This might be due to their genetic differentials. Similarly, Melaku [42] reported a significant difference between bread wheat varieties on days of physiological maturity.

An increase in fertilizer level from 0 to 250 kg NPS ha^{-1} decreased days to 90% physiological maturity significantly (Table 2). Earlier days to 90% physiological maturity (119 days) were recorded from plots treated with high NPS fertilizer level (250 kg ha^{-1}), while delayed maturity (128 days) was recorded on control treatment. This might be due to the role of phosphorus and sulfur nutrients in NPS fertilizer. Phosphorus is an essential nutrient to enhance flowering, seed formation, and seed maturation [43], and the maturity of seeds and fruits is delayed in the absence of adequate sulfur fertilizer [44].

Table 2. *The main effect of varieties and NPS fertilizer on days to heading, physiological maturity, and plant height of bread wheat varieties*

	Days to heading	Days to physiological maturity	Plant height (cm)
Varieties			
Alidoro	78.33[a]	133.06[a]	102.14[a]
Lemu	70.66[b]	129.06[b]	93.28[b]
Shorima	66.46[c]	117.6[c]	87.76[bc]
Wane	60.33[d]	112.86[d]	84.48[c]
Mean	68.94	123.15	91.91
LSD (0.05)	3.08	3.17	5.61
NPS level (Kg ha^{-1})			
0	75.08[a]	127.5[a]	68.24[d]
100	71.33[b]	125.16[ab]	91.86[c]
150	68.08[bc]	122.41[bc]	95.07[bc]
200	66.58[cd]	121.75[bc]	104.49[a]
250	63.66[d]	118.91[c]	99.91[ab]
Mean	68.95	123.15	91.91
LSD (0.05)	2.76	3.54	6.27
CV (%)	6.04	3.48	8.26

Values with different letter(s) in a column are significantly different at 5% probability level

Growth Parameters

Plant height

Varieties and NPS fertilizer level had a highly significant (P<0.01) effect on plant height, but the interaction effect of the two was not significant (Table 2). Alidoro recorded the highest plant height (102.15cm), while variety Wane scored the lowest (84.48cm). This variation in plant height is due to more differences in internode length due to their genetic variability. Similarly, Kifle [28] reported that tallness in wheat plants is mostly associated with the genetic makeup of the variety. The tallest plant height (104.49 cm) was recorded from the application of 200 kg NPS ha$^{-1,}$ whereas the lowest plant height (68.24 cm) was recorded from the control. This could be due to the contribution of NPS fertilizer for vigorous vegetative growth and development. Similarly, Tagesse et al. [41] reported as NPS fertilizer enhanced plant heights.

Leaf area

The leaf area of bread wheat varieties was highly significant (P<0.01) affected by the main effect of varieties and NPS fertilizer level as well as their interaction (Table 3). The highest leaf area (60.67 cm^2) was recorded from Alidoro with the application of 250 kg NPS ha^{-1}, which was par with the Lemu variety with 250 kg NPS ha^{-1}. Similarly, the lowest leaf area (16.51 cm^2) was recorded by the Shorima variety, which is statistically at par with all control treatments. This is due to NPS fertilizer, which plays a vital role in photosynthesis, functioning in the capture and transfer of energy into chemical bonds. In line with this finding, Kifle [39] reported that the Leaf area was affected by interaction effects of varieties and phosphorus fertilizer.

Table 3. *Interaction effects of variety and NPS fertilizer level on leaf area of bread wheat*

Treatments	Varieties				
NPS (kg ha^{-1})	Alidoro	Wane	Lemu	Shorima	Mean
0	17.75^{l}	18.72^{l}	18.09^{l}	16.51^{l}	17.75
100	45.13^{defg}	31.39^{ij}	39.53^{gh}	22.67^{kl}	34.70
150	48.4^{cde}	37.33^{gh}	40.65^{fgh}	26.72^{jk}	38.27
200	51.97^{bc}	42.13^{efgh}	50.08^{bcd}	30.42^{j}	43.65
250	60.67^{a}	46.38^{cdef}	55.67^{ab}	32.67^{ij}	48.84
Mean	44.79	35.19	40.804	25.798	36.64
LSD (0.05)			5.97		
CV (%)			9.87		

Value with the different letter(s) in a column and row are significantly different at 5% probability level

Yield and Yield Component Parameters of Bread Wheat

Total number of tillers per plant

The main effect of varieties and NPS fertilizer rate, as well as their interaction, was highly significant (P< 0.01) on the total number of tillers produced per plant of bread wheat (Table 4). The maximum number of total tillers per plant (6.76) was produced from the application of 200 kg NPS ha^{-1} with the Lemu variety, while the minimum number of total tillers per plant (1.96) was produced from control fertilizer treatment with the Alidoro variety. This variation may be due to the role of phosphorus found in NPS in emerging radical and seminal roots during seedling establishment in wheat, and high phosphorus levels increase the availability of balanced nutrients for better growth and development of the plant. Phosphorus plays a key role in root development, energy transformation, and metabolic processes in plants [45].

Table 4. *Interaction effects of variety and NPS fertilizer level on the total number of tillers of bread wheat varieties*

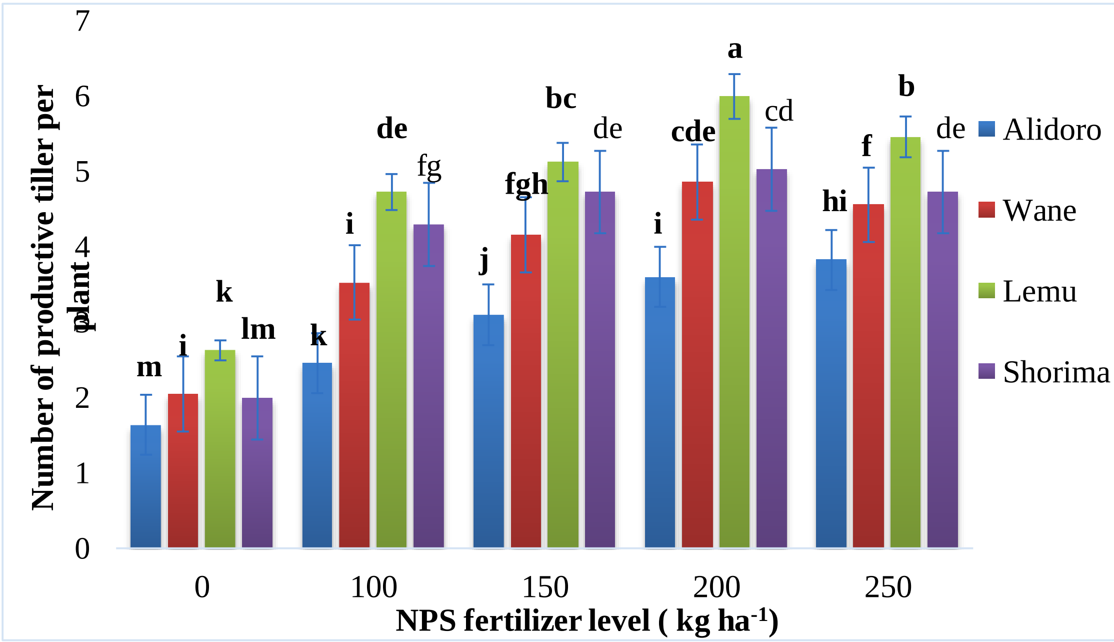
Treatments	Varieties				
NPS (kg ha^{-1})	Alidoro	Wane	Lemu	Shorima	Mean
0	1.96^{j}	2.43^{i}	3.03^{h}	2.13^{ij}	2.38
100	2.9^{h}	4.26^{f}	5.16^{de}	4.8^{e}	4.28
150	3.56^{g}	4.83^{e}	5.66^{cd}	5.33^{cd}	4.84
200	4.0^{f}	5.63^{cd}	6.76^{a}	5.73^{bc}	5.53
250	4.31^{f}	5.2^{de}	6.13^{b}	5.43^{cd}	5.26
Mean	3.34	4.47	5.34	4.68	4.46
LSD (0.05)			0.42		
CV (%)			5.74		

Value with the different letter(s) in a column and row are significantly different at 5% probability level

Number of productive tillers

The main effects of varieties, NPS fertilizer rate, and their interaction were highly significant (P < 0.01) and affected the number of productive tillers per plant (Fig.2.). The maximum number of productive tillers per plant (6.0) was produced from the application of 200 kg NPS ha^{-1} with Lemu variety, while the minimum number (1.64) was produced from control with Alidoro variety. Application of the highest level NPS fertilizer with Lemu variety increased the number of productive tillers by 72.66% compared to control NPS treatment with

Alidoro variety; this might be due to the availability of nutrients to the plant from NPS fertilizer and good response of the genotypes to NPS fertilizer. In agreement with this finding, Melaku [42] reported that the interaction of varieties and NPSB fertilizer significantly affects the number of productive tillers.



Value with the different letter(s) in a figure is significantly different at 5% probability level.

Fig.2. *Interaction effects of varieties and NPS fertilizer on the number of effective tillers*

Spike length

The analysis of variance indicated that the main effect of varieties, NPS fertilizer rate, and their interaction had a highly significant (P<0.01) effect on Spike length (Table 5). The longest spike length (11.46 cm) was obtained from the application of 200 kg NPS ha^{-1} with Alidoro variety, which was par with 250 kg ha^{-1} NPS with the same variety (Table 5). Nevertheless, the shortest spike length (6.3 cm) was recorded in 0 kg NPS ha^{-1} with Wane variety. In line with this finding Lemi and Negash [46] reported the interaction effect of varieties and blended fertilizer on spike length.

Table 5. *Interaction effects of variety and NPS fertilizer level on spike length of bread wheat varieties*

Treatments	Varieties				Mean
NPS (kg ha^{-1})	Alidoro	Wane	Lemu	Shorima	
0	7.4^{ijk}	6.3^{l}	8.23^{fghij}	7.03^{kl}	7.24
100	9.43^{cde}	6.93^{kl}	8.7^{efgh}	7.96^{hijk}	8.26
150	10.33^{bc}	7.2^{jkl}	9.03^{efg}	8.1^{ghij}	8.66
200	11.46^{a}	7.2^{jkl}	10.16^{bcd}	8.5^{efgh}	9.33
250	10.83^{ab}	7.8^{hijk}	9.23^{def}	8.36^{fghi}	9.06
Mean	9.89	7.086	9.07	7.99	8.51
LSD (0.05)			0.93		
CV (%)			6.62		

Value with the different letter(s) in a column and row are significantly different at 5% probability level

Number of kernels per spike

The number of kernels per spike of bread wheat was significantly (P<0.01) affected by the main effect of varieties and NPS fertilizer level, as well as their interaction (P<0.05) (Table 6). The maximum number of kernels per spike of bread wheat (62.06) was produced from the application of 200 kg NPS ha^{-1} fertilizers with Lemu variety, but statistically at par with 200 kg NPS ha^{-1} with Alidoro, Wane, and Shorima; and 250 kg NPS ha^{-1} with Lemu and Alidoro; and 150 kg NPS ha^{-1} with Wane variety (Table 6). The minimum number of kernels per spike of bread wheat (35.63) was produced from control with the Shorima variety but statistically not significantly different from the control treatment with Alidoro and Wane varieties. This might be due to the role of P and S nutrients in NPS fertilizer and their synergistic effect to increase kernel number per spike and grain production. In line with this study, Lemi and Negash [46] indicated that varieties and blended fertilizers affect the number of grains per spike.

Table 6. *Interaction effects of variety and NPS fertilizer level on number of kernels per spike of bread wheat varieties*

Treatments	Varieties				
NPS (kg ha^{-1})	Alidoro	Wane	Lemu	Shorima	Mean
0	40.5^{f}	40.96^{f}	52.23^{bcd}	35.63^{f}	40.99
100	51.23^{cd}	42.4^{ef}	53.33^{bcd}	52.56^{bcd}	49.88
150	52.36^{cde}	47.93^{de}	57.63^{abc}	54.13^{bcd}	53.01
200	57.63^{abc}	58.23^{abc}	62.06^{a}	56.7^{abc}	58.65
250	58.36^{abc}	53.66^{bcd}	59.23^{ab}	56.5^{abc}	56.93
Mean	52.01	47.57	56.89	51.10	51.89
LSD (0.05)			6.51		
CV (%)			7.55		

Value with the different letter(s) in a column and row are significantly different at 5% probability level

Above ground dry biomass yield

The main effect of varieties, NPS fertilizer rate, and their interaction showed a highly significant (P<0.01) effect on dry biomass yield (Table 7). The highest above-ground dry biomass yield (16.88 t ha^{-1}) was obtained from 250 kg NPS ha^{-1} with the Alidoro variety, while the lowest (7.34 t ha^{-1}) was produced from Shorima with the 0 kg NPS ha^{-1}. This might be due to the synergetic effect of nutrients in the NPS fertilizer to improve root growth and increased uptake of nutrients favoring better growth and delayed senescence of leaves and related to a plant height of bread wheat. When plant height increased as a result it may have been attributed to an increase in biomass yield [47].

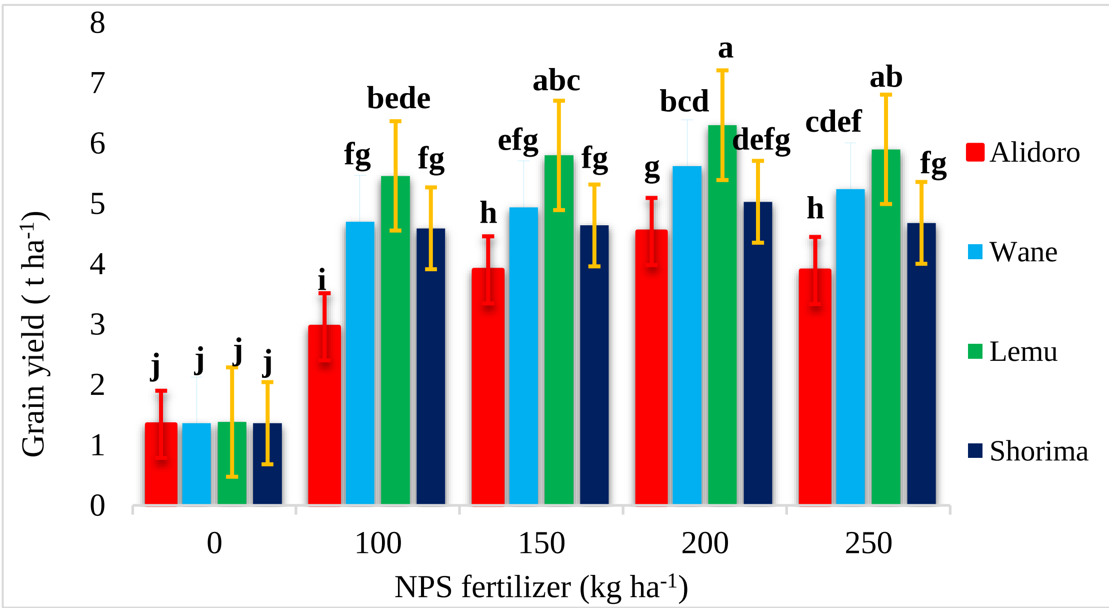
Table 7. *Interaction effects of variety and NPS fertilizer level on above-ground dry biomass yield of bread wheat varieties*

Treatments	Varieties				
NPS (kg ha^{-1})	Alidoro	Wane	Lemu	Shorima	Mean
0	7.69^{g}	8.04^{g}	8.04^{g}	7.34^{g}	7.78
100	10.55^{f}	11.57^{def}	12.27^{bcdef}	10.64^{ef}	11.25
150	12.27^{bcdef}	11.74^{cdef}	12.94^{bcd}	11.53^{def}	12.12
200	13.47^{bcd}	12.79^{bcde}	14.21^{b}	11.87^{cdef}	13.08
250	16.88^{a}	13.14^{bcd}	13.87^{bc}	12.67^{cdef}	14.14
Mean	12.17	11.46	12.26	10.81	11.67
LSD (0.05)			1.88		
CV (%)			9.77		

Value with the different letter(s) in a column and row are significantly different at 5% probability level.

Grain yield

The main effects of varieties, NPS fertilizer level, and their interaction significantly (P< 0.01) affected the grain yield of bread wheat (Fig.3.). The highest grain yield (6.3t ha^{-1}) was obtained from Lemu variety with the application of 200 kg NPS ha^{-1}, while the lowest (1.34 t ha^{-1}) grain yield of bread wheat was recorded from control treatment with Alidoro which was statistically as par with the rest of tested varieties. The highest grain yield obtained from 200 kg ha^{-1} NPS fertilizer with Lemu variety exceeds by 78.73 % over the control with Alidoro. This could be due to the synergetic effect of the three nutrients on the number of effective tiller and kernels per spike which ultimately increased grain yield. In agreement with this finding, Melaku [42] reported that the grain yield of bread wheat was affected by interactions between varieties and blended fertilizer rates.



Value with the different letter(s) in a figure is significantly different at 5% probability level.

Fig.3. *Interaction effects of varieties and NPS fertilizer on grain yield of bread wheat*

Straw yield

The main effect of varieties and NPS fertilizer level, and their interaction exhibited a highly significant (P<0.01) effect in straw yield (Table 8). The maximum straw yield (12.99 t ha^{-1}) was obtained from Alidoro variety with the application of 250 kg NPS ha^{-1}, while the lowest (5.97 t ha^{-1}) was registered on the Shorima variety with control fertilizer treatment. This could be due to the role of NPS fertilizer that is attributed to the high vegetative growth of the crop. Similarly, Melesse [48] also stated that the straw yield of bread wheat was affected by the interaction effects of varieties and fertilizer treatments.

Table 8. *Interaction effects of variety and NPS fertilizer level on straw yield (t ha^{-1}) of bread wheat varieties*

Treatments	Varieties				
NPS (kg ha^{-1})	Alidoro	Wane	Lemu	Shorima	Mean
0	6.35^{cd}	6.68^{cd}	6.65^{cd}	5.97^{d}	6.41
100	7.58^{bcd}	6.78^{cd}	6.80^{cd}	6.05^{d}	6.80
150	8.36^{bc}	6.80^{cd}	7.14^{bcd}	6.89^{bcd}	7.30
200	8.92^{b}	7.17^{bcd}	7.91^{bcd}	6.83^{bcd}	7.77
250	12.99^{a}	7.89^{bcd}	7.96^{bcd}	7.99^{bcd}	9.14
Mean	8.84	7.06	7.29	6.74	7.48
LSD (0.05)			1.77		
CV (%)			14.35		

Value with the different letter(s) in a column and row are significantly different at 5% probability level

Harvest index

The Harvest index of bread wheat was highly significantly ($P < 0.01$) affected by the main effects of Varieties and NPS fertilizer levels as well as their interaction (Table 9). The highest harvest index (44.88%) was recorded on the Lemu variety with 150 kg NPS ha^{-1} and it was statistically at par with Lemu variety at 250, 200, and 100; the Wane variety with 250, 200, and 100 kg NPS; and with Shorima variety with 200, 150 and 100 kg ha^{-1} NPS (Table 9). However, the lowest was recorded at the control NPS fertilizer with Alidoro variety, which was statistically at par with Wane and Shorima varieties with the control treatment. This might be due to the physiological efficiency of the varieties to convert the total dry matter into final grain yield under optimal NPS fertilizer level. In line with this study, Tagesse *et al.* [41] reported that the highest Harvest index was produced by applying 200 kg ha^{-1} NPS.

Table 9. *Interaction effects of variety and NPS fertilizer level on harvest index of bread wheat varieties*

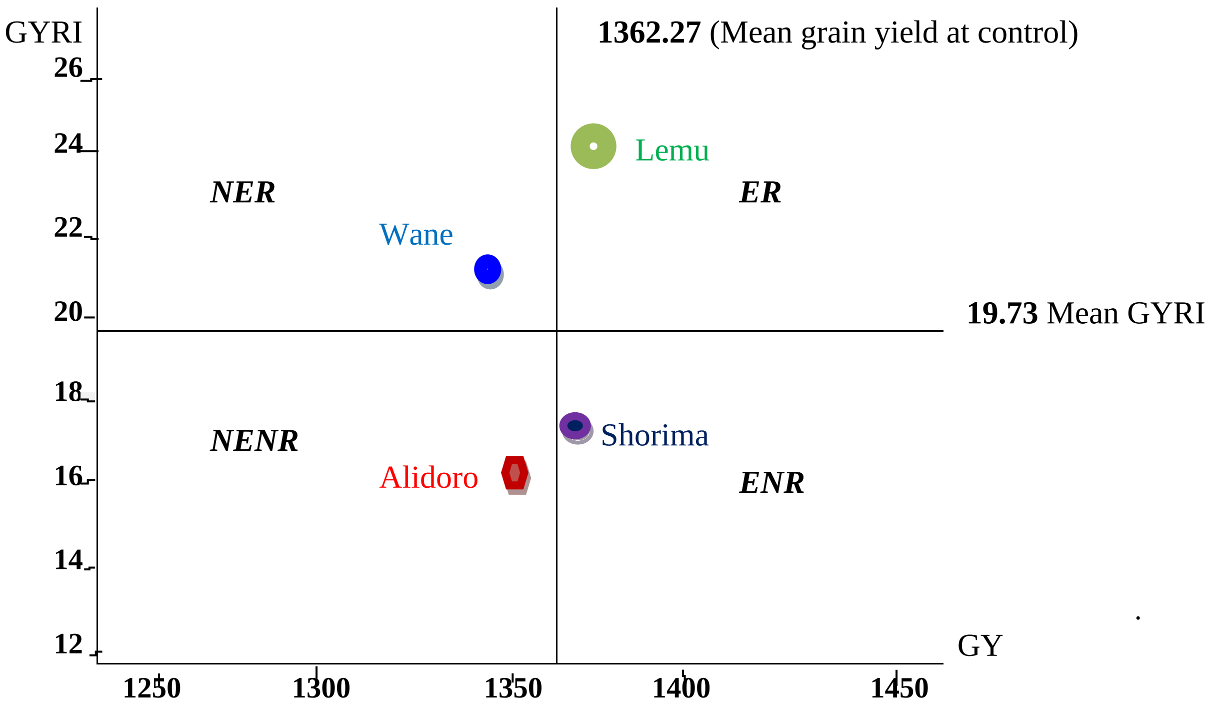
Treatments	Varieties				
NPS (kg ha^{-1})	Alidoro	Wane	Lemu	Shorima	Mean
0	17.24^{g}	17.47^{g}	18.1^{e}	18.69^{g}	17.87
100	28.05^{ef}	41.48^{ab}	44.57^{a}	43.2^{ab}	39.32
150	31.64^{de}	43.11^{ab}	44.88^{a}	40.23^{abc}	39.96
200	33.8^{cde}	44.02^{ab}	44.35^{a}	42.41^{ab}	41.59
250	23.29^{fg}	39.93^{abc}	43.04^{ab}	36.98^{bcd}	35.78
Mean	26.78	37.2	38.98	36.30	34.81
LSD (0.05)			6.01		
CV (%)			10.65		

Value with the different letter(s) in a column and row are significantly different at 5% probability level

Grain yield response index

The highest grain yield response index (GYRI) (24.6) was recorded from the Lemu variety, while the lowest grain yield response index was observed from the Alidoro (16.04) variety. The average mean value of grain yield at zero level of NPS fertilizer level and average mean of grain yield response index of all tested bread wheat varieties was 1362.27 kg ha^{-1} and 19.78 kg grain kg NPS^{-1} fertilizer, respectively (Fig.4.). Accordingly, Alidoro variety belongs to neither the efficient nor responsive category, since the yields of this variety at zero level are less than the mean average of all varieties at zero level. Moreover, the value of the grain yield response index is less than the average value.

The Shorima variety belongs to the efficient but not responsive group because its grain yield is more than the average grain yield at zero NPS level but its grain yield response index is less than the average value. Wane variety belongs to the non-efficient but responsive category because the grain yield of the responsive index is more than the average nevertheless, its grain yield is less than the average grain yield of all tested bread wheat varieties. Lemu variety belongs to the efficient and responsive category. The grain yield at zero level and grain yield responsive index of Lemu variety were more than average values. Therefore, these varieties have a good response to NPS fertilizer at low and high levels. The use of the Lemu variety increased the grain yield response index by 53.4%, 36.8%, and 15.4% over the Alidoro, Shorima and Wane varieties, respectively. In line with this study, Nemat *et al.* [30] also reported that GYRI were significantly different between different wheat varieties.



GYRI= Grain yield response index, GY= Grain yield at 0 kgha^{-1} NPS, NER= Non efficient but responsive, ER=Efficient and Responsive, NENR= not efficient and not responsive, ENR= Efficient but not responsive.

***Fig.4.** Grain yield Response index bread wheat varieties.*

Economic Analysis

A partial budget analysis of the combination of varieties and NPS fertilizer level is presented in Table 10. The highest net benefit of ETB 89,102.5 ha^{-1} with a marginal rate of return 840.9% with a cost ratio of ETB 13.35 per unit of investment was obtained from a combination of Lemu Variety with 200 kg NPS ha^{-1} fertilizer level. In contrast, the lowest net benefits of ETB 23,999.6 ha^{-1} was obtained from Shorima bread Wheat Variety with control. Therefore, the Lemu variety with 200 kgha^{-1}NPS was economically feasible for the production of bread wheat in the Welmera district area.

Table 10. *Summary of partial budget analysis of the effects of NPS fertilizer application on bread wheat varieties in Wolmera district*

No.	Treatment: Variety	Treatment: NPS (kg ha^{-1})	Ad.GY (kg ha^{-1})	Ad.SY (kg ha^{-1})	GFB (ETB)	TVC (ETB)	NB (ETB)	MRR (%)
1	Alidoro	0	1206.27	5721.66	26676.5	2100	24576.5	-
2	Alidoro	100	2671.38	6830.46	50316.4	4635	45681.4	832.5
3	Alidoro	150	3514.5	7530.93	64013.9	5390	58624.4	1715.44
4	Alidoro	200	4093.74	8034.39	73457.7	6226	67231.7	1028.96
5	Alidoro	250	3502.44	11691.5	70073.9	7063	63011.4^{D}	-
6	Wane	0	1224.81	6014.97	27394.6	2550	24844.6^{D}	-
7	Wane	100	4313.7	6104.43	73862.1	5085	68777.1	1733.04
8	Wane	150	4452.21	6121.44	75965.3	5840	70125.8	178.75
9	Wane	200	5059.53	6453.63	85573.4	6676	78897.4	1048.61
10	Wane	250	4724.37	7105.14	81523.3	7513	74010.8^{D}	-
11	Lemu	0	1243.71	5989.5	27639.9	2550	25089.9^{D}	-
12	Lemu	100	4918.23	6124.77	82960.6	5085	77875.6	2082.28
13	Lemu	150	5217.75	6430.41	87911.9	5840	82072.4	556.23
14	Lemu	200	5673.33	7119	95778.5	6676	89102.5	840.92
15	Lemu	250	5322.78	7168.14	90593.9	7513	83081.4^{D}	-
16	Shorima	0	1232.1	5378.76	26549.6	2550	23999.6^{D}	-
17	Shorima	100	4134.06	5450.67	70186.9	5085	65101.9	1621.39
18	Shorima	150	4175.55	6204.51	71940	5840	66100.5	132.35
19	Shorima	200	4291.74	6392.61	73965	6676	67289	142.08
20	Shorima	250	4454.91	6956.55	77258.5	7513	69746	293.72

Where, D = dominated treatments. ETB = Ethiopian Birr; Market price for grain of Bread wheat = 15 ETB kg^{-1}; Market price of straw= 1.5 ETB kg^{-1}; Cost of NPS fertilizer =15ETB kg^{-1}; Cost of Urea (N-source) fertilizer = 13 ETB kg^{-1}, Cost of seed for Alidoro=14 ETB kg^{-1}, Cost of seed for Wane, Lemu and Shorima=17 ETB kg-^{1}Labor cost for fertilizer per persons 50 ETB day^{-1}

CONCLUSION

Based on the result of the study, the soil physicochemical analysis of the study area before sowing showed the soil of the study is highly acidic with low organic matter, total N, and available P, and with very low S contents. Hence, applying NPS fertilizer improved soil productivity and grain yield of bread wheat in the study area. Varieties and level of NPS fertilizer significantly influenced phenology, growth, yield, and yield components of bread wheat. Days to heading and maturity were decreased as NPS fertilizer increased. However, days to the grain filling, leaf area, spike length, number of total tillers, the number of productive tillers, kernel per spike, and grain yield were increased with increased NPS fertilizer level up to 200 kg ha^{-1} but when NPS fertilizer increased furthermore these parameters decreased, except leaf area, above-ground biomass, and straw yield which grew with increasing NPS fertilizers.

Among bread wheat varieties, the Lemu variety had a good performance. It was found under the efficient and responsive category for NPS fertilizer utilization based on the grain yield response index. Moreover, the Lemu variety with 200 kg NPS ha^{-1} fertilizer gave the maximum grain yield (6.3t ha$^{-1)}$ and net benefit of ETB 89,102.5; with a marginal rate of return 840.9 and a value-to-cost ratio of ETB 13.35 per unit of investment in the study area. Therefore, applying 200kg NPS ha^{-1} fertilizer with Lemu variety is recommended to improve the production and productivity of Bread wheat in Wolmera district and similar agroecology.

REFERENCES

[1] Braun HJ, Atlin G, Payne T. (2010): Multi-location testing as a tool to identify plant response to global climate change. In: Reynolds CRP (ed) Climate change and crop production. CABI, London

[2] GAIN (Global Agricultural Information Network).(2012): Assessments of commodity and trade issues made by USDA staff and not necessarily statements of official U.S. government policy.Report number, ET 1201.

[3] CSA (Central Statistics Agency). (2019): Agricultural sample survey of 2018/2019 Report on area and production of major crops for private peasant holdings, meher season. Addis Ababa, Ethiopia. Statistical Bulletin, 589.

[4] CSA (Central Statistics Agency). (2015): Agricultural sample survey (2013/2014): Report on area and production for major crops for private peasant holding, main season. Addis Ababa, Ethiopia: CSA. Statistical Bulletin, 132.

[5] Mann M; Warner J. (2015): Ethiopian Wheat Yield and Yield Gap Estimation: A Small Area Integrated Data Approach. International Food Policy Research Institute (IFPRI), Addis Ababa, Ethiopia. 45pp.

[6] Alemayehu Adinew. (2019): Effect of Seed Sources and Rates on Productivity of Bread Wheat (*Triticum aestivum* L.) Varieties at Kersa, Eastern Ethiopia. Journal of Equity in Sciences and Sustainable Development, 3(1): 64-75.

[7] Kaleem, S., M. Ansar, M.A. Ali, A. Sher, G. Ahmad and M. Rashid. (2009): Effect of phosphorus on the yield and yield components of wheat variety Inqlab-91 under rain-fed conditions. Sarhad Journal Agriculture. 25(1): 21-24.

[8] Liu, D. and Shi, Y., (2013): Research Article Effects of Different Nitrogen Fertilizers on Quality and Yield in Winter Wheat. Advance Journal of Food Science and Technology, 5(5):646-649.

[9] Fernando S, Julio M, Miralles CDJ and Hugo MP. (2009): Sulfur fertilization improves nitrogen use efficiency in wheat by increasing nitrogen uptake. Field Crops Research, 113(2):170–177.

[10] Luo, L. G., Wen, D. Z., & Shen, S. M. (2000): Study on the percolation regularity of nutrient in rice field ecosystem of northern China. Scientia Agricultura Sinica, 2: 68–74.

[11] Gorfu Amanuel, R. F. Kühne, D. G. Tanner, and P. L. G. Vlek. (2002): Recovery of 15 N-Labelled Urea Applied to Wheat (*Triticum aestivum* L.) in the Ethiopian Highlands as Affected by P Fertilization. Journal of Agronomy and Crop Science, 189 (1):30-38.

[12] Elias E. (2016): Soils of the Ethiopian Highlands: Geomorphology and Properties. *CASCAPE Project*, *ALTERA*, Wageningen University and Research Centre (Wageningen UR). Netherlands, 385p.

[13] Endale K. (2010): Fertilizer consumption and agricultural productivity in Ethiopia. Addis Ababa, Ethiopia, *Ethiopian Development Research Institute (EDRI). Pp 32*

[14] Ministry of Agriculture and Rural Development. (2009): Animal and Plant Health Regulatory Directorate, crop variety register, Issue No.12.

[15] Fayera Asefa, Muktar Mohammed, and Debela Adugna. (2014): Effects of different rates of NPK and blended fertilizers on nutrient uptake and use efficiency of teff [*Eragrostis tef (Zuccagni) Trotter*] in Dedessa District, southwestern Ethiopia. Journal of Biology, Agriculture and Healthcare, 4(25): 254-258.

[16] Agegnehu Getachew, Lakew Berhane, and Nelson, P. (2014): Cropping sequence and nitrogen fertilizer effects on the productivity and quality of malting barley and soil fertility in the Ethiopian highlands. Archives of Agronomy and Soil Science, 60: 1261-1275.

[17] EthioSIS. (2015): Soil fertility status and fertilizer recommendation atlas for Tigray regional state, Ethiopia. Addis Ababa, Ethiopia..

[18] Assefa Menna, Johnson, S, M.R., N., Amuri and Tekalign Mamo. (2015): Wheat Response to Applied Nitrogen, Sulfur and Phosphorous in Three Representative Areas of the Central Highlands of Ethiopia. International Journal of Plant and Soil Science. 8 (5): 1–11.

[19] Ministry of Agriculture and Natural Resource. (2013): Ethiopia is transitioning into the implementation of soil test-based fertilizer use system. 35pp

[20] HARC (Holeta Agricultural research center). (2019): Agrometeorological data of Annual progress report. Holeta, Ethiopia.

[21] IUSS Working Group WRB. (2015): World Reference Base for Soil Resources 2014, update 2015 International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports Number. 106. FAO, Rome

[22] Getachew Agegnehu, Paul N. Nelson, Michael I. Bird & Christy van Beek. (2015): Phosphorus Response and Fertilizer Recommendations for Wheat Grown on Nitisols in the Central Ethiopian Highlands. Communications in Soil Science and Plant Analysis. 46(19): 2411-2424.

[23] Bouyoucos, G.S. (1962): Hydrometer method improved for making particle size analysis of soils. Agronomy Journal. 54: 464-465.

[24] Walkley, A and Black I. A. (1954): Estimation of soil organic carbon by chromic acid titration method. Journal of Soil Science. 37(1):29-38.

[25] Broad bent, F.E. (1953): The soil organic fraction. Advanced in Agronomy. 5: 153-183.

[26] FAO (Food and Agriculture Organization of the United Nations). (2008). Fertilizer and plant nutrition bulletin: Guide to laboratory establishment for plant nutrient analysis. FAO, Rome, Italy. 203p.

[27] Jackson ML. (1962): Soil chemical analysis. New Delhi, *Prentice Hall of India Pvt. Ltd*: pp 498.

[28] Bray, R.H. and Kurtz, L.T. (1945): Determination of Total Organic and Available Forms of Phosphorus in Soils. Soil Science, 59: 39-45.

[29] Rowell, D.L., (1994): Soil science: Methods & Applications. Addison Wesley Longman Singapore Publishers (Pte) Ltd., England, UK. 350 p.

[30] Nemat A. Noureldin, H.S. Saudy, F. Ashmawy, H.M. Saed. (2013): Grain yield response index of bread wheat cultivars as influenced by nitrogen levels. Annals of Agricultural Sciences, 58(2): 147-152.

[31] Fageria, N.K., Barbosa Filho, M.C., (1981): Screening rice cultivars for higher efficiency of phosphorus absorption. Brasilia, 26:777–782.

[32] SAS Institute (2018). SAS/STAT guide for personnel computers, version 9.4 M3, edition. Cary, NC: SAS Institute Inc.

[33] Gomez, K.A. and Gomez, A.A. (1984): Statistical procedure for agricultural research. *2nd Edition*. International Rice Research Institute. John Wiley and Sons Inc.

[34] CIMMYT. (1988): From Agronomic Data to Farmer. Recommendations: An Economics Training Manual. Completely revised edition. Mexico. D.F.

[35] Tekalign Mamo. (1991): Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa, Ethiopia.

[36] Mengel, K., and Kirkby, E. A. (1996): Principles of plant nutrition. Panimo Publishing Corporation, New Delhi, India.

[37] Hazelton P. and Murphy B. (2007): Interpreting soil test results. European Journal of Soil Science. 58:1219-1220.

[38] EthioSIS (Ethiopian Soil Information System). (2013): Soil analysis report. Agricultural Transformation Agency. Addis Ababa, Ethiopia.

[39] Kifle Zerga, Firew Mekbib, Tadesse Dessalegn. (2017): The Mean Performance of Different Bread Wheat (*Triticum aestivum* L.) Genotypes in Gurage Zone, Ethiopia. Landscape Architecture and Regional Planning. 2(1): 29-35.

[40] Anwar, S., Iqbal, B., Khan, A. A., Shah, W. A., Islam, M., Khattak, W. A., and Abbas, W. (2016): Nitrogen and phosphorus fertilization of improved varieties for enhancing phenological traits of wheat. Pure and Applied Biology. 5(3): 511-519.

[41] Tagesse Abera, Ketema Belete, Tamado Tana. (2018): Effect of Blended NPS Fertilizer Supplemented with Nitrogen on Yield Components and Yield of Bread Wheat (*Triticum aestivum* L.). Journal of Natural Science. 8(11):90-96.

[42] Melaku Tafese. (2019): Grain quality and yield response of bread wheat (*Triticum aestivum L.*) varieties to different rates of blended fertilizer at Kulumsa, South-eastern Ethiopia. Assela, Ethiopia. Journal of Agricultural Science and Practice. 4(4): 120-133.

[43] Alinajoati, S.S., Mirshekari, B. (2011): Effect of phosphorus fertilization and seed bio-fertilization on harvest index and phosphorus use efficiency of wheat cultivars. Food, Agriculture and Environment, 9(2): 388-397.

[44] Sahota, T.S. (2006): Importance of Sulphur in Crop Production. Northwest Link. 10–12p.

[45] Yadav, R.L., (2003): Assessing on-farm efficiency and economics of fertilizer N, P, and K in rice-wheat systems of India. Field Crops Research. 81(1):39-51.

[46] Lemi Aga and Negash Geleta. (2020): Effects of Variety and Fertilizer Rate on Yield of Bread Wheat (*Triticum aestivum*, L) Varieties in East Wollega Zone, Western Ethiopia Agricultural and Biological Sciences Journal. 6 (2): 60-71.

[47] Habtamu Kefale and Ahadu Menzir. (2019): Genetic Variation of Bread Wheat (*Triticum aestivum* L.) Varieties Based on Phenological, Morphological and Quality Traits at Guay Kebele in Debre Elias District, East Gojjam Zone, Northwestern Ethiopia. Journal of Biology, Agriculture and Healthcare. 9(11) 22-29.

.