Journal of Biodiversity and Environmental Sciences | JBES
ISSN: 2220-6663 (Print); 2222-3045 (Online)
Website: https://www.innspub.net
E-mail contact: info@innspub.net
Vol. 27, Issue: 1, p. 82-89, 2025

RESEARCH PAPER OPEN ACCESS

Effects of nitrogen fertilizer rate and timing of application on yield components and yield of bread wheat (*Triticum aestivum* L.) in Gombora District, Hadiya Zone, Central Ethiopia

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Key words: Inorganic N fertilizer, Bread wheat, Grain yield

DOI: http://dx.doi.org/10.12692/jbes/27.1.82-89 [Published: July 18, 2025]

ABSTRACT

Bread wheat productivity is constrained by incorrect use of inorganic nitrogen rate and time of application. The objectives of this study were to determine economically feasible rate and time of nitrogen for wheat. Five levels of nitrogen (0, 23, 46, 69 and 92 kg ha^{-1}) and three time (1/2 at the time of sowing and 1/2 at mid tillering stage, 1/3 at the time of sowing and 2/3 at mid tillering stage and 2/3 at time of sowing and 1/3 at mid tillering stage) were tested by using a randomized complete block design with three replicates. SAS software was used to analysis of variance which revealed almost all parameters were significantly ($p \leq 0.01$) affected by the main effects of nitrogen rate and its application time, except time of N had no significant effect on thousand kernels weight, straw yield and harvest index, while, their interaction effects had significant effect on grain yield, above ground dry biomass, spike length and plant height. The highest net benefit was obtained from the 92 kg/ha N with 1/3 at the time of seed sowing and 2/3 at mid-tillering stage, which produced high grain yields with the best profitability. Therefore, this treatment could be recommended as best for maximum seed yield of wheat. However, the experiment was carried out only in one location for one cropping season, additional studies at different locations for at least three years or seasons should be conducted.

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INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the most widely grown cereal grain in the world, and it is a member of the Poaceae family (Clayton *et al.*, 2015). It is a key industrial and food grain that is traded internationally and ranks second among the world's most important cereal crops after rice (Asadallah, 2014). Wheat is a strategic commodity in Sub-Saharan African countries as it generates farm income and improves food security (Amentae *et al.*, 2017). It is widely cultivated in the middle to high-altitude zones (1,800 - 2,400 m) and the total wheat area farmed and total production, Ethiopia is one of Africa's top wheat producers (CSA, 2012). But, the production of wheat is tremendously of a subsistence nature and is dominated by the country's numerous smallholder farmers that cultivate more wheat for consumption and less for the market. The farmers in most parts of the country in general and in the study area in particular have limited information on the impact of different types and rates of fertilizers except blanket recommendation of nitrogen (46 kg N ha^{-1}) and phosphorus (46 kg P_2O_5 ha^{-1}) moreover, essentially nitrogen fertilizer required for successful plant growth and good productivity.

The average productivity of wheat at national level, Central Ethiopia and study area are 3.04, 2.92, 2.89 ton ha^{-1}, respectively (CSA, 2020) and this is low compared to the world's average yield of 3.4 tones ha^{-1} (FAO, 2019). Low soil fertility is one among the major factors limiting maize production and productivity in the lowland areas of the country in general and in Central Ethiopia in particular, where depletion of macro-nutrient and micro nutrient, inappropriate fertilizer rate and application time are the most significant constraints limiting wheat production in Ethiopia including the study area (Demeke and Antonio, 2013). Techniques that increase the yield of the wheat crop on low soil fertility especially, low nitrogen soil by the application of appropriate rates and time of application are essential to sustain productivity and avoid soil fertility constraints. Therefore, the objectives of the study were on the effect of N fertilizer application rate and time of application on yield components and yield of bread wheat.

MATERIALS AND METHODS

Description of the study area

An experiment was conducted at Wera Keble Farmers Training Centre in 2022, which is located in Gombora District, Hadiya Zone, Central Ethiopia, during the main cropping season. The site is located on geographic coordinates of 7^{0} 33′ N 7^{0} 37′ N latitude and 37^{0} 35′ E to 37^{0} 40′ E longitudes at altitude of this District ranges from 1400 to 2400 meters above sea level. The annual rainfall varies from 600 to 2200mm, and the annual mean temperatures also vary from 15- 25°C (GDFEDO, 2022).

Soil sampling and analysis

Soil sample was taken from experimental plots to determine some physical and chemical properties. The prepared soil sample was composited to one sample and air dried, ground, and sieved using 2mm sieve. Then, these composited soil sample was analyzed for the determination of soil pH, organic carbon (OC), total nitrogen (N), available phosphorus (av. P), and cation exchange capacity (CEC) according to the standard laboratory procedures at wachemo university, soil and water analysis laboratory. Organic carbon content was determined by the wet digestion method of Walkley and Black (1934) and total N by the semi-micro-Kjeldahl method of Bremner and Breitenbeck (1983). CEC of the soil was determined by the neutral ammonium acetate (CH_3COONH_4) saturation method (Rhoades, 1982). The av. P was extracted with a sodium bicarbonate solution at pH 8.5 following the procedure described by Olsen and Khasawneh (1980). The pH of the soil was measured potentiometrically in the supernatant suspension of a 1:2.5 soil: water mixture by using a pH meter (Van Reeuwijk, 1992).

Experimental materials and design

Bread wheat variety 'kakaba' was used which was released by Kulumsa Agricultural Research Centre (KARC) in 2012. The treatments consisted of five levels of nitrogen (0, 23, 46, 69 and 92 N kg ha^{-1}) and three times of N application 1/2 at the time of sowing with seed and 1/2 at mid tillering, 1/3 at the time of sowing and 2/3 at mid tillering stage, 2/3 at the time of sowing and 1/3 at mid tillering stage. The experiment was laid in a randomized complete block design with three replications. The gross size of each plot was 2.5m x 3m consisting of ten rows and the distance between adjacent plots and blocks was 0.5 m and 1m apart respectively thus the net plot size was 2m x2m. The outermost row on both sides of each plot was considered a border row and was not used for data collection to avoid border effects.

Data collection and analysis

Plant height (cm): It was measured in cent meter from the soil surface to the tip of the spike (awns excluded) from 10 randomly pre-tagged plants from the net plot area at physiological maturity and their average was computed. Spike length (cm): it was measured from the bottom of the spike to the tip of the spike excluding the awns from 10 randomly tagged spikes from the net plot. Number of total tillers: It was determined from two rows per net plot at physiological maturity by counting the number of tillers. Number of productive tillers: It was determined at maturity by counting all spikes bearing kernels from two pre- demarked rows per plot at physiological maturity. Thousand kernels weight (g): It was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using electronic seed counter and weighed with sensitive balance. Then the weight was adjusted to 12.5 % moisture content. Aboveground dry biomass (kg): It was determined after the crop harvested from the net plot area after sun drying to a constant weight and converted to kilogram per hectare. Grain yield (kg): It was recorded after harvesting and threshing the seed yield from net plot area. The yield was adjusted to 12% moisture content. Finally, yield per plot was converted per hectare basis and the average yield was reported in kg ha^{-1}. Grain yield kg ha^{-1} at 12.5% moisture bas=Yield obtained (kg ha^{-1}) ×(100-%MC)/100-12.5%. Adjusted grain yield= (100-%MC) × unadjusted grain yield100-12.5%. Straw yield was obtained as the difference of the total above ground dry biomass and grain yield and expressed in kg ha^{-1}. Harvest index (%): Harvest index was calculated as ratio of grain yield per plot to total aboveground dry biomass yield per plot expressed as percent.

RESULTS AND DISCUSSION

Physicochemical properties of the experimental soil

Textural class of soil is clay loam; the soil pH is moderately acidic, organic carbon content of the experimental site was 2.8% which was medium according to the rating of Tekalign (1991). Mengel and Kirkby (1996) reported optimum pH range of 4.1 to 7.4 for wheat production. Total N content of 0.1% which is considered very low, medium in av. P mg/kg^{-1}, low in CECcmol+/kg (Table 1).

Table 1. Physicochemical properties of the experimental soil

Soil parameters			
Physical properties	Value	Rating	Reference
Clay (%)	38	High	Hazelton and Murphy (2007)
Sand (%)	28	Moderate	Hazelton and Murphy (2007)
Silt (%)	24	Moderate	Hazelton and Murphy (2007)
pH(1:2.5 H_2O)	5.9	Moderately acidic	Tekalign (1991)
N (%)	0.15	Poor	Tekalign (1991)
OC (%)	2.8	Medium	Landon (1991)
CECcmol+/kg	15	Low	Landon (1991)
A. P(ppm)	10.4	Medium	Tisdale (2002)

Yield and yield parameters of maize

The analysis of variance (ANOVA) showed that the main effects of nitrogen rate, time of application and their interactions had a significant ($p<0.01$) effect on both plant height and spike length. The tallest mean plant height (99.00cm) was recorded from the nitrogen rate of 92 kg ha^{-1}), in 1/3 of the dose at sowing and 2/3 at mid tillering stage, whereas, the shortest mean plant height

(67.83cm) was recorded from 0 kg N with (1/3 at sowing and 2/3 at mid-tillering stage (Table 2). Similarly, the longest mean spike length (9.47cm) was recorded from the nitrogen rate of 92 kg ha^{-1}), in 1/3 of the dose at sowing and 2/3 at mid tillering stage, whereas, the shortest mean spike length (6.03cm) was recorded from 0 kg N with (1/3 at sowing and 2/3 at mid-tillering stage.

Plant height generally increased with an increase in the rate and frequency of N application and the shortest plants were recorded from unfertilized plot. These results were in line with Khan *et al.* (2000) who reported that increasing nitrogen rates increased the wheat plant height. Similary, Amsal *et al.* (2000) observed a positive and linear response to applied N fertilizer to plant height in the central highlands of Ethiopia. According to Rahmatullah *et al.* (2007) and Amjed *et al.* (2011) who reported that spike length increased significantly with increased application of nitrogen.

Table 2. Plant height and spike length of bread wheat as influenced by the interaction of N rate and time of N application

N rate (kg ha^{-1})	Timing of application					
	Plant height(cm)			Spike length(cm)		
	T1	T2	T3	T1	T2	T3
0	69.00^{hi}	68.17^{i}	67.83^{i}	6.50^{fg}	6.03^{f}	6.43^{g}
23	73.17^{g}	76.20^{fg}	72.67^{gh}	7.63^{e}	7.67^{e}	7.50^{e}
46	78.5^{ef}	88.43^{bc}	81.67^{de}	8.40^{cd}	8.60^{c}	8.30^{d}
69	87.80^{c}	92.17^{b}	85.33^{cd}	8.60^{c}	9.07^{b}	8.47^{cd}
92	89.33^{bc}	99.00^{a}	92.00^{b}	9.00^{b}	9.47^{a}	8.57^{c}
LSD(0.05)		4.12			0.25	
CV (%)		9.03			11.86	

Parameter means followed by the same letter within a column are not significantly different at 5% level of significance according to Tukey Tests; LSD (5%) = least significant difference at 5% level and CV = coefficient of variation, T1= N application of 1/2 at sowing and 1/2 at mid-tillering; T2= N application of 1/3 at sowing and 2/3 at mid-tillering; T3= N application of 2/3rd at sowing, 1/3rd at mid-tillering.

Table 3. Number of total and productive tillers of bread wheat as influenced by main effects of N rate and time of N applications

N rate (kg ha^{-1})	Number of total tillers	Number of productive tillers
0	126^{e}	85.00^{d}
23	152.89^{d}	119.22^{c}
46	193.53^{c}	166.11^{a}
69	246.67^{b}	146.11^{b}
92	266.78^{a}	126.11^{c}
LSD (0.05)	8.04	19.55
N application time		
T1	199.00^{b}	127.33^{ab}
T2	207.53^{a}	139.33^{a}
T3	185.07^{c}	118.87^{b}
LSD (0.05)	6.22	15.14
CV (%)	12.22	15.76

Parameter means followed by the same letter within a column are not significantly different at 5% level of significance according to Tukey Tests; LSD (5%) = least significant difference at 5% level and CV = coefficient of variation, T1= N application of 1/2 at sowing and 1/2 at mid-tillering; T2= N application of 1/3 at sowing and 2/3 at mid-tillering; T3= N application of 2/3rd at sowing, 1/3rd at mid-tillering.

Number of total and productive tillers

The both number of total and productive tillers per meter square were significantly ($p<0.05$) affected by main effects of N fertilizer rate and time of applications but, not significantly interaction effect of the two factors. The maximum (266.78) and minimum (126.11) mean total number of tillers were recorded from the application of the highest rates of

N rate (92 kg ha⁻¹) and control treatments, respectively (Table 3). This result is in line with Hameed *et al.* (2003) who observed that increasing nitrogen application significantly increased the number of tillers per meter square and Genene (2003) who reported higher tillering and maximum survival percentage of tillers with increasing N application in bread wheat. Also the maximum (166.11) and minimum (85.00) mean productive number of tillers were recorded from the application of the rate of N (46 kg ha⁻¹) and control, respectively. This result agrees with those of Prystupa *et al.* (2004), who reported that the number of productive tillers was significantly affected by nitrogen application.

Aboveground dry biomass

Analysis of variance indicated that the aboveground dry biomass had respond significantly to the effects of N rate, N time of applications as well as interaction effect. The highest mean of above ground dry biomass (8920 kg ha⁻¹) was obtained from the interaction of 92 kg N ha⁻¹ with application time of 1/3 at the time of sowing and the rest 2/3 at mid tillering stage whereas, the lowest mean of above ground dry biomass (3460 kg ha⁻¹) was also recorded from the interaction of 0 kg N ha⁻¹ with application time of 2/3 at the time of sowing and the remain 1/3 at mid tillering stage (Table 4). The increase in above-ground dry biomass with a higher N rate might be due to improved N availability for bread wheat vegetative growth as well as appropriate fertilizer supply and assimilation in meristematic tissue which facilitated tillering and overall plant growth. These results are in conformity with the results of Jasemi *et al.* (2014) reported that vegetative growth and biological yield have a dependence on the consumption of chemical fertilizers. Similarly, Bekalu and Mamo (2016) also reported that increasing N rate from 23 to 69 kg ha⁻¹ increased the above ground dry biomass of wheat by about 22.6%.

Table 4. Aboveground dry biomass and grain yield of bread wheat as influenced by the interaction of N rate and time of N application

N rate (kg ha⁻¹)	Timing of application					
	Aboveground dry biomass (kg ha⁻¹)			Grain yield (kg ha⁻¹)		
	T1	T2	T3	T1	T2	T3
0	3833.3^{i}	3800.0^{i}	3460.0^{i}	1633.3^{f}	1616.7^{f}	1626.7^{f}
23	4383.3^{h}	4716.7^{gh}	4866.7^{g}	1900.0^{ef}	2063.3^{ef}	1900.0^{ef}
46	5633.3^{f}	6616.7^{e}	6466.7^{e}	2600.0^{d}	3416.7^{b}	3016.7^{c}
69	7138.3^{d}	7583.3^{cd}	7333.3^{d}	3383.3^{b}	3733.3^{a}	3296.7^{bc}
92	7813.3^{bc}	8920.0^{a}	8146.7^{b}	3420.0^{b}	4016.7^{a}	3760.0^{a}
LSD(0.05)		460.77			315.4	
CV (%)		14			8.83	

Parameter means followed by the same letter within a column are not significantly different at 5% level of significance according to Tukey Tests; LSD (5%) = least significant difference at 5% level and CV = coefficient of variation, T1= N application of 1/2 at sowing and 1/2 at mid-tillering; T2= N application of 1/3 at sowing and 2/3 at mid-tillering; T3= N application of 2/3rd at sowing, 1/3rd at mid-tillering.

Grain yield

Analysis of variance for grain yield indicated significant effects of N application rate, time and interaction with both N rate and time of applications. The highest mean grain yield (4016.7 kg ha⁻¹) was recorded from the interaction of 92 N kg ha⁻¹ with its application time of 1/3 at the time of sowing and 2/3 at mid tillering stage, while the lowest mean (1616.7 kg ha⁻¹) was obtained from the interaction of the 0 N kg ha⁻¹ with its application time of 1/3 of N at the time of sowing and the rest 2/3 of N at mid tillering stage (Table 4). This result showed that there is high potential to increase bread wheat yield through increased application of nitrogen fertilizer rates. Generally, wheat grain yield consistently increased as the rate of applied N increased to the highest level of N and the grain yields recorded due to each successive rate of N were significantly different. The results obtained from this study in lined with the research findings of many previous works, Haile *et al.* (2012), Getachew (2004) who reported significant increases in grain yields of bread wheat with increasing application levels of N fertilizer.

Straw yield

The results of analysis of variance revealed that the straw yield of bread wheat was significantly ($p<$ 0.01) affected by the N fertilizer rate. However, its application time and the interaction of the two factors were not significant. The highest (4561.1 kg ha^{-1}) and the lowest (2072.2 kg ha^{-1}) straw yield were recorded from the highest N rate of 92 kg ha^{-1} and control treatments, respectively (Table 5). This result is in line with Gul *et al.* (2012), who reported that higher nitrogen application has a greater contribution to higher straw yield production as compared to control treatment.

Table 5. Straw yield harvest index of bread wheat as influenced by main effects of N rate and time of N applications

N rate (kg ha^{-1})	Straw yield(kg ha^{-1})	Harvest index (%)
0	2072.2^{e}	44.26^{bc}
23	2701.1^{d}	42.08^{c}
46	3227.8^{c}	47.99^{a}
69	3863.9^{b}	47.36^{ab}
92	4561.1^{a}	45.03^{abc}
LSD (0.05)	260.39	3.37
CV (%)	8.21	7.71

Parameter means followed by the same letter within a column are not significantly different at 5% level of significance according to Tukey Tests; LSD (5%) = least significant difference at 5% level and CV = coefficient of variation, T1= N application of 1/2 at sowing and 1/2 at mid-tillering; T2= N application of 1/3 at sowing and 2/3 at mid-tillering; T3= N application of 2/3rd at sowing, 1/3rd at mid-tillering.

Harvest index (%)

The main effect of N rate had a highly significant ($p<0.01$) influence on harvest index; but the main effect of N application time as well as its interaction with N application rate did not influence this. The highest (47.99%) and the lowest (42.06%) of harvest index were recorded from the nitrogen rate of 46 kg ha^{-1} and 23 kg ha^{-1}, respectively (Table 5). This result is aligned with that of Sakatu (2017), who reported the maximum harvest index (0.43) at a nitrogen level of 190 kg N ha^{-1} while a minimum harvest index (0.35) was recorded from control. Similarly, Muhammed *et al.* (2012) who reported the highest harvest index (36.17%) was obtained from a treatment of 150 kg N ha^{-1} and the lowest harvest index (31.53%) was recorded from control.

CONCLUSION

The low productivity of bread wheat in the study area is diminished by inappropriate use of nitrogen rate and its time of application. Thus, increased usage of N fertilizer is considered to be a primary means of increasing wheat yield in this area. In view of this, a field experiment was conducted to determine the effect of N rate and time of application on yield components and yield of wheat; and to determine economically feasible rate and time of N application. The results of the field experiment revealed that all parameters were significantly affected by main effects of nitrogen rate and its application time, except time of N had no significant effect on thousand kernels weight, straw yield and harvest index, although, their interaction effects had significant effect on grain yield, above ground dry biomass, spike length and plant height. In general, the highest net benefit was obtained from the 92 N kg ha^{-1} with 1/3 at the time of seed sowing and 2/3 at mid-tillering, which produced high grain yield with the best profitability and this treatment could be recommended. However, the experiment was carried out only in one location for one cropping season, additional studies should be conducted.

ACKNOWLEDGEMENTS

I would like to acknowledge my Advisors for their interest in the work, frequent supervision with genuine comments, and reviewing, their guidance, encouragement, support and advices starting from proposal preparation to Thesis write up. My special thanks go to the Gombora Woreda Agriculture and Natural resource Office for providing me the research site I used for the experiment. Further, the magnificent support and contribution of all my families and friends are profoundly acknowledged which accentuated during my entire study.

REFERENCES

Amentae TK, Kaso HT, Gebresenbet G, Ljungberg D. 2017. Exploring wheat value chain focusing on market performance, post-harvest loss, and supply chain management in Ethiopia: The case of Arsi to Finfinnee market chain.

Amsal T, Tanner DG, Chanyalew M. 2000. Agronomic and economic evaluation of the farm N and P response of bread wheat grown on two contrasting soil types in central Ethiopia. In: The Eleventh Regional Wheat Workshop for Eastern, Central and Southern Africa, CIMMYT, Addis Ababa, Ethiopia, pp. 239–252.

Anteneh A, Asrat D. 2020. Wheat production price performance prediction in the Iranian north province. Cogent Food & Agriculture **6**, 1778893. https://doi.org/10.1080/23311932.2020.1778893.

Asadallah N. 2014. Wheat production price performance prediction in the Iranian north province. African Journal of Agricultural Research **9**(1), 74–79. https://doi.org/10.5897/AJAR11.429.

Bekalu A, Mamo M. 2016. Effect of the rate of N fertilizer application on growth and yield of wheat at Chencha, Southern Ethiopia.

Bremner JM, Breitenbeck GA. 1983. A simple method for determination of ammonium in semi micro-Kjeldahl analysis of soils and plant materials using a block digester. Communications in Soil Science and Plant Analysis **14**(10), 905–913.

Clayton WD, Govaerts R, Harman KT, Williamson H, Vorontsova M. 2015. World checklist of Poaceae. Royal Botanic Gardens, Kew. Accessed: 6/2015.

CSA (Central Statistical Agency). 2020. Agricultural sample survey: Report on area and production of major crops (private peasant holdings, Meher season). Statistical Bulletin No. 587, Central Statistical Authority.

Demeke M, Marc Antonio F. 2013. Analysis of incentives and disincentives for wheat in Ethiopia. Technical notes series, MAFAP, FAO, Rome.

FAO (Food and Agriculture Organization). 2019. Crop production data. Rome.

Genene G. 2003. Yield and quality response of bread wheat varieties to rate and time of nitrogen fertilizer application at Kulumsa, Southern Ethiopia. MSc Thesis, Alemaya University, Alemaya, Ethiopia.

Getachew F. 2004. Soil characterization and bread wheat response to nitrogen and phosphorus fertilization on Nitosol at Ayehu Research Substation in Northwestern Ethiopia. MSc Thesis, School of Graduate Studies, Alemaya University, Ethiopia.

Gombora District Agriculture and Rural Development, and Finance and Economic Development Offices. 2022. Statistical figure, profile. UN published, Habicho.

Gul H, Saeed B, Khan AZ, Haleema B, Parveen L, Badshah NL. 2012. Morphological and some yield attributes in cultivars of wheat response of varying planting dates and nitrogen application. ARPN Journal of Agricultural and Biological Science **7**(2), 100–109.

Haile D, Nigussie D, Amsalu A. 2012. Nitrogen use efficiency of bread wheat: Effects of nitrogen rate and time of application. Journal of Soil Science and Plant Nutrition **12**(3), 389–409.

Hameed E, Shah WA, Shad AA, Bakht J, Muhammad T. 2003. Effect of different planting dates, seed rate and nitrogen levels on wheat. Asian Journal of Plant Sciences **2**(6), 467–474.

Hazelton P, Murphy B. 2007. Interpreting soil test results: What do all the numbers mean? 2nd edition. CSIRO Publishing, 152 pp.

Husain A, Shah A, Ayoub M. 1995. Effect of nitrogen application on number of productive tillers in wheat. (As cited in secondary sources).

Jasemi SS, Akbari GA, Najafian G, Muradi F. 2014. Nutrition management effects on grain yield, yield components and some physiological characteristics of bread wheat cultivars. International Journal of Agronomy and Agricultural Research **5**(3), 1–6.

Kausar K, Akbar M, Rasul E, Ahmad AN. 1993. Physiological response of nitrogen, phosphorus and potassium on growth and yield of wheat. Pakistan Journal of Agricultural Research **14**, 126–130.

Khan MA, Hussain I, Baloch S. 2000. Wheat yield potential: Current status and future strategies. Pakistan Journal of Biological Sciences **3**, 82–86.

Landon JR. 1991. Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics. Booker Tate Ltd., England.

Makowska A, Obuchowski W, Sulewska H, Koziara W, Paschke H. 2008. Effect of nitrogen fertilization of durum wheat varieties on some characteristics important for pasta production. Techno Aliment 7(1), 29–39.

Muhammed MM, Shah A, Ahmed AA, Waqas WA. 2012. Optimizing rate of nitrogen application for higher growth and yield of wheat cultivars. Department of Agronomy, University of Agriculture, Pakistan **49**(4), 491–496.

Olsen SR, Khasawneh FE. 1980. Use and limitation of physical-chemical criteria for assessing the status of phosphorus in soils. In: Khasawneh FE (Ed.). The role of phosphorus in agriculture. Madison, Wisconsin: American Society of Agronomy.

Prystupa P, Slafer G, Savin A. 2004. Leaf appearance, tillering and their coordination in response to N and P fertilization in barley. Springer, Netherlands.

Rahmatullah K, Raza GA, Hussain GA, Sharif ZM. 2007. Effect of phosphorus application on rainfed wheat growing in the Mediterranean region. Field Crops Research **71**, 113–122.

Rhoades JD. 1992. Cation exchange capacity. In: Methods of soil analysis, agronomy series.

Sakatu H. 2017. Effects of seeding rates and nitrogen levels on yield and yield components of wheat (*Triticum aestivum* L.) on Vertisols in central highlands of Ethiopia. Journal of Natural Science Research **7**(11), 21–24.

Tekalign T. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

Tilahun C, Heluf G, Kibebew K, Tolessa D. 2017. Effect of rate and time of nitrogen fertilizer application on durum wheat (*Triticum turgidum* var. L. *durum*) grown on Vertisols of Bale highlands, southeastern Ethiopia. American Journal of Research Communication **5**(1), 39–56.

Tisdale SL, Nelson WL, Beaton JD, Halving JL. 2002. Soil and fertilizer potassium. In: Soil fertility and fertilizers (5th ed.), pp. 230–265. Prentice Hall, New Delhi, India.

Van Reeuwijk LP. 1992. Procedure for soil analysis. 2nd edition. International Soil Reference and Information Center (ISRIC), the Netherlands, 371 pp.

Walkley AJ, Black IA. 1934. Estimation of soil organic carbon by the chromic acid titration method. Soil Science **37**, 29–38.