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Optimizing Nitrogen Fertilizer for Wheat Production in Moisture-Deficit Areas of Northern Ethiopia

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ABSTRACT

Depleting soil nutrients is among the significant factors affecting production and productivity in Ethiopia. From the nutrients, nitrogen is the most yield-limiting, which governs wheat production. Therefore, the study was conducted to examine the effect of nitrogen on the yield and yield components of bread wheat varieties. The experiment was implemented in the 2019 and 2020 cropping seasons at Sekota and Lasta districts on the farmers' field. The treatments consisted of a factorial combination of four levels of nitrogen (0, 46, 69, and 92 kg ha^{-1}) and two varieties of wheat (Sekota-1 and Hibst), which were replicated three times in a randomized complete block design. Each treatment was provided with 23 kg ha^{-1} triple supper phosphate (P_2O_5). The study's results indicated that grain and yield-related traits were significantly affected by nitrogen application. The increasing rate of nitrogen up to 92 and 69 kg ha^{-1} increases wheat grain and biomass yield by (150.3% and 54.1%) and (95.9 and 60%) in Sekota and Lasta districts, respectively. The highest grain yield (2562 and 2980 kg ha^{-1}) was obtained from applying 92 and 69 kg ha^{-1} N at Sekota and Lasta, respectively. Therefore, applying 92 and 69 kg ha^{-1} N is the appropriate rate and recommended for the Sekota and Lasta districts, respectively.

Keywords: Biomass, grain yield, lasta, sekota, variety

INTRODUCTION

Wheat (*Triticum aestivum L.*) is one of the major global cereal crops, ranking second after paddy rice both in area and production and providing more nourishment than any other food crop (Curtis, 2002). Ethiopia is one of the largest wheat producers in sub-Saharan Africa (FAOSTAT, 2014), with an estimated area of more than 1.8 million hectares (CSA, 2021). Despite this ample area coverage, the productivity is below the world average. High depletion of soil fertility and low levels of chemical fertilizer usage are the major abiotic factors that lower the production and productivity of wheat (Martey et al., 2019; Getachew et al., 2011).

Fertilizers play a significant role in boosting yield. Nitrogen is often the most limiting nutrient for crop yield in many regions of the world. The increase in agricultural food production worldwide over the past four decades has been associated with a seven-fold increase in the use of N fertilizers (Hirel et al., 2007). Nitrogen is the most limiting nutrient for wheat production because it affects rapid plant growth and improves grain yield. Many studies showed that nitrogen application increased grain yield and other parameters of wheat (Subedi et al., 2007; Asif et al., 2009; Bereket et al., 2014; Bekalu and Arega, 2016). Abedi et al. (2011) reported that a higher grain yield (8230 kg ha^{-1}) was produced in a treatment receiving 240 kg N ha^{-1} than in control (3930 kg ha^{-1}), 120 kg N ha^{-1} (4400 kg ha^{-1}), and 360 kg N ha^{-1} (6530 kg ha^{-1}). Research conducted in Tigray, Northern Ethiopia, by Beyenesh et al. (2017) indicated that increasing the rate of nitrogen increases the grain and biomass yield. Tilahun and Temado (2019) also reported that increasing the N level from 23 to 92 kg ha^{-1} significantly increased the grain yield of bread wheat. Similarly, Alemu et al. (2019) reported that increasing N up to 96 kg ha^{-1} increased wheat's grain and biomass yield.

The findings, as mentioned above, showed that the application of nitrogen fertilizer positively impacted wheat yield and yield components. Hence, nitrogen is the universal limiting nutrient essential for plant growth and yield. Despite the positive response of nitrogen fertilizer to bread wheat production, research recommendations on nutrient management need to be made to enhance the productivity and profitability of wheat production in the study areas. Therefore, this experiment aimed to investigate the effect of N rates on yield and yield components of bread wheat and find economically appropriate rates of N fertilizer for the study areas.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted for two consecutive years, 2019 and 2020, in the Sekota and Lasta districts of the eastern Amhara Region, Ethiopia (Figure 1). The districts are in the Wag-himra and north Wollo zones of the Amhara regional state. These areas are usually referred to by undulating topography, uneven distribution, erratic rainfall, very shallow soil depth, high soil erosion, scattered forest coverage, and sloppy farming, which is commonly practiced. The major crops grown in the districts are sorghum, tef, wheat, barley, maize, fababean, and check pea. Sorghum is the leading crop (45.1% of the area of cultivated cereals), followed by tef (20.6%), barley (19.1%), wheat (12.01%), and maize (2.18%) in Wag-himra zone. At the same time, tef is the leading crop (31.8% of the area of cultivated cereals), followed by sorghum (25.3%), wheat (23.0%), barley (15.5%), and maize (3.4%) in north Wollo (CSA, 2021). Intercropping and rotation of cereals with legumes are commonly practiced in those districts to improve soil fertility. The maximum rainfall during the growing season was 386.84 mm and 265.37 mm in August 2020 at Lasta and July 2020 at Sekota districts, respectively (Figure 2). The highest rainfall was recorded in the Lasta district, compared to the Sekota district (NASA, 2019 and 2020).

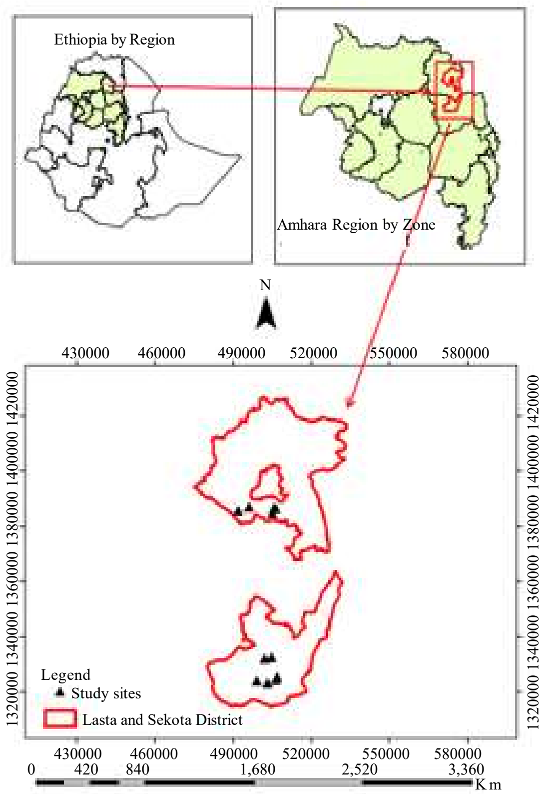

Figure 1: Study area map.

Treatment setup

The study followed a factorial arrangement, combining four nitrogen levels (0, 46, 69, and 92 kg ha^{-1}) with two varieties of bread wheat (Sekota-1 and Hibst). The design used a Randomized Complete Block Design (RCBD), which helps control variability and randomize the effects of factors. A uniform amount of phosphorus was applied for all treatments, each receiving 23 kg ha^{-1} P_2O_5. Nitrogen was applied in the form of urea [CO $(NH_2)_2$] with a nitrogen content of 46%, while phosphorus was applied in the form of triple superphosphate (46% P_2O_5). Distances between plots and blocks (replications) were maintained at 0.5 m and 1 m, respectively. Row planting was employed with a spacing of 20 cm between rows. The seed rate used was 125 kg ha^{-1} for both varieties. Land preparation activities, such as plowing and weeding, were carried out according to recommendations for wheat crop production.

Soil sampling and analysis method

Composite soil samples were collected from the surface soil (0 - 20 cm) at the experimental sites. The 0 - 20 cm depth is standard for assessing the topsoil, which is crucial for plant growth. Collected soil samples were air-dried, ground and sieved with a size of 2 mm. Particle size distribution, including sand, silt, and clay fractions, was determined using the hydrometer method as outlined by Bouyoucos (1962). Soil pH was determined from a filtered suspension of a 1:2.5 soil-to-water ratio. A glass electrode attached to a digital pH meter was used for accurate pH measurement, following the method outlined by Carter and Gregorich (2008). Organic carbon content in the soil was determined using the wet digestion method described by Walkley and Black (1934). Total nitrogen content in the soil was

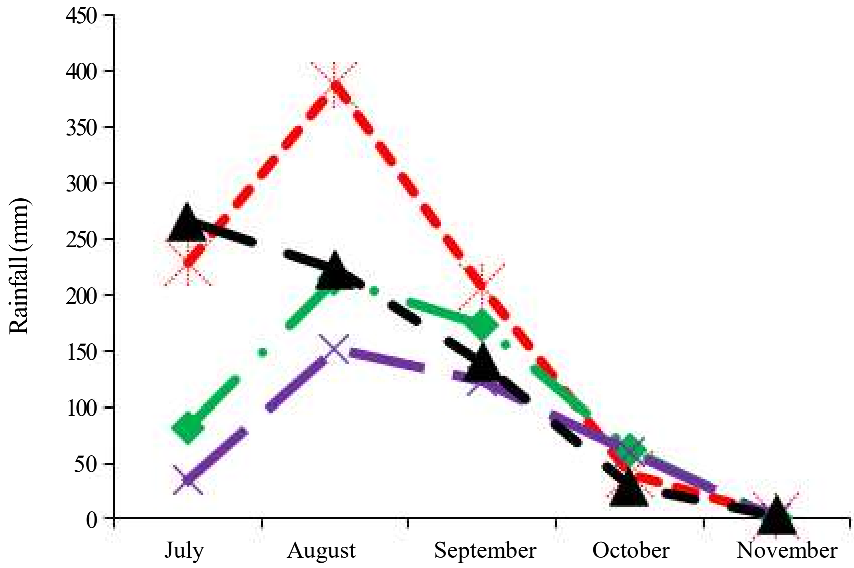

Figure 2: amount of rainfall during the growing season at Lasta and Sekota district. : Lasta 2020, : Sekota 2019, : Lasta 2019, : Sekota 2020.

determined through the Kjeldahl digestion, distillation, and titration method, as outlined by Bremner and Mulvaney (1982). Available phosphorus in the soil was determined using the standard Olsen method (Olsen et al., 1954).

Agronomic data collection

At maturity, five plants were randomly selected from the middle rows of each treatment to measure the plant height, spike length, seeds per spike, and thousand seed weight. Grain and biomass yield were measured from the central thirteen rows of each experimental plots. The grain yield and thousand seed weight were adjusted by 12.5% moisture content.

Partial budget analysis

The analysis considered fertilizer cost, with different values specified for the Lasta and Sekota districts (15.56 and 14.6 ETB kg^{-1}, respectively). It reflects the economic aspect of fertilizer application, an essential factor in the partial budget analysis. The price of wheat grain in both district were 30 ETB kg^{-1}. The grain yield was adjusted downward by 10% of the actual yield.

Data analysis

SAS software was used to analyze variances. ANOVA was employed to assess the statistical significance of differences in yield and yield components based on the factor of nitrogen fertilizer rates and wheat variety. The mean separation was conducted by LSD test at 5% level of significance.

RESULTS AND DISCUSSION

Selected soil physicochemical properties

The nutrient status of the soil greatly varied from farm to farm (Table 1). It shows that the heterogeneity of the soil from farm to farm is incredibly diverse, which might be affected by the farmer's application of manure and other soil improvement techniques. The soil pH (1:2.5 soil to water) value varied from 6.6 (site 1) to 8.2 at site 6, with a range of slightly acidic to moderately alkaline (Tekalign, 1991). The electrical conductivity of the soil ranged from 0.022 ds m^{-1} to 0.21 ds m^{-1} and was categorized as non-saline (Hazelton and Murphy, 2007). The soil organic carbon of the site varied from 0.3 to 0.88%, rated as very low to low. The total nitrogen content varied from 0.0013% to 0.031% recorded at sites 6 and 2. The values are categorized as very low (Tekalign, 1991). The available phosphorus content varied from 14.65 to 34.69 at sites 3 and 5, respectively. According to Tekalign (1991), the available phosphorus content was categorized as high. According to the USDA textural classification, the textural class of the site was sandy loam, sandy clay, and clay loam (Table 1). Generally, the soil nutrient status at all sites except phosphorus and the analyzed parameters were inferior.

Table 1: Selected parameters of the soil analysis result.

Experimental sites	pH (1:2.5)	EC (dS m^{-1})	SOC (%)	Total N (%)	Av P (ppm)	Textural class			
						Sand (%)	Silt (%)	Clay (%)	Class
Site 1	6.6	0.14	0.88	0.017	17.6	43	31	26	loam
Site 2	6.7	0.21	0.8	0.031	32.45	53	25	22	Sandy clay loam
Site 3	6.7	0.16	0.68	0.021	14.65	33	35	32	Clay loam
Site 4	7.8	0.049	0.3	0.0042	25.4	52	13	35	Sandy clay
Site 5	6.9	0.022	0.31	0.0014	34.69	77	13	10	Sandy loam
Site 6	8.2	0.033	0.38	0.0013	21.3	72	17	11	Sandy loam
Site 7	7.3	0.035	0.42	0.0014	17.45	60	23.2	16.8	Sandy loam

Note: EC= Electrical conductivity, SOC= soil organic carbon, Avail P=available phosphorous

Anova to nitrogen and varieties for yield and yield-related traits of wheat

The ANOVA result showed that the application of nitrogen fertilizer had significant effects on plant height, spike length, seed per spike, biomass yield, grain yield, and thousand seed weight of bread wheat at all locations. Similarly, seed per spike and grain yield were affected by variety at Lasta and Sekota, whereas biomass yield and seed weight were significantly affected by variety at Sekota district (Table 2). Generally, the results indicate that nitrogen application and wheat variety significantly influence various yield components of bread wheat.

Effects of nitrogen on yield components of bread wheat

The application of nitrogen was found to have a significant effect on the growth parameters of bread wheat in both the Lasta and Sekota districts (Table 2). A positive correlation was observed between the increasing rate of nitrogen and the enhancement of plant height, spike length, and seed per wheat spike. Hence, the increasing rate of nitrogen up to 92 kg ha^{-1} increases the plant height, spike length, and seed per spike of wheat but is statistically similar to the plant height, spike length, and seed per spike obtained at the N rate of 69 kg

Table 2. The mean square values main and interaction effects of nitrogen and variety on yield and yield component of bread wheat.

Source of Variation	DF	PH (cm)	SL (cm)	SPS (Count)	BY (kg ha^{-1})	GY (kg ha^{-1})	TSW (g)
		Lasta district					
N	3	1054.99**	30.95**	1344.63**	66916201.7**	17113197.15**	20.51^{ns}
V	1	7.91^{ns}	0.04^{ns}	595.01**	2857802.6^{ns}	1059404.79**	11.15^{ns}
Rep	2	10.88^{ns}	1.52^{ns}	45.82^{ns}	703538.3^{ns}	24635.45^{ns}	0.56^{ns}
N*V	3	110.81*	2.38*	74.61^{ns}	5164855.6^{ns}	483261.23**	3.47^{ns}
Error	14	30.65	0.72	80.50	2166306.8	39601.51	10.95
		Sekota district					
N	3	301.59**	3.71**	90.82*	25573503.72**	3613358.56**	0.13^{ns}
V	1	49.66^{ns}	0.23^{ns}	640.56**	17572739.46**	1690073.89**	19.88*
Rep	2	5.39^{ns}	1.43^{ns}	20.83^{ns}	20481.82^{ns}	6148.41^{ns}	1.17^{ns}
N*V	3	39.10^{ns}	1.91^{ns}	8.92^{ns}	4450875.33*	405407.65*	3.49^{ns}
Error	14	16.29	0.70	25.58	1310771.5	139733.03	4.53

PH= plant height, SL=spike length, SP= seed per spike, BY=biomass yield, GY= grain yield, TSW=thousand seed weight

Table 3. Effects of nitrogen and variety on growth parameters of wheat at Lasta and Sekota district.

	Lasta district				Sekota district			
Treatment N (kg ha^{-1})	PH (cm)	SL (cm)	SPS (count)	TSW (g)	PH (cm)	SL (cm)	SPS (count)	TSW (g)
0	62.41^{c}	5.44^{c}	25.85^{b}	37.61^{b}	67.30^{b}	6.91^{b}	41.49^{b}	34.07
46	72.99^{b}	7.29^{b}	40.38^{a}	39.38^{ab}	73.28^{a}	7.36^{ab}	43.88^{ab}	34.11
69	76.21^{a}	7.65^{ab}	41.55^{a}	39.59^{a}	74.28^{a}	7.68^{a}	46.19^{a}	34.24
92	76.60^{a}	7.98^{a}	40.40^{a}	39.39^{ab}	75.12^{a}	7.79^{a}	44.45^{a}	34.19
LSD ($p<0.05$)	3.18**	0.48**	5.16**	1.90*	2.32**	0.48*	2.91*	ns
Variety								
Sekota-1	71.76	7.11	34.55^{b}	39.34	71.77	7.38	41.42^{b}	33.70^{b}
Hibst	72.34	7.07	39.53^{a}	38.65	73.21	7.48	46.59^{a}	34.61^{a}
LSD ($p<0.05$)	ns	ns	3.65*	ns	ns	ns	2.05*	0.86*
CV (%)	7.68	11.99	24.21	8.48	5.56	11.26	11.49	6.23

PH= plant height, SL=spike length, SPS= seed per spike, TSW=thousand seed weight

N ha^{-1} (Table 3). The highest plant heights, 76.6 cm and 75.12 cm, were observed when applying 92 kg ha^{-1} N in Lasta and Sekota, respectively. The lowest plant heights, 62.41 cm and 67.30 cm, were recorded in the control treatment in Lasta and Sekota, respectively. By applying nitrogen, the plant height increased by 22.75% in Lasta and 11.62% in Sekota, as compared to the control treatment. This increment with the application of nitrogen might be because N is the essential constituent of proteins; it is involved in all the major processes of plant development and yield formation. A good supply of nitrogen for the plant is also important for the uptake of other nutrients (Bell, 2016). The current result is similar to the finding of Bereket et al. (2014), who reported that by applying nitrogen up to 92 kg ha^{-1}, the plant height increased by 17.44%.

The highest spike lengths (7.98 and 7.79 cm), maximum number of seed per spike (41.55 and 46.19), were recorded at 92 and 69 kg ha^{-1} nitrogen application rates in Lasta and Sekota districts, respectively. The spike length and seed per spike values obtained at the nitrogen rates of 92 and 69 kg ha^{-1} were statistically similar, indicating that both rates are effective in achieving comparable results. The study indicates that spike length and seed per spike significantly increased with the increasing nitrogen rate, suggesting a positive correlation between nitrogen levels and these yield-related traits. The study's findings align with previous research conducted by Bekalu and Arega (2016) in southern Ethiopia, and Hameed et al. (2002), both of which reported an increase in spike length with the application of nitrogen.

Effects of nitrogen on grain and biomass yield of bread wheat

The result showed that nitrogen application substantially affected grain yield in both Lasta and Sekota districts (Table 2). The highest grain yields were recorded at 69 and 92 kg ha^{-1} nitrogen application rates, with 2980 kg ha^{-1} and 2562 kg ha^{-1}, respectively (Table 4). Importantly, the grain yields obtained at 69 kg N ha^{-1} and 92 kg N ha^{-1} nitrogen rates were statistically similar. It suggests that these nitrogen rates were equally effective in achieving high grain yields. The lowest grain yield was observed in the control treatment, emphasizing nitrogen application's positive impact on wheat production. Applications of 69 and 92 kg ha^{-1} increase the grain yield by 150.29 and 54.05% compared with the control treatment at Lasta and Sekota respectively. The increase in grain yield of wheat with increasing N rates might be due to the role of N in increasing the leaf area and promoting photosynthesis efficiency, which promotes dry matter production and increased yield. Nitrogen is a constituent of all proteins and is essential for the growth of plants (Johnston et al., 1994). Research conducted on nitrogen application showed a positive effect on the yield component of wheat. A study conducted by Belaynesh et al. (2017) in northern Ethiopian Enderta areas showed that increasing the nitrogen application rate up to 69 kg N ha^{-1} significantly increased wheat grain yields by 159%. Belete et al. (2018) reported that increasing the rate of nitrogen up to 120 kg ha^{-1} resulted in a substantial increase in yield, reaching 220.53%. It suggests a high responsiveness of wheat to nitrogen fertilization

Table 4: Effects of nitrogen and variety on grain and biomass yield of wheat at Lasta and Sekota district.

	Lasta district		Sekota district	
Treatment N (kg ha^{-1})	BY (kg ha^{-1})	GY (kg ha^{-1})	BY (kg ha^{-1})	GY (kg ha^{-1})
0	3751.7^{c}	1190.71^{c}	4166.1^{c}	1663.2^{c}
46	5548.9^{b}	2210.22^{b}	5537.3^{b}	2297.6^{b}
69	7349.3^{a}	2980.25^{a}	5745.5^{b}	2356.4^{ab}
92	7138.8^{a}	2965.75^{a}	6665.7^{a}	2562.1^{a}
LSD (p<0.05)	847.19**	114.55**	659**	215.17*
Variety				
Sekota-1	6119.7	2441.78^{a}	5956.5^{a}	2352.51^{a}
Hibst	5774.7	2231.68^{b}	5100.8^{b}	2087.14^{b}
LSD (p<0.05)	ns	80.99**	465.98**	152.14
CV (%)	24.21	8.51	20.70	16.83

BY=Biomass yield in kilogram per hectare, GY= grain yield in kilogram per hectare

at the specified rate. Bekalu and Arega (2016) found that applying nitrogen at a rate of 69 kg ha^{-1} increased wheat grain yield by 64.80%. This study aligns with the findings of Haile et al. (2012), Bereket et al. (2014), and Tilahun and Temado (2019). These studies collectively reinforce the pattern of higher grain yields in response to increased nitrogen fertilizer application. The consistent positive outcomes across multiple studies confirm the importance of nitrogen application in enhancing wheat yield.

The Sekota-1 variety outperformed the Hibst variety regarding grain yield in both the Lasta and Sekota districts. Specifically, the grain yield of the Sekota-1 variety exceeded that of Hibst by 9.41% in Lasta and 12.71% in Sekota.

The nitrogen fertilizer application rate had a notable effect on the biomass yield of bread wheat in both the Lasta and Sekota districts. The highest biomass yields were obtained from 69 and 92 kg ha^{-1} N application rates in the Lasta and Sekota districts, with 7349.3 kg ha^{-1} and 6662.1 kg ha^{-1}, respectively. The lowest biomass yield was recorded from the control treatment. By applying nitrogen, the total biomass yield increased by 95.89% in Lasta and 59.91% in Sekota, compared to the control treatment. Generally, the results indicate that nitrogen fertilizer application significantly influences the biomass yield of bread wheat, with higher application rates leading to increased biomass production.

Bekalu and Arega (2016) reported that by applying nitrogen at a rate of 69 kg ha^{-1}, the biomass yield increased by 33.6%. This finding aligns with the concept that nitrogen application contributes to

Table 5 Partial budget analysis for Lasta and Sekota district.

Treatment (N kg ha^{-1})	Unadjusted yield (kg ha^{-1})	Adjusted yield (kg ha^{-1})	Gross benefit (ETB)	Costs that vary (ETB)	Net Benefit (ETB)	MMR (%)
Lasta district						
0	1190.71	1071.639	32149.17	0	32149.17	0
46	2210.22	1989.198	59675.94	1556	58119.94	1669
69	2980.25	2682.225	80466.75	2334	78132.75	2572
92	2965.75	2669.175	80075.25	3112	76963.25	D
Sekota district						
0	1663.2	1496.88	41912.64	0	41912.64	0
46	2297.6	2067.84	57899.52	1460	56439.52	994.99
69	2356.4	2120.76	59381.28	2190	57191.28	102.98
92	2562.1	2305.89	64564.92	2920	61644.92	610.08

Note: ETB= Ethiopian Birr, MRR=Marginal Rate of Return in percent, D=dominated treatment increased biomass production in wheat. Belaynesh et al. (2017) reported a substantial increase in biomass yield, noting that an increasing rate of nitrogen up to 69 kg ha^{-1} led to a remarkable 341.84% increase. Similar studies conducted by Hameed et al. (2002), Abebe (2012), and Bereket et al. (2014) support the current study that increasing nitrogen levels contribute to the enhancement of biomass yield in wheat. This evidence supports the understanding that optimizing nitrogen fertilization practices can have a substantial positive effect not only on grain yield but also on the overall biomass of wheat plants.

Partial budget analysis

Based on the partial budget analysis result, the highest net benefit (78132.75 and 61644.92 ETB ha^{-1}) was obtained from 69 and 92 kg N ha^{-1} treatments with a respective MRR of 2572% and 610.08% at Lasta and Sekota districts, respectively. The next highest net benefit (57191.28 with a MRR of 102.98%) was recorded from 69 kg N ha^{-1} at Sekota district. Considering the minimum acceptable rate of return for a treatment to be advisable for farmers (which is between 50 and 100% MRR) CIMMYT, (1988), both the treatments of 69 and 92 kg N ha^{-1} exceed this threshold and are therefore recommended for farmers in Lasta and Sekota areas as the first option, respectively. Additionally, the treatment with 69 kg N ha^{-1} is advised as the second option in Sekota and other areas with similar agro-ecological conditions (Table 5).

CONCLUSIONS

Appropriate fertilization practices are a cornerstone of sustainable agriculture, contributing to soil health, crop resilience, and increased productivity. The study emphasizes the importance of nitrogen application for improving wheat yield and yield components in the study areas. Among the different nitrogen rates tested, 92 kg ha^{-1} and 69 kg ha^{-1} were identified as the most economical and optimum levels of nitrogen fertilizer for wheat production in the Sekota and Lasta districts, respectively. Therefore, 92 and 69 kg ha^{-1} are the appropriate rates for the maximum wheat yield in the Sekota and Lasta districts and are recommended for the areas, respectively.

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REFERENCES

Abebe Getu. 2012. Soil characterization and evaluation of slow-release urea fertilizer rates on yield components and grain yields of wheat and tef on Vertisols of Jamma district of south Wollo ozone.[Thesis], Haramaya University, Haramaya, Ethiopia.

Abedi TA, Alemzadeh and SA Kazemeini. 2011. Wheat yield and grain protein response to nitrogen amount and timing. *Aust J Crop Sci* 5: 330-336.

Alemu D, K Belete and T Shimbir. 2019. Response of Wheat (*Triticum aestivum* L.) to different rates of nitrogen and phosphorus at Fiche-Salale, Highlands of Ethiopia. *Int J Plant Breeding Crop Sci* 6: 474-480.

Amsal T, DG Tanner, A Gorfu, T Geleta and Z Yilma. 1997. Several crop management factors affect bread wheat yields in the Ethiopian Highlands. *Africa Crop Sci J* 5: 161-174.

Asif M, A Ali, ME Safdar, M Maqsood, S Hussain and M Arif. 2009. Growth and yield of wheat as influenced by different levels of irrigation and nitrogen. *Int J Agric Appl Sci* 1: 25-28.

Bell C. 2016. The importance of nitrogen for plant health and productivity. Growcentia: Mammoth.

Belete F, N Dechassa, A Molla and T Tana. 2018. Effect of split application of different N rates on productivity and nitrogen use efficiency of bread wheat (*Triticum aestivum* L.). *Agric food secur* 7: 92. doi: https://doi.org/10.1186/s40066-018-0242-9.

Bekalu A and A Abebe. 2016. Effect of the time and rate of N-fertilizer application on growth and yield of wheat (Triticum aestivum l.) at Gamo-gofa Zone, Southern Ethiopia. *J Nat Sci Res* 6: 111-122.

Bereket H, H Dawit, M Haileselassie and G Gebremeskel. 2014. Effect of mineral nitrogen and phosphorus fertilizers on yield and nutrient utilization of bread wheat on the sandy soils of Hawzen District, Northern Ethiopia. *Agriculture, Forestry and Fisheries* 3: 189-198. doi: 10.11648/j.aff.20140303.18.

Beyenesh Z, N Dechassa and F Abay. 2017. Yield and nutrient use efficiency of bread wheat (Triticum Aestivum L.) as influenced by time and rate of nitrogen application in Enderta, Tigray, Northern Ethiopia. *Open Agriculture* 2: 611-624.

Bouyoucos GJ. 1962. Hydrometer method improved for making particle size analyses of soils 1. *Agronomy J* 54: 464-465.

Bremner JM and CS Mulvaney. 1982. Nitrogen-Total. In: Page AL, RH Miller and DR Keeney (eds). *Methods of soil analysis. Part 2. Chemical and microbiological properties*. American Society of Agronomy, Soil Science Society of America, Madison, Wisconsin, pp. 595-624.

CIMMYT (International Maize and Wheat Improvement Center). 1988. An Economic Training Manual: from agronomic data recordation. Mexico. 79p.

CSA (Central Statistics Agency). 2021. Report on area and production of major crops. Statistical Bulletin 590, Addis Ababa.

Curtis BC. 2002. Wheat in the World. In: BC Curtis, S Rajaram and HG Macpherson (eds). *Bread wheat improvement and production*, *plant production and protection Series* 30, FAO, Roma, pp 1-18.

Martey E, JKM Kuwornu and J Adjebeng-Danquah. 2019. Estimating the effect of mineral fertilizer use on land productivity and income: evidence from Ghana. *Land Use Policy* 85: 463-475.

FAOSTAT (FAO Statistical Databases). 2014. Agricultural production statistics. http://www.fao.org/faostat.

Getachew A, L Minale, M Adamu, F Abraham, B Agdew and G Fite. 2011. Research achievements in soil fertility management about barley in Ethiopia. In: B Mulatu and S Grando (eds). *Barley Research and Development in Ethiopia*. Proceedings of the 2 National Barley Research and Development Review Workshop. HARC, Holetta, Ethiopia. ICARDA, pp 137-153.

Haile D, R Nigussie-Dechassa, W Abdo and F Girma. 2012. Seeding rate and genotype effects on agronomic performance and grain protein content of durum wheat (*Triticum turgidum* l. var. *durum*) in southeastern Ethiopia. *African J Food Agr Nutr Develop* 12: 6080- 6094.

Hameed E, A Wajid, F Shad and B Jahan. Yield and yield components of wheat as affected by different planting dates, seed rate and N levels. *Asian J Plant Sci* 1: 502-506.

Hazelton P and B Murphy. 2007. Interpreting soil test results: What do all the numbers mean?. Csiro Publishing, Collingwood VIC. 151 p.

Hirel B, J Le Gouis, B Ney, and A Gallais. 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. *J Experimental Botany* 58: 2369-2387.

Johnston AE. 1994. The role of nitrogen in crop production and losses of nitrate by leaching from agricultural soil. *Marine Pollution Bulletin* 29: 414-419. doi: https://doi.org/10.1016/0025-326X(94)90664-5.

NASA 2019 and 2020: https://power.larc.nasa.gov/data-access-viewer/ accessed Juanary 12, 2021.

Olsen SR, CV Cole, FS Watanabe and LA Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA Circular* 939: 1-19.

Subedi KD, BL Ma and AG Xue. 2007. Planting date and nitrogen effects on grain yield and protein content of spring wheat. *Crop Science* 47: 36-44.

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 A and T Temado. 2019. Growth, yield component, and yield response of durum wheat (Triticum turgidum L. var. Durum) to blended NPS fertilizer supplemented with N rates at Arsi Negelle, Central Ethiopia. *African J Plant Sci* 13: 9-20.