Response of bread wheat to different rates of nitrogen at Lasta and Sekota districts of Ethiopia

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Abstract

Depletion of soil nutrient is among the major factor that affects crop production and productivity in Ethiopia. From the nutrients, nitrogen is the most yield-limiting which governs bread wheat production. Therefore, the study was conducted to examine the effect of nitrogen on yield and yield components of bread wheat. The experiment was implemented in the 2019

consist 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. The amount of phosphorous was 23 kg ha-1 P2O5 for all treatments. The results of the study indicated that grain and yield-related traits were significantly affected by nitrogen fertilizer. The increasing rate of nitrogen up to 92 and 69 kg ha-1 increases the grain and biomass yield of wheat at Sekota and Lasta districts respectively. The highest grain yield (2562.1 and 2980.25 kg ha-1) was obtained from the application of 92 and 69 kg ha-1 N at Sekota and Lasta respectively. Therefore, the application of 92 and 69 kg ha-1 N is the appropriate rate and recommended for Sekota and Lasta districts respectively.

Keywords: Nitrogen, Variety, Grain yield, Biomass yield

Introduction

Wheat (Triticum aestivum L.) is one of the major global cereal crops; ranking second after paddy rice both in area and production, and provides 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 1 million hectares (ha) (CSA, 2000). Despite this large area coverage, the productivity of this crop is very low because of the high depletion of soil fertility, low levels of chemical fertilizer usage, limited knowledge on time and rate of fertilizer application, and the unavailability of other modern crop management inputs (Asnakew et al., 1991; Amsal et al., 1997). Especially 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 7-fold increase in the use of N fertilizers (Hirel et al., 2007). Nitrogen is the most limiting nutrient for wheat production that affects rapid plant growth and improves grain yield. Many researches showed that nitrogen application increased grain yield and other parameters of wheat (Subedi et al., 2007; Asif et al. 2012; Bereket et al. 2014; Bekalu and Arega 2016; Abrham et al., 2020). Abedi et al. (2011) reported that 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 Belaynesh 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 the grain and biomass yield of wheat. The above mention findings showed that the application of nitrogen fertilizer had a positive impact on the yield and yield component of Wheat. Despite, the positive response of nitrogen fertilizer on bread wheat production there are no research recommendations on nutrient management to enhance the productivity and profitability of wheat production in the study areas. Therefore, the objective of this experiment was to investigate the effect of N rates on yield and yield components of bread wheat and find economically appropriate rates of N fertilizer rates for the study area.

Materials and Methods

Description of the study area

The experiment was conducted for two consecutive years 2019 and 2020 in Sekota and Lasta districts of eastern Amhara Region, Ethiopia (Fig 1). The districts are located in Wag-himra and north Wollo zones of the Amhara regional State. These areas are usually referred as by undulated topography, uneven distribution and erratic rainfall, very shallow soil depth, high soil erosion, scattered forest coverage, and sloppy farming is commonly practicing. The major crops: - sorghum, tef, wheat, barley, maize, fababean, and check pea are grown in these districts. 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. Whereas Tef is the leading crop (31.8% of 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.

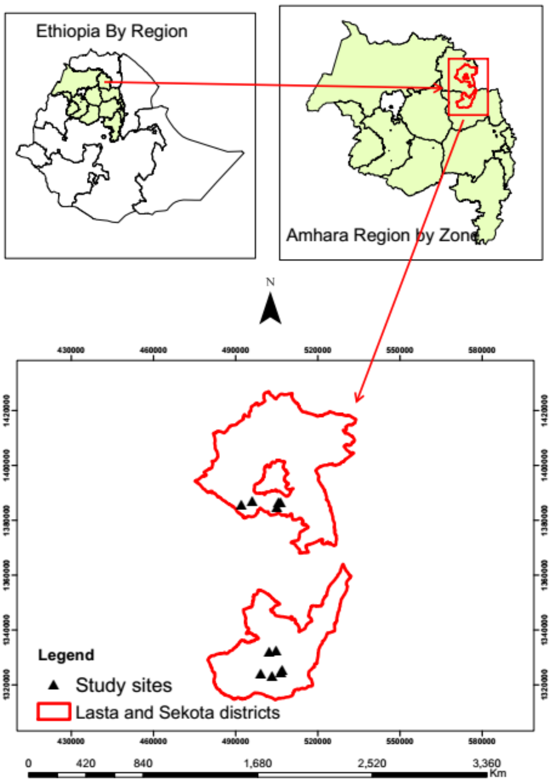
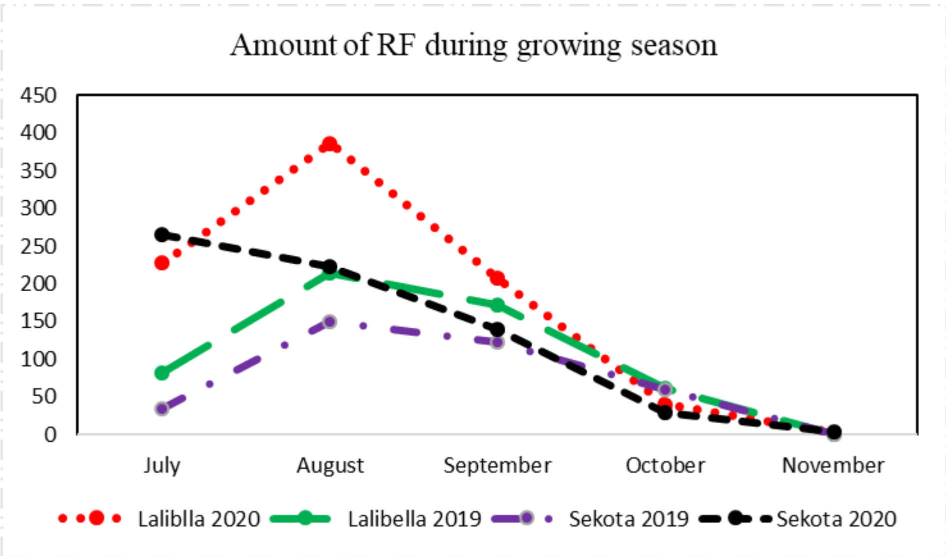
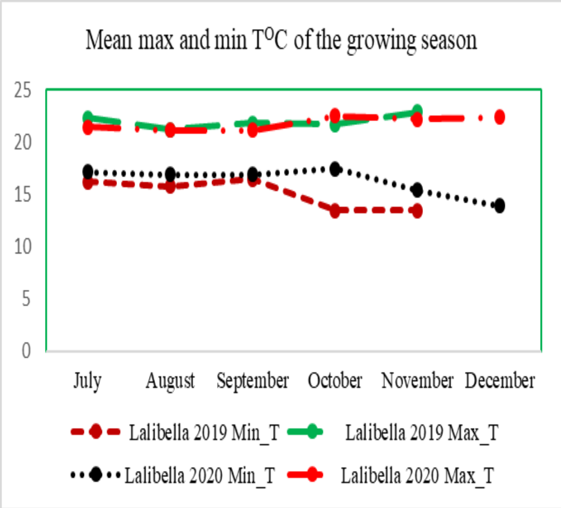


Fig 1: Map of study area

The maximum amount of rainfall during the growing season was 386.84 mm and 265.37 mm in August 2020 at Lalibela and July 2020 at Sekota districts respectively (Fig 2). Relatively the highest rainfall was recorded at Lasta district as compared with Sekota district (Fig 2). Whereas the mean minimum and maximum temperatures of the growing season were 16.01 and 26.51°C, respectively (NASA 2019 and 2020).





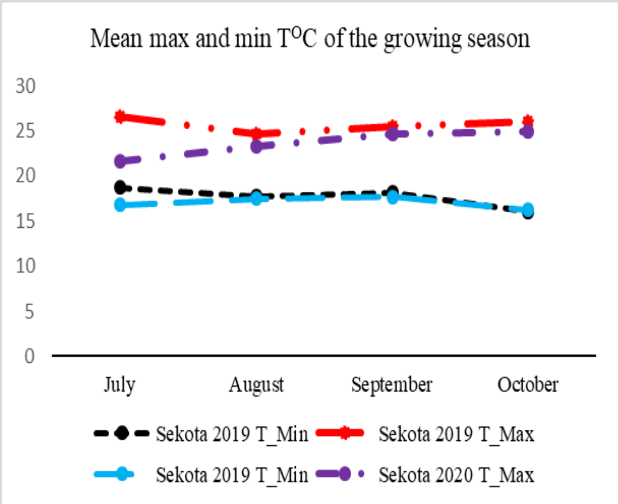


Fig 2: amount of rainfall, max and min temperature of during the growing season at Lasta and Sekota district

Treatment setup

The treatments were four levels of nitrogen 0, 46, 69, and 92 kg ha^{-1} and two varieties of bread wheat (Sekota-1 and Hibst) combined in factorial arrangement with randomized complete block design (RCBD). The amount of phosphorous used for all treatments was 23 kg ha^{-1} P2O5. The plot size was 3X3, and the distance between the plots and blocks (replications) was kept at 0.5 m and 1 m apart, respectively. Fertilizer sources used for the study were N in the form of urea [CO (NH2)2] (46% N) and phosphorus in the form of triple superphosphate (46% P2O5). Row planting with a spacing of 20cm between rows and a 125 kg ha-1 seed rate was used. Land preparation such as ploughing and weeding was carried out as per the recommendation for wheat crop production.

Data Collection

At crop maturity, five plants were randomly selected from the middle rows of each treatment for measuring the plant height, spike length, and seeds per spike. Grain and biomass yield were measured from the central thirteen rows of each experiment.

Prior to planting composite soil samples were collected from surface soil (0 - 20 cm) from the experimental sites for soil physicochemical analysis. Samples were air-dried and ground to pass through a 2-mm sieve to get the fine earth fraction (< 2 mm separates). Particle size distribution (sand, silt, and clay separate) was determined by hydrometer method as outlined by Bouyoucos (1962). Soil pH was determined from the filtered suspension of 1:2.5 soils to water ratio using a glass electrode attached to a digital pH meter (Carter and Gregorich 2008). The organic carbon of the soil was determined following the wet digestion method as described by Walkley and Black (1934). Total nitrogen was determined by the Kjeldahl digestion, distillation, and titration method (Bremner and Mulvaney 1982), and available phosphorus was determined by the standard Olsen method (Olsen et al. 1954). The result of the soil analysis with their respective rating is presented in Table 1.

Table 1: soil analysis result

	Soil parameter								
Experimental sites	pH (1:2.5)	EC/ms	SOC %	Total N%	AvP 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
Rating	Sl acidic to mo alkaline	Non-saline	Low to very low	very low	High				
Source	Tekalign (1991)	Hazelton & Murphy (2007)	Tekalign (1991)	Tekalign (1991)	Olsen 1954	USDA			

Sl=slightly, mo= moderately, SOC soil organic carbon, Avai P=available phosphorous

Partial budget Analysis

The cost of fertilizer (15.56 and 14.6 ETB kg^{-1}) and wheat grain price of 30 ETB kg^{-1} was used for the partial budget analysis for Lasta and Sekota districts. The marginal rate of return was calculated as a change of benefit divided by a change in total cost that varies as described by CIMMYT (1988). The grain yield was adjusted downwards by 10 % of the actual yield to reflect the difference between the experimental yield and the yield of farmers.

Data analysis

Analyses of variances for recorded data were done using SAS software to determine the relationship between yield and yield components due to application of N fertilizer rates and variety. Least significant difference (LSD) test at 5% probability was used for mean separation when the analysis of variance indicated the presence of significant differences.

Results and discussion

Anova for Lasta and Sekota areas

The results of combined analysis over years on the effects of N application, variety and their interactions are presented in (table 2). Nitrogen levels were significantly ($p < 0.01$) affected plant height, spike length, seed per spike, biomass yield, grain yield and thousand seed weight of bread wheat at all location. Furthermore, seed per spike and grain yield were affected by variety at Lasta and Sekota whereas biomass yield and thousand seed weight were significantly affected by varieties at Sekota district only.

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

		Mean Square					
Source of Variation	DF	Lasta district					
		PH cm	SL cm	SP	BY kg ha^{-1}	GY kg ha^{-1}	TSW
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	71	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	71	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

Effects of nitrogen on yield components of bread wheat

Application of nitrogen was significantly affected the growth parameters of bread wheat at Lasta and Sekota districts. The increasing rate of nitrogen up to 92 kg ha^{-1} increases the plant height, spike length and seed per spike of wheat but, statistically similar with the plant height, spike length and seed per spike obtained at N rate of 69 kg N ha^{-1}. The highest plant height (76.6 and 75.12 cm) was obtained from application 92 kg ha^{-1} N and the lowest plant heights (62.41 and 67.30 cm) were recorded from control treatment from Lasta and Sekota districts respectively (Table 3). By applying nitrogen, the plant height was increased by 22.74 and

11.62% as compared with control. This increment with application of nitrogen might be due to the fact that 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 the other nutrients (Bell, 2016). The current result is similar with finding of Bereket *et al.* (2014) who reported that by applying nitrogen up 92 kg ha^{-1} the plant height was increased by 17.44%.

The highest spike length (7.98 and 7.79 cm) and maximum seed per spike (42 and 46) were recorded from application of 92 and 69 kg ha^{-1} N at Lasta and Sekota districts respectively, which were statistically at par with application of both fertilizer rate (69 and 92 N kg ha^{-1}). Spike length and seed per spike were significantly increased with increasing nitrogen rate. Study conducted by Bekalu and Arega (2016) in southern Ethiopia showed that by applying N at rate of 69 kg ha^{-1} gave the highest spike length. Similar results were also reported by Hameed *et al.,* (2002) who said that increasing rate of nitrogen increases the spike length of bread wheat. Seed per spike was significantly affected by variety at Sekota and Lasta district. High number of seed per spike was recorded from Hibst variety and the lowest was recorded from Sekota 1.

Effects of nitrogen on grain and biomass yield of bread wheat

The result showed that application of nitrogen had a significant effect on the grain and biomass yield of bread wheat in the tested districts. The increasing rate of nitrogen increased the grain yield of bread wheat in the two districts ((Table 3&4)). The highest grain yield (2980.25 and 2562.1 kg ha^{-1}) were obtained from the application of 69 and 92 N kg ha^{-1} which was statistically similar with the grain yield obtained at N rates of 92 and 69 kg N ha^{-1} at Lasta and Sekota respectively, whereas the lowest was obtained from the control treatment. By applying 69-92 kg ha^{-1} nitrogen the grain yield was increased by 150.29 and 54.05% as compared to the control at Lasta and Sekota districts respectively.

Table 3: effects of nitrogen and variety on growth and yield of wheat at Lasta district

Treatment	PH cm	SL cm	Seed/spike	BY kg ha^{-1}	GY kg ha^{-1}	TSW g
N kg ha^{-1}						
0	62.41^{c}	5.44^{c}	25.85^{b}	3751.7^{c}	1190.71^{c}	37.61^{b}
46	72.99^{b}	7.29^{b}	40.38^{a}	5548.9^{b}	2210.22^{b}	39.38^{ab}
69	76.21^{a}	7.65^{ab}	41.55^{a}	7349.3^{a}	2980.25^{a}	39.59^{a}
92	76.60^{a}	7.98^{a}	40.40^{a}	7138.8^{a}	2965.75^{a}	39.39^{ab}
LSD	3.18**	0.48**	5.16**	847.19**	114.55**	1.90*
Variety						
Sekota-1	71.76	7.11	34.55^{b}	6119.7	2441.78^{a}	39.34
Hibst	72.34	7.07	39.53^{a}	5774.7	2231.68^{b}	38.65
LSD (5%)	ns	ns	3.65*	ns	80.99**	ns
CV (%)	7.68	11.99	24.21	24.21	8.51	8.48

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

Table 4: effects of nitrogen and variety on growth and yield of wheat at Sekota district

Treatment	PH cm	SL cm	Seed/spike	BY kgha^{-1}	GY kgha^{-1}	TSW g
N kg ha $^{-1}$						
0	67.30^{b}	6.91^{b}	41.49^{b}	4166.1^{c}	1663.2^{c}	34.07
46	73.28^{a}	7.36^{ab}	43.88^{ab}	5537.3^{b}	2297.6^{b}	34.11
69	74.28^{a}	7.68^{a}	46.19^{a}	5745.5^{b}	2356.4^{ab}	34.24
92	75.12^{a}	7.79^{a}	44.45^{a}	6665.7^{a}	2562.1^{a}	34.19
LSD (5%)	2.32**	0.48*	2.91*	659**	215.17*	ns
Variety						
Sekota-1	71.77	7.38	41.42^{b}	5956.5^{a}	2352.51^{a}	33.70^{b}
Hibst	73.21	7.48	46.59^{a}	5100.8^{b}	2087.14^{b}	34.61^{a}
LSD (5%)	ns	ns	2.05*	465.98**	152.14*	0.86*
CV (%)	5.56	11.26	11.49	20.70	16.83	6.23

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

The increase in grain yield of the wheat with increasing N rates might be due to the role of N in increasing the leaf area and promoting photosynthesis efficiency. This again promoted dry matter production and increase yield; which showed N is crucial as a constituent of all proteins and is essential for the growth of plants (Johnston et al., 1994). A study conducted by Belaynesh *et al.*, (2017) in northern Ethiopia (Enderta areas) showed that increasing the rate of nitrogen application up to 69 kg ha^{-1} N significantly increased the grain yields of the wheat by 159 %. Belete *et al.*, (2018) reported that increasing the rate of nitrogen up to 120 kg ha^{-1} increases the yield by 220.53%. Similarly, Bekalu and Arega (2016) reported that the application of nitrogen at a rate of 69 kg ha^{-1} had increased the grain yield of wheat by 64.80%. Concomitant with the results of this study, higher grain yields in response to increased application of nitrogen fertilizer were also reported by (Haile et al 2012, Bereket *et al.,* 2014, Belete *et al.,2018*, Tilahun and Temado 2019).

The rate of N fertilizer application was significantly affected the biomass yield of bread wheat in both districts (Table 3&4). The highest total biomass (7349.3 and 6662.1 kg ha^{-1}) was obtained from application 69 and 92 kg ha^{-1} N at Lasta and Sekota districts whereas the lowest (3751.7 and 4166.1 kg ha^{-1}) was found from the control treatment. By application of nitrogen, the total biomass yield was increased to 95.89 and 59.91%. Similar results were reported by Bekalu and Arega (2016) by applying N at a rate of 69 kg ha^{-1}. These authors reported that the biomass yield was increased by 33.6 %. Belaynesh *et al.,* (2017) also reported that increasing the rate of nitrogen up to 69 kg ha^{-1} increased the biomass yield of wheat by 341.84%. The current study is in line with the findings of Hameed *et al.,* (2002), Abebe (2012), Bereket *et al*., (2014).

Sekota-1 bread wheat variety gave a higher yield than Hibst in both districts. Nitrogen fertilizer significantly affected the grain yield of Sekota 1 wheat variety than Hibst which indicated Sekota 1 bread wheat variety was more responsive to nitrogen fertilizer than Hibst. Thus, the grain yield of this variety Sekota 1 exceeded that of Hibst by 9.41 and 12.71% at Lasta and Sekota districts respectively.

Partial budget analysis

Table 5 partial budget analysis for Lasta and Sekota districts

(N levels)	Unadjusted yield	Adjusted yield	Gross benefit	Costs that vary	Net Benefit	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

For a treatment to be considered as advisable to farmers, between 50 and 100% marginal rate of return (MRR) is the minimum acceptable rate of return (CIMMYT 1988). The partial budget analysis showed that the highest net benefit of 78132.75 Birr ha^{-1} and 61644.92 Birr ha^{-1} with the highest MRR was obtained from the treatment that received 69 and 92 kg N ha^{-1} (Table 5) at Lasta and Sekota districts respectively. The next higher net benefit 57191.28 with MRR % 102.98 was recorded for the treatment with 69 kg N ha^{-1} at Sekota district. Therefore, the application of 69 and 92 N ha^{-1} is profitable and recommended for farmers in Lasta and Sekota areas as the first option respectively and 69 kg N ha^{-1} is the second option at Sekota and other areas with similar agro-ecological conditions.

Conclusion and recommendation

For sustainable crop production, appropriate fertilization application based on actual limiting nutrients is a very important task for farmers to boost the production and productivity of bread wheat. This study shows that the application of nitrogen can improve the yield and yield components of bread wheat in the study areas. Among the rates of nitrogen, 92 and 69 kg ha^{-1} were identified to be the most economical optimum rates of nitrogen fertilizer for bread wheat production at Sekota and Lasta districts. Therefore, 92 and 69 kg ha^{-1} is the appropriate rate for maximum yield of wheat at Sekota and Lasta districts and are recommended for these and similar areas and soil types respectively.

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