



Effects of Nitrogen on Yield and Yield Components of Wheat (*Triticum aestivum* L.) under NPSB Blended Fertilizer in Tsegedie and Welkait Districts Westren Zone Tigray, Ethiopia

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Authors' contributions

This work was carried out in collaboration among all authors. Author NG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TS, HA, NT and WH managed the analyses of the study and the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Decisions concerning optimum rates of fertilization directly involve fitting some type of rates to yield when several rates of fertilizer are tested. This study was carried out to investigate the effects of nitrogen fertilizer rates yields and yield components of bread wheat and determine optimum rate of N. The field experiment was carried out in 2016 and 2017 main cropping season at Tsegedie and Welkait districts in Western Tigray Regional State, Ethiopia. The experiment consists of seven levels of nitrogen (0, 23, 46, 69, 99, 115 and 138 kg ha⁻¹) arranged in randomized completed block design with three replications. Nitrogen was applied splits, half at planting and remaining at tiller stage. NPSB was applied as basal application for all experimental plots except the negative control. Soil samples were collected before planting for analysis of some selected physicochemical properties. The soil properties of the experimental sites of the two districts varied in most of the soil properties. Application of nitrogen significantly influenced grain yield and yield components of

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wheat in both study sites. The highest grain yield 3926 kg ha⁻¹ and 2131 kg ha⁻¹ were obtained from 138 kg N ha⁻¹ and 115 kg N ha⁻¹ at the study sites of Tsegedie and Welkait districts, respectively. Highest marginal rate of returns were however obtained at nitrogen rates of 46 kg ha⁻¹ and 23 kg ha⁻¹ at Tsegedie and Welkait districts, respectively. Hence, it could be concluded that the use of N at 46 kg ha⁻¹ and 23 kg ha⁻¹ with 100 kg NPSB fertilizer could give optimum bread wheat yield at Tsegedie and Welkait districts, respectively.

Keywords: Wheat; nitrogen; yield.

1. INTRODUCTION

Wheat (*Triticum aestivum* L.) is a major crop to the nutrient supply of the global population and also a very versatile crop that shows wide adaptation to diverse agro-ecological conditions and cropping technologies [1]. High quality seed of wheat is the key to successful agriculture [2]. Wheat is a staple of many people's diets, the primary source of calories for over 1.5 billion people. It has been intensively grown throughout the twentieth century and now constitutes over a part of all cereal output [3].

In Ethiopia, low soil fertility is one of the factors limiting the yield of crops, including wheat. It may be caused as a result of removal of surface soil by erosion crop removal of nutrients from the soil, total removal of plant residue from farmland and lack of proper crop rotation, program [4]. Soil nitrogen (N) is frequently deficient in continuous cereal cropping systems, and this is commonly encountered in soils on which crops are cultivated more than once annually [5]. Maintaining soil fertility and use of plant nutrients in sufficient and balanced amounts is one of the key factors in increasing crop yield [6]. Nitrogen is deficient in most agricultural soils and limits crop yield in many region of the world [7]. Nitrogen is the first limiting macro-element on many farms where bread wheat (*Triticum aestivum*) has been grown continuously for more than a decade [8-10]. It is the most important fertilizer element playing vital role in yield improvement of wheat [11]. Increasing wheat production to meet higher demands by growing populations is still a challenge in many countries [12-14]. The most important role of N in the plant is its presence in the structure of protein and nucleic acids, which are the most important building and information substances of every cell. In addition, N is also found in chlorophyll that enables the plant to transfer energy from sunlight by photosynthesis. Thus, N supply to the plant will influence the amount of protein, amino acids, protoplasm and chlorophyll formed. Moreover, it influences the cell size, leaf area and

photosynthetic activity [15-18,6]. Yet nitrogen was reported as the most deficient nutrient in the soil of the study districts of Welkait and Tsegedie [19]. Therefore, current study was conducted to determine the optimum rates of nitrogen for wheat production, promote sustainable intensification of wheat production system in the Western highland of Tigray and providing soil series-specific fertilizer recommendation through soil fertility trials based on newly developed soil fertility Atlas of Tigray region.

2. MATERIALS AND METHODS

This study was conducted at Tsegedie (Tabia Cheguar kudo) and Welkait (Tabia Degen) districts in western Tigray, North Ethiopia. Welkait district is situated at 36°50'29" - 37°20'25"E and 13°48'6.6" - 14°6'41"N with an elevation range of 700- 2353 meters. Agro ecology of the district are Dega, Wena Dega and Kola. The mean annual rain fall varies from 700-1800 mm and with maximum and minimum 25°C and 17.5°C respectively [20]. Tsegedie district is situated at 36°51'0'29" - 37°05'25"E and 13°4'25" - 14°6'55"N with an elevation range of 700- 3000 masl. Agro ecology of the district are Dega, Wena Dega and Kola. The mean annual rain fall varies from 700-1800 mm and with maximum and minimum 25°C and 17.5°C respectively [20].

Field experiments were in order to study the response of wheat to different rates of nitrogen fertilizer under the same level of NPSB blended fertilizer Tsegedie district (Tabia Cheguar kudo) and Welkait district (Tabia degena). Lime was applied to the experimental fields at Tsegedie because soil acidity is a common problem in the district. Field experiments were conducted using Randomized Complete Block Design (RCBD) and treatments were replicated three times. The experiments consisted of seven rates of nitrogen fertilizers (0, 23, 46, 69, 92, 115 and 138 kg ha⁻¹). Nitrogen was applied in split, half at sowing and the remaining applied 3 weeks after sowing. 100 kg NPSB blended fertilizer was applied based on soil fertility Atlas of the districts [19].

The field was prepared well before sowing by ploughing twice with oxen and well leveled for seed bed. Seeds of wheat (*Triticum aestivum* L.) were planted in rows 3 m by 3 m with spacing of 0.2 m between rows. Plots were separated by 1m and blocks by 1.5 m unplanted distances. All agronomic operations were kept normal and uniform for all treatments. The plants were harvested at maturity and traits such as plant height, number of seeds per panicle and number of tillers plant were recorded on 5 randomly selected plants in each plot. Grain yield and biological yield were obtained by harvesting an area of 3 m 2.6 from the middle of each plot, to avoid marginal effects. Data analysis was done using Genstat version 16 computer software packages and comparison of means was investigated using Duncan's Multiple Range Test (DMRT) at 0.05% probability.

3. RESULTS AND DISCUSSION

3.1 Selected Physicochemical Properties of Soils of the Experimental Sites

Soil textural class of both Tsegedie and welkait districts experimental sites was sandy loam (Table 1). According to [21] the preferable pH ranges for most crops and productive soils are from 4 to 8. Thus, the pH of the experimental sites soils was within the range for productive soils. According to [22] rating of soil pH, the pH of soils of Cheguar kudo site in Tsegedie district was strongly acidic and that of Dejena site in Welkait district was neutral. The organic carbon and total N content of both sites was low (Table 1). [23] Reported that soil texture influence the rate of soil organic matter (SOM) decomposition. Soils with high clay content may have higher SOM content, due to slower decomposition of organic matter.

Available phosphorous of soils of Tsegedie site (Cheguar kudo) was low while it was medium for soil of Welkait site (Dejana) According to rating of [24]. According to [25] rating, CEC was medium

for soils of Cheguar kudo site in Tsegedie district and high for soil of Dejena in Welkait district (Table 1).

3.2 Response of Wheat Yield and Yield Components to Nitrogen Fertilizer

3.2.1 Days to maturity

Days to maturity was significantly affected by nitrogen rates. Days to maturity consistently increased with increased nitrogen rates (Table 2). The observed increasing trend in days to maturity could be due to increased rates and the relatively better availability of N from the control plot which could lead to the late maturity of the plant control. The results obtained from this study were in line with results reported by [26] that better availability of N from fertilized plot delayed maturity of wheat crop. The longest days to maturity were recorded for plots received 138 N kg ha⁻¹ and 115 N kg ha⁻¹ and the shortest DTM for plots received zero kg N ha⁻¹. [27] and [28] also reported that increasing N rates delayed days to maturity. The longest days to maturity were higher at Cheguar kudo in Tsegedie compared to that of Dejena site in Welkait. This might be due to higher rainfall of the area. Under normal condition crops may take long days to maturity to exploit the available moisture and nutrients in the soil.

3.2.2 Plant height

Plant height was significantly affected by rates of nitrogen. Plant height increased with increasing rates of nitrogen in the two sites (Table 2). A difference in plant height was only significant between the control and the other treatments. This may be due to the sufficient nitrogen in soil and abundant amount of rain fall. It was higher for plots received 115 kg ha⁻¹N in the two districts and the shortest plant height was recorded on plots that received zero kg ha⁻¹ N. The results obtained was in line with the findings of [29] who

Table 1. Initial soil (0-20 cm) physical and chemical property of the experimental fields Tsegedie and Welkait

District	Textural class	pH-H ₂ O	CEC(Cmol(+) kg ⁻¹ soil	OM (%)	Total – N (%)	Available P (gm kg ⁻¹)
Tsegedie	Sandy Loam	5.2	25.0	0.72	0.040	0.74
Welkait	Sandy Loam	6.6	27.4	0.87	0.041	5.1

Where; pH= power of Hydrogen, OM= Organic Matter, TN= Total Nitrogen, Av.P= Available Phosphorus and CEC= Cation Exchange Capacity

stated that there was no significant difference between wheat plant heights on plots treated with different rates of urea.

3.2.3 Number of tillers per plant

Number of tillers contributes a lot to the total biomass, grain yield and other yield attributes. The analysis of variance showed there was highly significant difference ($P < 0.01$) due to the difference in nitrogen rates. The highest numbers of tillers were recorded for plots treated at 115 kg N ha⁻¹ and 138 kg N ha⁻¹ at Tsegedie and Welkait, respectively (Table 2). The lowest numbers of tillers were recorded for plots received zero nitrogen. This might be due to the role of N in accelerating vegetative growth of plants. The results were in agreement with [30] reported shows increasing in the number of tillers with nitrogen fertilization. [31] also reported that nitrogen fertilization have significant effect on number of tillers of wheat.

3.2.4 Number of seeds per panicle

The analysis of variance showed significant difference ($P < 0.05$) on number of seeds per panicle due to the effects of sources and rates of nitrogen (Table 3). There was an increasing trend in the number of seeds per panicle. The lowest and highest value was recorded at zero nitrogen treatment and 115 kg N ha⁻¹ in both study sites. Similar results have been reported for the influence of urea on yield and yield components including number of seed per panicle of wheat [32].

3.2.5 Grain yield

Grain yield of wheat was significantly influenced ($P < 0.05$) by application of nitrogen fertilizer (Table 3). In both sites, there was inconsistent increment in the amount of grain yield with rates of N. The highest grain yield was recorded from plots treated with 138 kg N ha⁻¹ (3926 kg ha⁻¹)

Table 2. Mean of day to maturity, plant height and number of effective tillers as affected by urea and fertilizer on wheat

Nitrogen levels (kg ha ⁻¹)	Experimental site					
	Tsegedie (Cheguar kudo)			Welkait (Dejena)		
	DM	PH (cm)	NTPP ⁻¹	DM	PH (cm)	NTPP ⁻¹
Control	156.5 ^b	67.43 ^b	1.433 ^d	101 ^c	56.04 ^b	0.98 ^d
23	159.3 ^{ab}	87.63 ^a	1.9 ^c	107.4 ^a	70.31 ^a	2.9 ^b
46	160.7 ^a	74.57 ^{ab}	2.2 ^{bc}	107.4 ^a	70.22 ^a	3.3 ^{ab}
69	160.2 ^{ab}	85.23 ^{ab}	2.7 ^b	106.4 ^{bc}	70.91 ^a	3.4 ^{ab}
92	159.8 ^{ab}	88.53 ^a	2.4 ^{bc}	106.3 ^c	72.33 ^a	3.2 ^{ab}
115	160.5 ^a	92.87 ^a	3.4 ^a	107.2 ^{ab}	74.09 ^a	4.2 ^a
138	160.7 ^a	88.87 ^a	2.8 ^b	107.2 ^{ab}	70.98 ^a	3.4 ^{ab}
CV (%)	0.9	17.5	21.6	0.7	7.3	33
LSD(0.05)	2.36	24.6	0.9	1.2925	8.3	1.7

DM = Day to Maturity, PH= Plant Height; NTPP = Number of tillers per plant. Means with the same letter are not significantly different

Table 3. Mean of number of seeds per spike, biomass yield and grain yield as affected by urea and fertilizer on wheat

Nitrogen levels (kg ha ⁻¹)	Tsegedie (Cheguar kudo)			Welkait (Dejena)		
	NSPP ⁻¹	BY kg ha ⁻¹	GY (kg ha ⁻¹)	NSPP ⁻¹	BY kg ha ⁻¹	GY (kg ha ⁻¹)
Control	33.83 ^c	4722 ^c	1353 ^c	34.9 ^d	1826 ^d	716 ^d
23	36.9	6045 ^{bc}	1938 ^{bc}	44.8 ^c	3739 ^c	1540 ^c
46	40.4	6054 ^{bc}	1847 ^{bc}	45.7 ^{bc}	3662 ^c	1830 ^{abc}
69	38.67	8553 ^{ab}	2863 ^{ab}	46.23 ^{bc}	4351 ^b	1884 ^{ab}
92	42.57	5709 ^{bc}	2786 ^{ab}	49.8 ^{ab}	4673 ^{ab}	1790 ^{bc}
115	44.93	8492 ^a	3432 ^a	53.8 ^a	5278 ^a	2131 ^a
138	40.17	9239 ^a	3926 ^a	51.33 ^a	5188 ^a	2119 ^a
CV (%)	22.3	27.2	25.5	9	14.8	17.6
LSD(0.05)	21.7	3046.4	1081.2	6.9	999.2	499.1

NSPP = number of seeds per panicle, BY= biomass yield and GY = grain yield. Means with the same letter are not significantly different

and 115 kg N ha⁻¹ (2131kg ha⁻¹), whereas the lowest was recorded from plots that received zero kg N ha⁻¹ (1353 kg ha⁻¹ and 716 kg ha⁻¹) at Tsegedie and Welkait sites respectively. [31] Also reported that increasing rate of nitrogen fertilization increased grain yield of wheat. [33] Also reported denitrification rate in wheat crop were observed when N fertilizer was applied and rain was more frequent and intensive. Mean grain yield at Cheguar kudo site in Tsegedie was higher compared with that of Dejena in sites in Welkait. This could be due to differences in wheat variety used, soil fertility status and amount of rainfall received.

3.2.6 Biomass yield

Biomass yield was affected by the rates of N ($p < 0.05$) in both sites (Table 3). At both sites, biomass yield showed that showed increasing trend even though there were some inconsistencies. The lowest biomass yields were obtained from control plots with no nitrogen treatments (4722 kg ha⁻¹ and 1826 kg ha⁻¹) and the highest from plots that received 138 kg N ha⁻¹ and 115 kg N ha⁻¹ (9239 kg ha⁻¹ and 5278 kg ha⁻¹) in Cheguar kudo site in Tsegedie

and Dejena site in Welkait, respectively (Table 3). Similarly, [26] and [31] reported that wheat straw yield increased with N rates.

3.3 Partial Budget Analysis of Nitrogen Rates and Sources

The results of MRR of the two districts are presented in Tables 4 and 5. The highest net revenue was obtained from plots fertilized with N rate of 138 kg N ha⁻¹ at Cheguar kudo in Tsegedie and 115 kg N ha⁻¹ N at Dejena in Welkait. At Cheguar kudo in Tsegedie and Dejena site in Welkait, the highest marginal rate of return was obtained from plots treated with 46 kg N ha⁻¹ (1717.44%) and 23 kg N ha⁻¹ (418.76%) respectively. According to the manual for economic analysis of [34] the recommendation is not necessarily based on the treatment with the highest marginal rate of return compared to that of neither next lowest cost, the treatment with the highest net benefit, and nor the treatment with the highest yield. The identification of a recommendation is based on a change from one treatment to another if the

Table 4. Partial budget N rate and blended (NPSB) on wheat compiled Tsegedie wereda

N (Kg ha ⁻¹)	Fertilizer cost (Birr)	Application cost (Birr)	Total variable cost (Birr)	Grain yield adjusted (10%)	Total revenue* 12	Net revenue [TR-TVC]	MRR (ratio)	MRR (%)
Control	0	0	0	1217.70	14612.40	14612.40		
23	431.25	172.5	603.75	1744.20	20930.40	20326.65	D	D
46	862.5	345	1207.5	1662.30	19947.60	18740.10	17.17	1717.44
69	1293.75	517.5	1811.25	2576.70	30920.40	29109.15	D	D
92	1725	690	2415	2507.40	30088.80	27673.80	10.56	1055.58
115	2156.25	862.5	3018.75	3088.80	37065.60	34046.85	7.84	783.68
138	2587.5	1035	3622.5	3533.4	42400.8	38778.3	10.70	1070.48

Where N = nitrogen; ha= hectare and MRR= Marginal Rate of Return, D= dominated

Table 5. Partial budget N rate and blended (NPSB) on wheat compiled Welkait district

N Kg ha ⁻¹	Fertilizer cost (Birr)	Applicati on cost (Birr)	Total variable cost (Birr)	Grain yield adjusted (10%)	Total revenue* 12	Net revenue	MRR (ratio)	MRR (%)
Control	0	0	0	644.40	7732.80	7732.80		
23	431.25	172.5	603.75	1386.00	16632.00	16028.25	4.1876	418.76
46	862.5	345	1207.5	1647.00	19764.00	18556.50	D	D
69	1293.75	517.5	1811.25	1695.60	20347.20	18535.95	D	D
92	1725	690	2415	1611.00	19332.00	16917.00	D	D
115	2156.25	862.5	3018.75	1917.90	23014.80	19996.05	-1.21	-121.47
138	2587.5	1035	3622.5	1907.1	22885.2	19262.7	3.327	332.7

Where N = nitrogen; ha= hectare and MRR= Marginal Rate of Return, D= dominated

marginal rate of return of that change is greater than the minimum rate of return (100%). According to the marginal rate of return at Cheguar kudo 46 kg N ha⁻¹ and 23 kg N ha⁻¹ at Dejena were found economically profitable compared to other treatments.

4. SUMMARY AND CONCLUSION

Understanding plant nutrients requirement of a given area has vital role in enhancing crop production and productivity on sustainable basis. Excessive use of N fertilizers is economically unfavorable, because incremental increases in yield diminish with increasing amounts of N applied, and it could lead to detrimental effects on the quality of soil and water resources. Therefore, application of nitrogen fertilizer at the right rate is vital for the enhancement of soil fertility and crop productivity. This study was initiated to investigate effects of optimum rate of nitrogen under blended fertilizer (NPSB) for wheat production in Western Tigray, Ethiopia.

A field experiment was conducted on two locations during the 2016 and 2017 main cropping season at Cheguar kudo site in Tsegedie and at Dejena sites in Welkait district of Tigray Regional state, Ethiopia. Highest grain yield and highest profit were obtained from plots treated with 138 kg N ha⁻¹ and 115 kg N ha⁻¹ at Cheguar kudo in Tsegedie and at Dejena in Welkait, respectively. However, the highest marginal rate of return was obtained at 46 kg N ha⁻¹ and 23 kg N ha⁻¹ at Cheguar kudo in Tsegedie and at Dejena in Welkait, respectively. Therefore, N should be used at the rate of 46 kg ha⁻¹, with basal application of 23 kg ha⁻¹ NPSB to boost up bread wheat production and productivity at Tsegedie and Welkait district respectively.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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