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Response of Bread Wheat (*Triticum aestivum* L.) to Application of Slow Releasing Nitrogen Fertilizer in Tigray

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ከተለያዩ የናይትሮጅን ማዳበሪያ ምንጮች ውስጥ ዩርያ አንዱ ሲሆን በቀላሉ የመሟሟት ማለትም ወደ መሬት በመስረግ፣ በትነት መልክ በቀላሉ ከአፈርና ከተክል ስርዓት በመጥፋት በምርት ላይ አሉታዊ ተፅዕኖ ያሳድራል:: ይህን ለመቅረፍ ቀስ እያለ የሚሟሟ ዩርያ ስቴብል(UREA^{Stabil}) የተባለ ማዳበሪያ እና የተለመደው ዩርያ ማዳበሪያ (conventional urea) በስንዴ ምርት ላይ ያላቸውን ተፅዕኖ ለማወቅ በክረምት 2007 ዓ.ም በሓውዜን እና እምባ ኣላጀ ወረዳዎች ሙከራ ተካሂደዋል:: አራት የናይትሮጅን መጠን ከዩርያ ስቴብል 0፣32፣64፣96 ኪሎ ግራም ናይትሮጅን እና 64 ኪሎ ግራም ናይትሮጅን ከተለመደው ዩርያ ለማወዳደርያነት በማካተት በራንደማይዝድ ኮምፕሊት ብሎክ ዲዛይን (RCBD) በሶስት ድግግሞሽ ተፈትሿል:: የቅድመ ተከላ የኣፈር ናሙና እንደሚያመለክተው የናይትሮጅን መጠን በሓውዜን የምርምር ጣቢያ ዝቅተኛ ሲሆን በእምባ ኣላጀ ደግሞ መካከለኛ መጠን ኣለው:: በሓውዜን የምርምር ጣቢያ የተሻለ ምርት የተሰበሰበው 64 ኪሎ ግራም ናይትሮጅን በዩርያ ስቴብል መልክ በመጨመር ሲሆን ይህም መጠን ኢኮኖሚያዊ አዋጭነቱ ከሌሎች ቅንብሮች/ አያያዝ የተሻለ መሆኑ ተረጋግጧል:: በተቃራኒው በእምባ አላጀ ግን 64 ኪሎግራም ናይትሮጅን በተለምዶ ዩርያ መልክ መጨመር የተሻለ ምርት ከማስገኘቱም ባሻገር የኢኮኖሚ ኣዋጭነቱ ተረጋግጧል::

Abstract

Highly soluble N fertilizers like urea may be lost from the soil plant system through leaching, volatilization, and denitrification thereby reduce yields and NUE of arable crops. This study was carried out to investigate the effects of slow nitrogen (N) releasing fertilizer (UREA^{Stabil}) on NUE and yields of bread wheat and determine optimum rate of N application for bread wheat production. A field experiment was carried out in 2015 main cropping season at Hawzien and at Emba Alaje districts in Tigray Regional State, Ethiopia. Cambisols and Vertisols are the two dominant soil types at Hawzien and Emba Alaje districts, respectively. The experiments were arranged in a randomized complete block design with three replications on six farmers' fields. Treatments were four levels of nitrogen fertilizer (0, 32, 64 and 96 kg N ha^{-1}). The nitrogen source was UREA^{Stabil}, which is slow N releasing fertilizer. Conventional urea at recommended rate (64 kg N ha^{-1}) was included as a control at both sites. Soil samples were collected before planting and analyzed for selected physicochemical properties. Pre-planting soil analysis results revealed that total N was low at Suluh site in Hawzien (0.051% to 0.082%) and medium at Ayba and Atsela sites in Emba Alaje (0.157% to 0.211%). Application of 64 kg N ha^{-1} as UREA^{Stabil} and conventional urea resulted in the highest grain yields of 1708.33 kg ha^{1} and 5467.9 kg ha^{-1} from in Hawzien and Emba Alaje districts, respectively. The highest agronomic efficiency of 9.46 kg kg^{-1}and apparent N recovery of 55% were obtained from 64 kg N ha^{-1} as UREA^{Stabil}. However, the maximum physiological efficiency of 60.28 kg kg^{-1} was obtained from the same rate as conventional urea at Suluh site in Hawzien district. The highest agronomic efficiency of 22.2 kg kg^{-1}, physiological efficiency of 87.05 kg kg$^{-1, and}$ apparent N recovery of 59.7% was obtained from 64 kg N ha^{-1} as conventional urea at Atsela and Ayba sites in Emba Alaje district. Both biological and partial budget analysis reveals that the use of N at rate of 64 kg N ha^{-1}as UREA^{Stabil} and 64 kg N ha^{-1} as conventional urea could give optimum bread wheat yield in Hawzien and in Emba Alaje, respectively, and in areas where the rainfall distribution and soil type is similar with study districts where this experiment was conducted. Further study is also required on split application of UREA^{Stabil} at the study sites.

Introduction

Nitrogen (N) is often the most limiting nutrient for crop yield in many regions of the world. Nitrogen fertilizer is one of the main inputs for cereals production systems. The increase of 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).

Availability of nitrogen applied as fertilizer to crop depends not only on the rate but also on the nature of the N fertilizer, soil types, cropping system, management as well as on temperature and precipitation during the growing season (Przulj and Momcilovic, 2001). Highly soluble N fertilizers like urea may be lost from the soil plant system through leaching, ammonia (NH_3) volatilization, denitrification and immobilization or may be fixed on the soil colloids as NH_4-N form (Bock, 1984). The disadvantage of urea fertilizer is that considerable amounts of N can be lost from through volatilization which may result in very low N fertilizer use efficiency (Chen *et al.* 2008), if not incorporated into soil soon after application. The N recovery by crops from the soluble N fertilizers such as urea is often as low as 30–40%, with a potentially high environmental cost associated with N losses via NH_3 volatilization, NO_3^- leaching and N_2O emission to the atmosphere (Zhou *et al.,* 2003).

There are different mechanisms to improve the nitrogen fertilizer use efficiency. Cropping system, soil and water management, use of appropriate N fertilizer, application rate and time are among the main management options to increase N fertilizer use efficiency. In addition, use of slow N releasing fertilizers, nitrification inhibitor, efficient species or genotypes, and control of disease, insects and weeds are also important for improvement of N fertilizer use efficiency (Fageria, 2009).

Slow nitrogen release urea fertilizers can increase nitrogen use efficiency through either slowing the release rate or by altering reactions that lead to losses (Kathrine, 2011). $UREA^{Stabil}$ is one form of slow nitrogen releasing urea. $UREA^{Stabil}$ is urea enriched with the inhibitor of urease NBPT (N-(nbutyl) - thiophosphoric triamide). A new fertilizer was registered in the Czech Republic in 2006. $UREA^{Stabil}$ reduces losses due to volatilization, leaching, and denitrification (Mraz, 2007).

In Hawzien and Emba Alaje Districts application of N as Urea fertilizer and P as DAP at the rate of 100 kg urea and 100 kg DAP ha^{-1} is a recommended to enhance wheat production and productivity. Nevertheless, wheat production and productivity is not as such satisfactory from year to year. At Hawzien district, N losses from applied urea fertilizer might be through volatilization and leaching. At Emba Alaje district, leaching and dinitrification may be the causes for N loss of urea fertilizer due to soil nature which is Vertisols and high rain fall. Therefore, appropriate source of N fertilizer, rate and time of application may improve N fertilizer use efficiency of the crop. However, the effects of slow nitrogen releasing fertilizer ($UREA^{Stabil}$) on yields and nitrogen use efficiency of bread wheat have not been well investigated at Hawzien and Emba Alaje districts. Furthermore, effective rate of application for slow N releasing fertilizer for increasing wheat productivity at both districts has not been established. Therefore, the objectives of this study were to:

- compare effects of $UREA^{Stabil}$ with conventional Urea fertilizer on yield and yield components of bread wheat;
- determine optimum application rate $UREA^{Stabil}$fertilizer for wheat production; and
- investigate the effects of $UREA^{Stabil}$ on nitrogen use efficiency of bread wheat at Suluh site in Hawzien and at Atsela and Ayba sites in Emba Alaje districts.

Materials and Methods

Description of the study areas

The study was conducted in Eastern and Southern Zones of Tigray Region, at Hawzien and Emba Alaje Districts, respectively on six farmers' field in 2015 main cropping season. Hawzien district is located at 78 km away from Mekelle, the capital of the region to east direction and 861 km from Addis Ababa to south direction. Its altitude ranges from 1500 to 2300 masl. Agroecological zone of the district is tepid to cool sub moist mountains plateau (Anonymous, 2000). The experiments were carried out at Suluh Kebele in Hawzien district on three farmers' fields. The geographical location of the experimental fields are 39^0 27' 43.11'' E, and 13^0 59' 37.416'' N, and 2263 masl (Field1), 39^0 27' 21.911'' E, and 13^0 59' 20.299'' N and 2270 masl, (Field 2) and 39^0 27' 33.747'' E and 13^0 59' 11.801''N, and 2273 masl (Field 3). Soils of Hawzien District are one of the most degraded soils in the Tigray Region, which are very low in soil organic matter content and macronutrients such as N, P, and K (EthioSIS, 2014). The dominant soil type in the District is Cambisols (TFEB, 1995). Wheat, groundnut and grass pea are the most common crops cultivated in the District. The area is characterized by bimodal rainfall distribution pattern and in the cropping season receives annual rainfall of 371.9 mm. The average annual maximum and minimum temperatures were 27.6 and 9.83 ^OC, respectively.

Emba Alaje District is located at 100 km and 683 km away from Mekelle and Addis Ababa, respectively. Its altitude ranges from 2300 to 3300 masl. The experiment was conducted on three farmers` fields, one at Atsela Kebele and two at Ayba Kebele in Emba Alaje District. The geographical locations of the experimental fields are 39^0 32' 6.72'' E, and 12^0 55' 39.54'' N, and 2471.928 masl (Field 1), 39^0 32' 45.221'' E and 12^0 52' 45.842'' N, and 2735 masl, (Field 2) and 390

32' 29.305'' E and 12^0 52' 43.722'' N, and 2728 masl (Field 3). Soils of Emba Alaje district are deficient in N, P, K (Ethiosis, 2014). Vertisols are the major soil types found in the district (TFEB, 1995). Wheat, barley, fababean and field pea are the most commonly cultivated crops in the District. The area is characterized by bimodal rainfall pattern, which receives annual rainfall of 960.4 mm. The mean annual maximum and minimum air temperatures were 22.2 and 10.3, respectively.

Experimental design, treatments and procedures

The experimental design was randomized complete block design (RCBD) with three replications. The experiment was conducted in Hawzien district at Suluh Kebele on three farmers' fields and in Emba Alaje District at Atsela Kebele on one farmer field and Ayba Kebele on two farmers` fields. Following the history of preceding production season, farmlands, which were covered with wheat and barley last year, were selected. Plot sizes were 4 m by 3 m. The spacing between plots and blocks were 50 and 100 cm, respectively. The spacing between wheat plant rows was 20 cm. The bread wheat variety used for the experiment was Pica flor (*kakaba*), which is disease resistant, early maturing, and relatively high yielding, at Suluh kebele in Hawzien district. . Hidase variety, which is less susceptible to rust and has high grain yielding potential and disease resistant, was used at Atsela and Ayba in Emba Alaje District.

Treatments were four levels of nitrogen fertilizer (0, 32, 64 and 96 kg N ha^{-1}). The nitrogen source was $UREA^{Stabil}$, which is slow N releasing fertilizer. Treatments were applied at planting. Conventional urea was included with split application of 1/3 of 64 kg N ha^{-1} at planting and the remaining N at tillering stage.

Phosphorus fertilizer was applied at the rate of 20 kg P ha^{-1} in the form of triple super phosphate (TSP). Potassium was applied at the rate of 80 kg K_2O ha^{-1} as () in the form of murite of potash (KCl). Sulfur was applied at the rate of 30 kg S ha^{-1} as $CaSO_4$. Phosphorus, K and S fertilizers were applied at planting as basal to all plots.

Soil analysis

Soil samples collected before planting were subjected to analysis of texture, pH, organic matter, total nitrogen, available P, and cation exchange capacity (CEC), following the standard procedure.

Plant tissue sampling and analysis for nitrogen content

At maturity, five non-boarder wheat plant samples were randomly collected from each plot and partitioned into grain and straw. The straw samples were washed with distilled water to clean the samples from contaminants such as dust. The grain and straw samples were oven dried at 70^0C to constant weight. After drying, the samples were ground and passed through 0.5 mm sieve.

The samples were analyzed for nitrogen concentration following wet digestion method. The nitrogen use efficiencies of wheat such as agronomic efficiency, physiological efficiency and apparent recovery efficiency of N were calculated as describe by Fageria and Baligar (2001).

1) Agronomic Efficiency of Nitrogen:

$$\text{Agronomic N use efficiency } (\text{kg kg}^{-1}) = \left(\frac{\text{Gf} - \text{GU}}{\text{Na}}\right)$$

Where Gf is the grain yield in the fertilized plot (kg); Gu is the grain yield in the unfertilized plot (kg);and Na is the quantity of N applied (kg).

2) Physiological Efficiency of Nitrogen:

$$\text{Physiologcal N use efficiency } (\text{kg kg}^{-1}) = \left(\frac{\text{Yf} - \text{Yu}}{\text{Nf - Nu}}\right)$$

Where Yf is the total biological yield (grain plus straw) of the fertilized plot (kg); Yu is the total biological yield in the unfertilized plot (kg); Nf is the N accumulation in the fertilized plot (kg); and Nu is the N accumulation in the unfertilized plot (kg).

3) Apparent Recovery Efficiency of Nitrogen :

$$\text{Apparent N recovery } (\text{kg kg}^{-1}) = \left(\frac{\text{Nf} - \text{Nu}}{\text{Na}}\right)$$

Where Nf is the N accumulation by the total biological yield (straw plus grain) in the fertilized plot (kg); Nu is the N accumulation by the total biological yield (straw plus grain) in the unfertilized plot (kg); and Na is the quantity of N applied (kg).

Agronomic data

Grain yield (kg ha^{-1}): Grain yield obtained from each plot was used to estimate grain yield in tons per hectare. The grain yield was adjusted to 12.5% moisture content and weighed.

Straw yield (kg ha^{-1}): After threshing and measuring the grain yield, the straw yield was measured by subtracting the grain yield from the total above ground biomass yield.

Seed moisture content was determined using seed moisture tester instrument. Then the grain yield of each treatment was adjusted to the standard moisture level by computing the conversion factor for each treatment to get the adjusted yield using the following formula (Biru, 1979):

$$\textbf{Conversion factor (C.F)} = \frac{100-Y}{100-X}$$

Where Y is actual moisture content and X is the standard moisture content to which the yield is to be adjusted (for cereals the standard moisture content is 12.5%).

Adjusted yield = C.F * Plot yield

Data analysis

The collected data were subjected to analysis of variance (ANOVA) using SAS software program version 9.1.3 (SAS, 2002). Significant difference among treatment means were assessed using the least significant difference (LSD) at 0.05 level of probability (Gomez and Gomez, 1984). Marginal rate of return (MRR) was calculated as the change in net revenue (NR) divided by the change in total variable cost (TVC) of the successive net revenue and total variable cost levels (CIMMYT, 1988). Daily labor costs were calculated by assuming 60 Birr per person per day and revenue was calculated by considering the prevailing market price, which is 9 Birr kg^{-1} of wheat grain yield for Hawzien and 11 ETB for Emba Alaje Districts. The prices of conventional urea (11.2557 Birr kg^{-1}) and$UREA^{Stabil}$ (11.931042 ETB kg^{-1}) were calculated based on Enderta union blended fertilizer factory and the cost of $UREA^{Stabil}$ was 6% more than the cost of conventional urea.

Result and Discussion

Physical properties of soils

Textural classes of Suluh site soils in Hawzien and Atsela site soil in Emba Alaje Districts were sandy loam and clayey, respectively (Table 1). For soils of Ayba site, the textural classes varied from clay loam to clayey. The sand content of soils of Suluh site fields was higher than that of Atsela and Ayba sites, whereas the clay content of soils of Atsela and Ayba site fields was higher than that of Suluh site fields (Table 1). Berhanu (1985) reported that Vertisols in Ethiopia generally contain over 40% clay in their surface horizons. Bereket *et al.* (2014) also reported low clay content for Cambisols of Hawzien district relative to Vertisols. Cambisols are characterized by slight or moderate weathering of parent material and by absence of appreciable quantities of illuviated clayand organic matter, while Vertisols are characterized by high clay content with swelling and shrinking characteristics (FAO, 2014).

Chemical properties of soils

The pH of soils of the experimental sites varied from 6.12 to 6.7 (Table 1). Thus, the pH of the experimental site soils was within the range for productive soils. The organic matter content of soils of Suluh site was low in all fields and in soils of Atsela and Ayba sites in Emba Alaje ranged from low to medium (Table 1). According to Birhanu (1980), total nitrogen content of Suluh site was low in all fields and medium for soils of Atsela and Ayba sites. Relatively higher organic matter and nitrogen contents of soils of Atsela and Ayba sites might be due to the properties of Vertisols of the sites with higher clay contents that could lessen oxidation of organic matter. These findings were in line with Azlan *etal.*(2012) who reported that soil texture influences 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. At Emba Alaje, minimum land degradation, high precipitation, and biomass production may have contributed for higher SOC formation than other sites. Furthermore, farmers at Atsela and Ayba sites have been practicing crop rotation, composting and leaving crop residues after harvesting which are the management options to increase soil organic matter and nitrogen content.

Available soil phosphorous (Olsen P) at Suluh site was low in all fields while it was medium at Atsela and Ayba sites (Cottenie, 1980). Available soil K content was low on field 1and field 2 at Suluh site but it was medium on field 3. In soils of Atsela and Ayba sites in Emba Alaje district available K was low and medium, respectively (Marx *et al.,* 1999). According to Landon (1991), CEC was medium for soils of Suluh site in Hawzien district and high to very high for soils of Atsela and Ayba sites in Emba Alaje district (Table 1). The high CEC in soils of Atsela and Ayba sites in Emba Alaje district may be due to the high content of clay and organic matter.

Table 1. Selected physical and chemical properties of the soils of experimental sites sampled at the depth of 0-20 cm
SL- Sandy Loam, C- Clayey, CL- Clay loam, K- Potassium

Soil Parameters	Experimental Sites					
	Suluh (Hawzien)			Atsela	Ayba (Emba Alaje)	
	Field 1	Field 2	Field 3	Field 1	Field 2	Field 3
Sand (%)	71	65	63	25	27	19
Silt (%)	13	15	19	29	35	25
Clay (%)	16	20	18	46	38	56
Textural Class	SL	SL	SL	C	CL	C
pH(1:2.5 H_2O)	6.2	6.1	6.2	6.7	6.4	6.6
Organic Matter (%)	1.38	0.89	1.18	1.667	2.972	2.61
Total Nitrogen (%)	0.082	0.051	0.073	0.157	0.211	0.204
Available Phosphorous(mg kg^{-1})	5.04	6.34	5.54	9.7	16.74	11.86
Available K (ppm)	122	127	228	144	191	162
Cation Exchange Capacity (cmol (+) kg^{-1})	19.4	21.4	18.8	38	57.4	48.2

Grain Yield

The analysis of variance showed that grain yield of wheat was significantly influenced ($P < 0.01$) by sources and rates of N. At Suluh in Hawzien site the increase in grain yield was not consistent with N rates. The highest grain yield (1708.33kg ha^{-1}) was recorded from with the application of 64 kg N ha^{-1} as UREA^{Stabil} and the lowest (1102.73 kg ha^{-1}) was recorded from the control, i.e. without N application (Table 2). Grain yield obtained from plots treated with 32 kg N ha^{-1} as UREA^{Stabil} was not significantly different from 64 kg N ha^{-1} in the form of conventional urea. This might be due to the slow releasing effect and low volatilization of N when applied as UREA^{Stabil}, which could contribute to the higher grain yield. Khan *et al.* (2013) reported higher grain yield of wheat when N was applied as super urea (urease plus nitrification inhibitor treated urea). Hou *et al.* (2006) also reported that combination of urease and nitrification inhibitors significantly reduced urea hydrolysis and in turn increase the grain yield of wheat.

At Atsela and Ayba sites in Emba Alaje there was increasing trend in grain yield with N application rates. Bereket *et al*. (2014) also reported that increasing rate of nitrogen fertilization increased grain yield of wheat. The highest grain yield was recorded for plots that received 64 kg N ha^{-1} (5467.9kg ha^{-1}) as conventional urea. This might be due to application of UREA^{Stabil} only at planting while N as convectional urea was applied in two splits. Therefore, split application of conventional urea (1/3 at planting and 2/3 at tillering stage) has an advantage to obtain higher grain yield at Atsela and Ayba sites in Emba Alaje District. Kelly *et al.* (2014) reported that split-N applications as urea (Urea+NBPT) generally resulted in greater wheat yields than application of N at planting only. Juan *et al*. (2010) also reported that the highest grain yield of durum wheat was recorded from split application of urea. From this result, it is possible to predict that split application of N as UREA^{Stabil} could result in higher grain yield than conventional urea at Atsela and Ayba sites in Emba Alaje (Table 2). Application of full dose of UREA^{Stabil} at planting may increase the loss, especially due to denitrification and leaching at Emba Alaje District. This was in line with Liliana *et al.* (2014) who reported that denitrification rate in wheat crop was observed when N fertilizer was applied and rain was more frequent and intensive.

Mean grain yield at Suluh site in Hawzien was lower compared with that of Atsela and Ayba sites in Emba Alaje. This could be due to differences in wheat variety used, soil fertility status and amount of rainfall received. The fertility status of soils of Atsela and Ayba sites in Emba Alaje is better than that of Suluh site in Hawzien (Table 1). Amount of rainfall was also higher at Emba Alaje (960.4 mm) than that received in Hawzien (371.9 mm) during the cropping season. As a result, grain yield was not as such satisfactory at Suluh site in Hawzien.

Straw Yield

Straw yield was affected both by sources and rates of N fertilizer ($P < 0.001$) at all sites. At Suluh site in Hawzien, straw yield showed increasing trend even though some inconsistencies were observed. The lowest and highest straw yields were obtained from the control treatment (2259.3 kg ha^{-1}) and from 64 kg N ha^{-1} (3400.0 kg N ha^{-1}) in the form of UREA^{Stabil},respectively. Statistically significant differences were not observed in straw yield between plots treated with the same rates of N as conventional urea and UREA^{Stabil} (Table 2). Marcelo *et al.* (2013) reported that Urea+ NBPT had significant effect on straw yield of wheat. Numerically, straw yield obtained from as the application of UREA^{Stabil} at the rate of 64 kg N ha^{-1} was higher than straw yield obtained from conventional urea with the same rate (). This indicates that UREA^{Stabil} as N fertilizer is superior to conventional urea in improving wheat straw yield at Suluh site.

At Atsela and Ayba sites in Emba Alaje, straw yield showed consistently increasing trend with N rates applied as UREA^{Stabil} (Table 2). The highest and lowest straw yields were recorded from with the addition of 64 kg N ha^{-1} as conventional urea (7810.1 kg ha^{-1}) and from the control, respectively. Abebe (2012) and Bereket *et al.* (2014) reported that wheat straw yield increased with N rates. For the same rates of N Split application of conventional urea at the rate of 64 kg N ha^{-1} resulted in higher straw yield than the straw yield obtained from UREA^{Stabil} with the same rate applied at planting only. This implies the importance of split application of N at Atsela and Ayba sites in Emba Alaje district.

Table 2. Mean grain and straw yields (kg ha^{-1}) of wheat as affected by conventional Urea and UREA^{Stabil} fertilizers.

Nitrogen Levels (kg ha^{-1})	Experimental Sites			
	Suluh (Hawzien)		Atsela and Ayba (Emba Alaje)	
	Grain Yield	Straw yield	Grain yield	Straw Yield
0 N	1102.73d	2259.3c	4043.5c	5906.0d
32N(UREA^{Stabil})	1393.22c	2850.0b	4313.9c	6277.6cd
64N(UREA^{Stabil})	1708.33a	3400.0a	4812.2b	6718.2bc
96N(UREA^{Stabil})	1633.91ab	3127.8ab	4909.1b	7064.0b
64N(Conventional Urea)	1543.19bc	3168.5a	5467.9a	7810.1a
Location (field)	852990**	449129.6*	18704958.56**	77523716.1**
LSD (0.05)	151.89	311.09	486.13	548.13
CV (%)	10.761	10.988	10.797	8.487

Means with the same letter are not significantly different at $p<0.05$.
*,** significant at 1% and 5% probability levels.

Partial Budget Analysis of Nitrogen Rates and Sources

The results of marginal rate of return (MRR) of the two districts are presented in Tables 3 and 4. The highest net revenue was obtained from UREA^{Stabil} applied at the rate of 64 kg N ha^{-1} at Suluh site in Hawzien and 64 kg N ha^{-1} as conventional urea at Ayba and Atsela site in Emba Alaje. At Suluh site in Hawzien and Atsela and Ayba sites in Emba Alaje the highest MRRs of 3838.85% and 1070.529% were obtained from the application of 64 kg N ha^{-1} as UREA^{Stabil} and and (conventional urea, respectively. As indicated in Tables 3 and 4, 96 kg N ha^{-1} at Suluh site in Hawzien and 64 kg N ha^{-1} in the form of UREA^{Stabil} at Ayba and Atsela sites in Emba Alaje district were dominated treatments. The negative marginal rate of returns values obtained at both sites were rejected. According to the manual for economic analysis of CIMMYT (1988) 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 marginal rate of return of the change is greater than the minimum rate of return (100%). Accordingly, at Suluh site in Hawzien and at Ayba and Atsela sites in Emba Alaje 64 kg N ha^{-1} as UREA^{Stabil} and 64 kg N ha^{-1} as conventional urea, respectively were found economically profitable compared to other treatments.

Table 3. Partial budget analysis for wheat at Suluh site in Hawzien District

Nitrogen Levels(kg ha^{-1})	Fertilizer cost (Birr)	Fertilizer application and transport cost [Birr]	Total variable cost (TVC) [Birr]	Grain Yield (kg ha^{-1})	Adjusted Grain yield (10%)down (kg ha^{-1})	Total revenue (TR) [Grain yield*9ETB]	Net revenue [TR-TVC]	Marginal rate of return (ratio)	Marginal rate of return (%)
0 N	0	0	0	1102.73	992.457	8932.113	8932.113	0	0
32N(UREA^{Stabil})	829.98	240	1069.98	1393.22	1253.898	11285.08	10215.1	1.199	119.9
64N(Conventional Urea)	1566	480	2046	1543.19	1388.871	12499.84	10453.84	0.2446	24.46
64N(UREA^{Stabil})	1659.96	420	2079.96	1708.33	1537.497	13837.47	11757.51	38.388	3838.85
96N(UREA^{Stabil})	2489.94	480	2969.94	1633.91	1470.519	13234.67	10264.73	D	D

Table 4. Partial budget analysis for wheat at Atsela and Ayba sites in Emba Alaje

	Nitrogen Levels (kg ha^{-1})	Fertilizer cost (Birr)	Fertilizer application and transport cost [Birr]	Total variable cost (TVC) [Birr]	Grain yield (kg ha^{-1})	Adjusted Grain yield (10%)(kg ha^{-1})	Total revenue (TR) [Grain yield*11]	Net revenue [TR-TVC]	Marginal rate of return (ratio)	Marginal rate of return (%)
	0 N	0	0	0	4043.5	3639.15	40030.65	40030.65	0	0
	32N(UREA^{Stabil})	829.98	240	1069.98	4313.9	3882.51	42707.61	41637.63	1.501	150.187
	64N(Conventional Urea)	1566	480	2046	5467.9	4921.11	54132.21	52086.21	10.705	1070.529
	64N(UREA^{Stabil})	1659.96	420	2079.96	4812.2	4330.98	47640.78	45560.82	D	D
	96N(UREA^{Stabil})	2489.94	480	2969.94	4909.1	4418.19	48600.09	45630.15	D	D

D = Dominated treatment

Nitrogen use efficiency indices

Agronomic and physiological efficiencies

Agronomic efficiency is the amount of additional yield obtained for each additional kg of nutrient applied, whereas physiological efficiency is the biological yield obtained per unit of nutrient uptake (Mengel and Kirkby, 2001; Fageria and Baligar, 2001). Agronomic efficiency showed inconsistent trend at all sites. The highest agronomic efficiency was recorded from the addition of 64 kg N ha^{-1} and the lowest from 96 kg N ha^{-1}, both applied as $UREA^{Stabil}$at Suluh site in Hawzien (Table 5). At Atsela and Ayba sites in Emba Alaje, the highest and lowest agronomic efficiency were obtained at 64 kg N ha^{-1} (22.26 kg kg^{-1}) as conventional urea and 32 kg N ha^{-1} (8.45 kg ka^{-1}) as $UREA^{Stabil,}$ respectively (Table 5). Therefore, application of one kg of N caused increase in grain yield by 22.26 kg from plots treated with 64 kg N ha^{-1} in the form of conventional urea. Even though there were some inconsistent trends, physiological efficiency (PE) decreased with N rates at all sites. The highest PE was recorded from plots fertilized with 64 kg N ha^{-1} as conventional urea at all sites.

The result from Suluh site in Hawzien was nearly in line with the findings of Abebe (2012) and Bereket *et al.* (2014), where AE and PE of wheat decreases with N rates. Craswell and Godwin (1984) asserted that high agronomic efficiency could be obtained if the yield increment per unit N applied is high because of reduced losses and increased N uptake.

Apparent nitrogen recovery efficiency

Apparent nitrogen recovery efficiency is a measure of the ability of the crop to extract N from the soil (Fageria and Baligar, 2001). Both nitrogen fertilizer sources and rates of application influenced apparent nitrogen recovery. There was nearly a decreasing trend with N rates at all sites. The highest N recovery was obtained from 64 kg N ha^{-1} applied as $UREA^{Stabil}$ (55%) at Suluh in Hawzien and from the same rate as conventional urea (59.7%) at Atsela and Ayba in Emba Alaje (Table 5). Thus slow release of N from $UREA^{Stabil}$ increased apparent N recovery of wheat at Suluh site. Marcelo *et al.* (2013) reported that wheat plants fertilized with urea+NBPT had higher apparent nitrogen recovery, total shoot N accumulation, and NUE than plants fertilized only with urea. Zaman *et al.* (2009) and Xu *et al.* (2002) also reported that the use of urease and nitrification inhibitors reduced N losses and increased N use efficiency by various crops.

Table 52. Agronomic, physiological and apparent recovery efficiency as affected by Urea and UREA^{Stabil} fertilizers on wheat at both sites

Levels of N (kg/ha)	Suluh (Hawzien)			Atsela and Ayba (Emba Alaje)		
	AE (kg kg^{-1})	PE (kg kg^{-1})	ARE (%)	AE (kg kg^{-1})	PE (kg kg^{-1})	ARE (%)
0 N	-	-	-	-	-	-
32 N (UREA^{Stabil})	9.08	52.35	53	8.45	42.85	46.8
64 N (UREA^{Stabil})	9.46	49.78	55	12.01	71.27	34.6
96 N (UREA^{Stabil})	5.53	45.14	32	9.02	69.55	30.3
64N (Conventional Urea)	6.88	60.28	35	22.26	87.06	59.7

AE- Agronomic Efficiency, PE- Physiological Efficiency, ARE- Apparent Recovery efficiency

Conclusion

Application of different rates of UREA^{Stabil} and conventional urea significantly affected grain and straw yields of wheat at both sites. At Suluh site in Hawzien the highest grain yield was obtained from with the application of 64 kg N ha^{-1} as UREA^{Stabil} and the lowest was recorded from the control. At Atsela and Ayba sites in Emba Alaje the highest grain yield was obtained from 64 kg N ha^{-1} applied as conventional urea and the lowest was recorded from the control treatment. Both biological and partial budget analysis revealed that the highest grain yield and highest profit were obtained from 64 kg N ha^{-1} applied as conventional urea and 64 kg N ha^{-1} in the form of UREA^{Stabil} at Atsela and Ayba sites in Emba Alaje and at Suluh site in Hawzien, respectively.

Therefore, based on the results of the study and the above summary, it can be recommended that;

- UREA^{Stabil} can be used as N source of fertilizer with basal application of P, K, and S to increase bread wheat production and productivity in Hawzien district.
- Further study should be conducted on split application of slow N releasing fertilizer (UREA^{Stabil}) at Atsela and Ayba sites in Emba Alaje.
- Further study should be conducted on slow releasing nitrogen fertilizer with basal application of micro nutrients specially zinc and degradability of UREA^{Stabil} .

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