Performance of UREA^{stabil} in the Nitisols and Vertisols of North-Western Ethiopia

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Abstract

Nitrogen is a critical yield-limiting plant nutrient for crop production in Ethiopia. The demand for synthetic fertilizer is significantly increasing. Urea is the main source of synthetic nitrogen fertilizer that is mainly applied to the surface resulting in significant nitrogen loss. UREA^{stabil} fertilizer is urea with N-(n-butyl) thiophosphoric triamide (NBPT) that reduces the rate of urea hydrolysis by urease to reduce nitrogen loss and increase crop productivity. The research was conducted in Yilmana Densa district in the Amhara National Regional State of Ethiopia for two years to evaluate the performance of UREA^{stabil} compared to the conventional urea. The research evaluated the effect of UREA^{stabil} fertilizer technology: on two dominant cereal crops: bread wheat (Triticum aestivum) and tef (Eragrostis tef), on two major soils (Nitisol and Vertisol), at different rates and with and without splinting. The finding of this research denies our prior hypothesis that UREA^{stabil} could give better yields of teff and wheat with lower rates of nitrogen at a single application rate compared to the conventional urea. Reducing the amounts of nitrogen by one third using UREA^{stabil} resulted in an intolerable significant yield penalty for all the study sites and both years on wheat. Both the grain and straw yields were increased by splitting the UREA^{stabil,} indicating that the enzyme that hydrolysis urea was merely inhibited. Split application of the maximum UREA^{stabil} rate (130% nitrogen) gave non-significant and equivalent yields with conventional urea of the same rate. Considering a non-significant yield difference between the conventional urea and from UREA^{stabil} for all crops, soils, rates, and forms of applications UREA^{stabil} is not promising. The additional cost that may associate with UREA^{stabil} makes it less preferable to conventional urea. Further research with different rates of NBPT as well as different nitrification inhibitors needs to be evaluated for their efficiency to improve crop yield and reduce nitrogen loss for different crops, different soils, and agro-ecologies.

Keywords: Conventional urea, Grain yield, nBTPT, Urease inhibitor, UREA^{stabil}

Introduction

The agricultural productivity of Ethiopia depends mainly on the amount and distribution of the rainfall as well as on the state of soil fertility. The state of soil fertility has been the major reason for wealth disparities among and between Ethiopian farmers. Synthetic fertilizers have been used to improve the state of soil fertility and to increase crop productivity since the 1970s in the country; and yet with very high potential for further yield gap closings (Dercon and Hill, 2009). Nitrogen is the most yield-limiting nutrient under all soils, landscapes, agro-ecologies, and regions of the region (Tadele et al., 2018). It is also a universal yield-limiting nutrient (Hirel et al., 2007). Synthetic nitrogen fertilizer accounted for about 50% of food increased in the world (Yang et al., 2016). The primary sources for synthetic nitrogen fertilizers in Ethiopia is urea as it has high contents of nitrogen (46%), its low cost, ease of handling, storage, and transport makes urea to be used worldwide for the agricultural production that accounts for about 56% (Mira et al., 2017). However, the recovery of nitrogen from urea is only about 30-40% (Zhou et al. 2003), 30-50% (Abalos et al., 2014), 50% (Janssen et al., 1990), 30-65% (Herrera et al, 2016). According to Zaman et al. (2013), the key nitrogen losses could be summarized as NH_3 volatilization, NO_3^- leaching and N_2O emission.

Integrated soil fertility management, selection of fertilizer sources, identifying and applying at a critical time, improving the reaction of urea fertilizer through various modifications increase the nitrogen fertilizer recovery and efficiency as well as reduce environmental impacts. Among the measures, a split application of urea is reducing the nitrogen losses (Hinton et al., 2015). New technologies that reduce the loss of nitrogen by modifying the conventional urea are getting the attention of researchers and development practitioners. These technologies release nitrogen more slowly than the conventional urea and hence improve the recovery of fertilizers (Trenkel, 2010, Feng et al., 2016). UREA^{stabil} is one of the slow-releasing nitrogen fertilizers and hydrolysis of urea is reduced by the presence of N-(nbutyl) thio-phosphoric-triamide that slows down urease activity of urea hydrolysis thereby improve recovery of nitrogen applied (Abalos et al., 2012; Krajewska, 2009, Watson et al., 2008). This fertilizer technology increased crop productivity (Abalos et al., 2014, Qiao et al., 2015). However, the effect of urease inhibitor (nBTPT) depends on the climate, soil, crop and management (Thapa et al., 2016). Therefore the present research was conducted to evaluate the advantages of UREA^{Stabil} Compared to the conventional urea in increasing the productivity of two major cereal crops: Bread wheat (Triticum aestivum) and Tef (Eragrostis tef) for Nitisols and Vertisols of northwestern Ethiopia.

Materials and methods

Description of the study areas

The research was conducted in Yilmana Densa district of the west Gojjam zone of the Amhara National Regional State of Ethiopia (Figure 1). Yilmana Densa is located at about 42 km from Bahir Dar; the capital city of the Amhara National Regional State on the way to Addis Abeba through Mota.

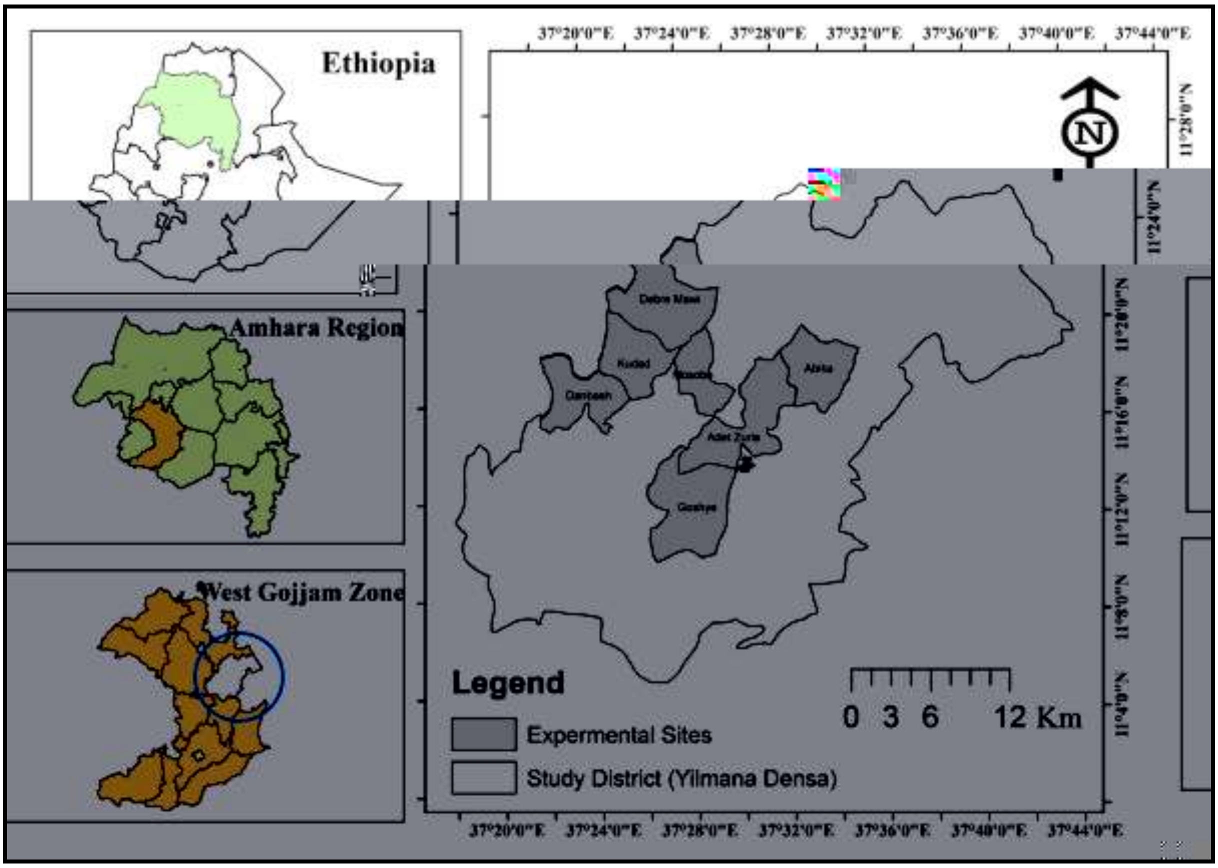

Figure 2. Location of the study

The mid-altitude takes the lion's share of the district. The district receives a uni-modal type of rainfall that begins in May-June and ends in October with an annual average rainfall that ranges from 1100 to 1270 mm and a temperature range of 8.8 to 25.2 ^{O}c (Destaw and Yalemthsehay, 2015). The dominant soils according to the FAO/UNESCO classification system (IUSS Working Group WRB, 2015) the soils of the study sites are Nitisols and Vertisols. The farming system is characterized by a mixed livestock raising and crop production. Tef (Eragrostis tef) and bread wheat (Triticum aestivum) are the leading cereal crops in the study area. Yilmana Densa is one of the highly populated districts of the Amhara National Regional State (CSA, 2007).

Experimental set-up

The experiment was conducted for two consecutive rainy seasons with the treatment setups shown in Table 1. This on-farm research was conducted on multi-locations of Nitisols and Vertisols. The test crops were bread wheat and tef with varieties TAY and kuncho, respectively.

Table 1. Treatment set up

Treatments	Rates of Nitrogen (kg/ha)*		
	Wheat (Nitisols)	Tef (Nitisol)	Tef(Vertisol)
Control (without N)	0	0	0
Recommended N from Urea*	92 (30/62)	40 (13/27)	60 (20/40)
67% of the rec. N from UREA^stabil at planting	61	27	40
Recommended N from UREA^stabil at planting	92	40	60
Recommended N from UREA^stabil*	92 (30/62)	40 (13/27)	60 (20/40)
133% of the rec. N from UREA^stabil at planting	122	53	80
133% of the recommended N from UREA^stabil*	122(41/81)	53 (18/35)	80 (27/53)
133% of the recommended N from UREA*	122(41/81)	53 (18/35)	80 (27/53)

**Numbers in bracket indicated nitrogen rates (Kg/ha) applied as 1/3 at planting and 2/3 at the tillering stage while those rates without brackets indicated that they were not splitted; 46, 60 and 40 P_2O_5 kg/ha were applied as a basal at planting for wheat, Tef (N) and Tef (V); respectively.*

A randomized completed block design (RCBD) with three replications was used. Both crops were planted in rows with seed rates of 125 kg/ha and 10 kg/ha for wheat and tef respectively. Major agronomic data including grain and biomass yields were collected. The grain weight and moisture content of wheat were simultaneously taken and finally adjusted to 12.5% moisture content. Collected data were subjected to the analysis of variance (ANOVA) using SAS software (SAS, 2003). The ratio of yield response was calculated by dividing the yield of treatments to the yield of the recommended nitrogen for each crop.

Soil sampling, preparations, and analysis

Composite soil samples were collected at depth of 0-20 cm before planting for each site. Samples were air-dried, ground and sieved. Soil pH was determined in a 1:2.5 soil to water suspension following the procedure outlined by Sahilemedihn and Taye (2000). Soil organic carbon content was determined by the wet digestion method using the Walkley and Black procedure (Nelson and Sommers, 1982). Total nitrogen was determined using the Kjeldahl method (Bremner and Mulvaney, 1982) while the available phosphorus was determined following the Olsen procedure (Olsen and Sommer, 1982). The exchangeable potassium was measured by flame photometer after extraction of the samples with 1N ammonium acetate at pH-7 following the procedures described by Sahilemedihn and Taye (2000).

Results and discussion

Soil properties of the study sites

The pH of the soil ranged between 4.82 to 5.48 for the Nitisols and 5.01 to 7 for the Vertisols. The soil organic carbon was below the critical level of 2% (Murphy, 2014). It was varying between 1.11 to 1.67% for the Nitisol and 0.57% to 1.35% for Vertisols. The total nitrogen was lower for both soils that ranged from 0.15% to 0.21% for the Nitisol and 0.09 to 0.15% for the Vertisol. The available phosphorus was also in the ranges of 8.24 to 14 mg/kg for the nitisol and 13 to 17 for the vertisol. The exchangeable potassium ranged from 0.83 to 1.31 cmol (+)/kg of soil for the Nitisol and 0.86 to 1.16 cmol (+)/kg of soil for the Vertisol and all of them are above the critical levels of 0.25 cmol (+)/kg of soil (IPI, 2016).

Yield response of crops to UREA^{stabil}

Yields from treatments without nitrogen (control) were significantly ($P < 0.05$) lower than other treatments (Table 2), indicating nitrogen is still the major yield-limiting plant nutrient in the farming system of northwestern Ethiopia as stated by Tadele et al. (2018). Reducing the rate of nitrogen to 67% (61 kg/ha) using UREA^{stabil} without splitting significantly decreased both grain and straw yields for all sites in both years (Table 2) as compared to the recommended rate (92 kg/ha) using conventional urea. The grain yield penalty ranged between 700 and 900 kg/ha (mean 889 kg/ha). The highest straw yield penalty (1514.3kg) was observed for the second year (Table 2). The overall implication of the finding for wheat indicated that UREA^{stabil} was not better than the conventional urea to improve wheat productivity with rates less than the conventional urea. Application of the same rates of nitrogen (92 kg N/ha) from conventional urea and UREA^{stabil} (without split) resulted in insignificant yield differences (Table 2) with better yields from conventional urea. However, the split application of UREA^{stabil} resulted in a better but insignificant yield compared to the same rates of nitrogen with conventional urea (Table 2). Application of recommended nitrogen (92 kg/ha) from UREA^{stabil} with and without split indicated a non-significant yield difference but yield increased (278 kg/ha on average) by splitting than a single dose. The grain yield using 92 kg N/ha from UREA^{stabil} by splitting was only slightly lower than from

122 kg N/ha UREA^{stabil} without splitting (70 kg/ha). However, upon splitting, their difference increased to 374.2 kg/ha. This again justifies the importance of splitting and the weakness of UREA^{stabil} against fast hydrolysis. Increasing recommended nitrogen from UREA^{stabil} up to 122 kg N/ha (130%) gave a higher yield over a single application of the same rate but the equivalent yield was found with conventional urea of the same rate. The response ratio of the grain yield and straw yield clearly showed that the overall implications of using UREA^{stabil} (Figure 2) was not better than the conventional urea.

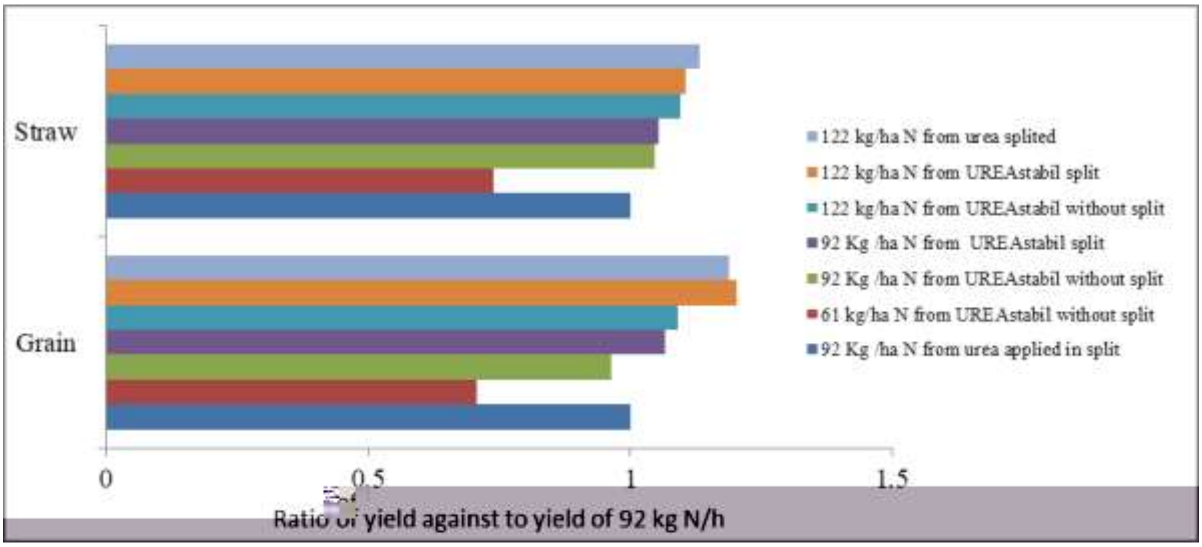

Figure 3. Grain and straw yields response ratios of bread wheat to treatments against the recommended nitrogen (92 kg N/ha with split)

The findings of the research for tef showed lower yields from treatments without nitrogen than other treatments (Table 3 and Table 4). Unlike the yield response of wheat, the yield response of tef to conventional and UREA^{stabil} was irregular (Table 3) and hence difficult to draw conclusions that might be due to a smaller rate used (40 kg N/ha) for the Nitisols that needs future considerations. In 2017 applying 27 kg N/ha (67% of the recommended nitrogen) from UREA^{stabil} on the Nitisol showed a yield reduction; pronounced on the straw yield than the grain yield while in 2018 there were little yield differences among and between treatments that received nitrogen and there was no uniform trend of increase or decrease as a result of UREA^{stabil}. The significant yield difference ($P < 0.05$) was only observed between the control (without nitrogen fertilizer) and other treatments.

The yield response of tef on Vertisol did not support our hypothesis that the rate of nitrogen from UREA^{stabil} could be reduced significantly to bring about equivalent yield to the recommended rate of nitrogen using conventional urea (60 kg N/ha) (Table 4). Both grain and straw yields were reduced when the rate of nitrogen reduced from 60 to 40 kg N/ha (Table 4 and Figure 3).

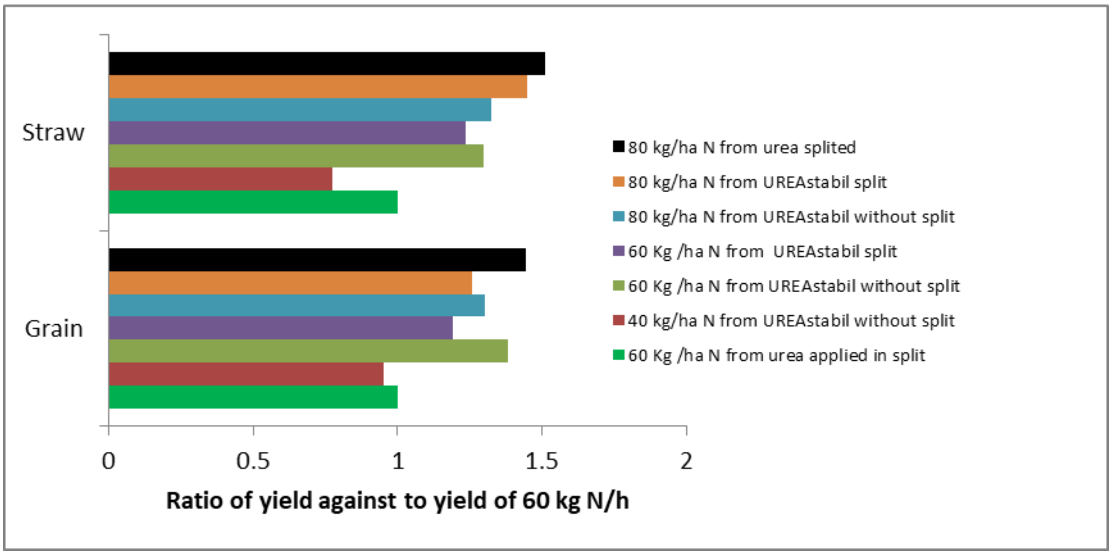

Figure 3. Grain and straw yields response ratios of tef to treatments against the recommended nitrogen (60 kg N/ha with split) in Vertisol

Combined analysis of the grain yield showed that the application of a full dose of UREA^{stabil} at planting (no spilt) surpassed the splitted application with no significant differences (P > 0.05), (Table 4 and Figure 3). The response ratio of the yield compared to the recommended nitrogen from urea (60 kg N/ha) was above one except for 40 kg N/ha (67% recommended N from UREA^{stabil}) indicating that the recommended rate was biological optimum (Figure 3). The grain yield of tef from 60 kg N/ha (1448.9 kg/ha) with a single application from UREA^{stabil} was equivalent to the maximum yield (1512 kg/ha) observed from the application of 80 kg N/ha from conventional urea. Application of 80 kg N/ha from UREA^{stabil} by split or single dose was not better than nitrogen from conventional urea with similar rates. The yield was proportionally increased with increasing rates of nitrogen from conventional urea.

Table 2. Grain yield response of wheat (Kg/ha) for urea and UREA^{stable}

Treatments	Year 1 (2017)				Year 2 (2018)				
	Site 1	site 2	site 3	Mean	Site 1	site 2	site 3	Mean	Combined
Grain Yield (Kg/ha)									
Control (without N)	301.0	1341.0	469.2	703.7	567.0	1037.0	484.0	696.0	699.9
92 kg/ha N from Urea*	2010.9	2927.6	2651.5	2530.0	2730.0	3121.0	2929.0	2926.7	2728.4
61 kg/ha N from UREA^{stabil}	1293.5	2743.6	2159.0	2065.4	1726.0	2614.0	1054.0	1798.0	1931.7
92 kg/ha N from UREA^{stabil}	1824.5	2863.7	3042.9	2577.0	2314.0	3109.0	2638.0	2687.0	2632.0
92 kg/ha N from UREA^{stabil*}	2264.6	2645.7	3334.0	2748.1	2672.0	2788.0	3754.0	3071.3	2909.7
122 kg/ha N from UREA^{stabil}	2274.2	3363.9	2798.9	2812.3	2974.0	3351.0	3115.0	3146.7	2979.5
122 kg/ha N from UREA^{stabil*}	2390.7	3032.3	3331.2	2918.1	3710.0	3643.0	3596.0	3649.7	3283.9
122 kg/ha N from UREA*	2502.2	2949.0	3159.7	2870.3	3691.0	3538.0	3637.0	3622.0	3246.2
LSD (α = 0.05)	308.4	887.07	829.5	564.3	596.2	703.5	574.9	442	375.3
CV (%)	9.6	18.7	18.3	24.9	13.5	14.0	12.5	18.4	23.3
Straw yield (Kg/ha									
Control (without N)	624.9	1668.3	456.8	916.7	943.0	1254.0	1161.0	1119.3	1018.0
92 kg/ha N from Urea*	2803.9	3368.7	2487.4	2886.7	3806.0	3728.0	4871.0	4135.0	3510.9
61 kg/ha N from UREA^{stabil}	1623.2	2719.4	3350.3	2564.3	2493.0	3298.0	2071.0	2620.7	2592.5
92 kg/ha N from UREA^{stabil}	2620.0	2923.3	3438.6	2994.0	3650.0	35310	5890.0	4357.0	3675.5
92 kg/ha N from UREA^{stabil*}	2550.2	2930.5	3078.0	2852.9	3734.0	2915.0	7027.0	4558.7	3705.8
122 kg/ha N from UREA^{stabil}	3049.9	3210.2	3080.7	3113.6	4135.0	3967.0	5635.0	4579.0	3846.3
122 kg/ha N from UREA^{stabil*}	3118.6	2477.0	2965.1	2853.6	5040.0	3965.0	5727.0	4910.7	3882.2
122 kg/ha N from UREA*	3146.0	3023.2	2905.1	3024.8	4434.0	4171.0	6206.0	4937.0	3980.9
LSD (α = 0.05)	1021.1	1134.6	1459.0	701.0	1213.6	830.3	1368.5	1028.4	757.0
CV (%)	24.0	22.9	31.0	27.8	19.9	14.3	16.7	28.3	35.0

** indicates that nitrogen was applied in split*

Hence, the finding of this research is in line with the finding from a one-year experiment in the Northern parts of Ethiopia (Sofanyas et al. 2018). They reported a yield advantage of 655.7 kg/ha (13.62%) grain wheat using 64 kg N/ha from conventional urea over the same rate of nitrogen from UREA^{stabil}. They made further research recommendations on the split application of UREA^{stabil}. The finding of our research did not support our key interest to avoid split nitrogen application and reduce associated costs using UREA^{stabil} than using the conventional urea. This finding is not in line with the findings of authors (Hinton et al., 2015; Huérfano, 2015, Thapa, et al., 2016, Trenkel, 2010). The additional cost of UREA^{stabil} over the convention urea ranges from 6% (Sofanyas et al., 2018) and 20% (Růžek et al., 2014). Zaman et al., (2013) also indicated that for 25 kg N/ha, the cost of recommended nBTPT is 3.2 US dollars/ha, higher than the cost of urea per hectare for their study area. Accordingly, our finding unjustified the use of UREA^{stabil} for the soils and crop types covered by the research. A similar finding was reported for potato (Drapal et al., 2013) where the conventional urea at a rate of 90 kg N/ gave a yield advantage of 10.2% tuber yield than UREA^{stabil} with the same rate of nitrogen. Rose et al., (2018b) also did not get any evidence of nitrogen recovery and yield advantage from enhanced fertilizers including urease inhibitors on rice. The overall yield advantage of UREA^{stabil} observed from the study opposed to other findings (Abalos et al., 2014, Qiao et al., 2015, Rose et al., 2018a, Thapa et al., 2016, Zaman et al., 2013). Zaman et al., (2013) found a 16.1% yield advantage using urease inhibitor (nBTPT) over the conventional urea with the same rates of nitrogen (30 kg N/ha). Moreover, many authors proved that the recovery of nitrogen improved using nitrification inhibitors and urease inhibitors (nBTPT (Abalos et al., 2012, Abalos et al., 2014, Krajewska, 2009, Drapal, et al., 2013, Ni et al., 2014, Rose et al., 2018, Růžek et al., 2014, Tapha et al., 2016, Watson et al., 2008). The poor performance of UREA^{stabil} to our finding could be related to the quantity of urease inhibitor (nBTPT), and the efficiency of nBTPT depends on factors including soil properties (McGeough et al., 2016, Watson et al., 2008, Watson et al., 1994), temperature (Abalos et al., 2017, Abalos et al., 2014, Watson et al., 2008), rainfall (Abalos et al., 2017) and management (Abalos et al., 2014). In Brazil, Mira et al., (2017) found reduced loss of nitrogen from urea in the ammonia using urease inhibitor nBTPT up to 1000 mg /kg urea. According to the authors, rates of nBTPT in Brazil were based on the findings in the temperate region (240 to 500 nBTPT mg/kg urea) that necessarily could not reflect the tropical regions. With a similar argument and finding of Mira et al., improving the efficiency of UREA^{stabil} by increasing the rate of nBTPT should be considered in the farming system of Ethiopia.

Table 3. Yield response of tef (Kg/ha) for urea and UREA^{stabil} in Nitisol

Treatments	Year 1 (2017)			Year 2 (2018)			Combined
	Site 1	site 2	Mean	Site 1	site 2	Mean	
Grain Yield (Kg/ha)							
Control (without N)	450.8	238.0	344.4	324.7	142.7	233.7	289.1
40 kg/ha N from Urea*	1079.2	823.0	951.1	834.4	1065.6	950.0	950.6
27 kg/ha N from UREA^{stabil}	918.8	813.0	865.9	1048.7	1083.2	1066.0	966.0
40 kg/ha N from UREA^{stabil}	1115.1	1016.0	1065.6	1103.1	1054.7	1078.9	1072.3
53 kg/ha N from UREA^{stabil*}	1076.0	795.0	935.5	1063.8	898.0	980.9	958.2
53 kg/ha N from UREA^{stabil}	1161.5	601.0	881.3	661.5	1105.5	883.5	882.4
53 kg/ha N from UREA^{stabil*}	1198.4	874.0	1036.2	800.8	1105.5	953.2	994.7
53 kg/ha N from UREA*	1045.3	1216.0	1130.7	930.5	971.1	950.8	1040.8
LSD (α = 0.05)	215.1	425.5	273.9	507.4	755.3	640.0	593.1
CV (%)	12.4	30.8	26.0	34.7	16.5	28.1	26.5
Straw yield (Kg/ha)							
Control (without N)	1424.2	804.0	1114.1	1498.2	247.9	873.1	993.6
40 kg/ha N from Urea*	3504.2	2511.0	3007.6	3879.2	3778.1	3828.7	3418.2
27 kg/ha N from UREA^{stabil}	2675.0	2260.0	2467.5	4185.7	4034.0	4109.9	3288.7
40 kg/ha N from UREA^{stabil}	3468.2	3229.0	3348.6	4313.5	4518.2	4415.9	3882.3
53 kg/ha N from UREA^{stabil*}	3924.0	2278.0	3101.0	4144.5	3008.2	3576.4	3338.7
53 kg/ha N from UREA^{stabil}	4151.0	2108.0	3129.5	2880.2	4519.5	3699.9	3414.7
53 kg/ha N from UREA^{stabil*}	4374.5	3136.0	3755.3	3313.8	4285.2	3799.5	3777.4
53 kg/ha N from UREA*	4267.2	3368.0	3817.6	3835.2	4367.4	4101.3	3959.5
LSD (α = 0.05)	852.7	924.2	916.7	2375.4	1359.2	2817.0	2227.3
CV (%)	14.18	21.7	26.5	39.1	16.6	30.9	30.7

** Indicates that nitrogen was applied in split*

Table 4. Yield response of tef (Kg/ha) for urea and UREA^{stable} in Vertisol

Treatments	Grain Yield (Kg/ha) Year 1 (2017) Site 1	Year 2 (2018) Site 1	Year 2 (2018) Site 2	Year 2 (2018) Mean	Combined
Control (without N)	629.2	301.9	310.0	306.0	413.7
60 kg/ha N from Urea*	1367.7	859.4	914.8	887.1	1047.3
40 kg/ha N from UREA^{stabil}	1171.1	1009.0	810.2	909.6	996.8
60 kg/ha N from UREA^{stabil}	2259.1	981.3	1106.5	1043.9	1448.9
60 kg/ha N from UREA^{stabil*}	1876.3	897.5	915.6	906.6	1249.1
80 kg/ha N from UREA^{stabil}	1598.7	1150.2	1343.5	1246.9	1364.1
80 kg/ha N from UREA^{stabil*}	1643.0	1112.5	1191.5	1152.0	1315.6
80 kg/ha N from UREA*	2152.0	1152.1	1233.8	1193.0	1512.6
LSD (α = 0.05)	895.0	385.5	346.6	233.4	440.1
CV (%)	32.5	23.6	20.5	20.9	40.0
Straw yield(kg/ha)					
Control (without N)	1922.9	1031.5	481.7	756.6	1145.3
60 kg/ha N from Urea*	3059.4	3099.0	1647.7	2373.4	2602.0
40 kg/ha N from UREA^{stabil}	2631.0	2053.5	1377.3	1715.4	2020.6
60 kg/ha N from UREA^{stabil}	4668.0	3393.8	2060.2	2727.0	3374.0
60 kg/ha N from UREA^{stabil*}	4373.7	3394.2	1584.4	2489.3	3215.6
80 kg/ha N from UREA^{stabil}	3713.8	4120.6	2510.6	3315.6	3448.4
80 kg/ha N from UREA^{stabil*}	4440.3	4429.2	2454.4	3441.8	3774.6
80 kg/ha N from UREA*	4657.0	4618.8	2516.3	3567.6	3930.7
LSD (α = 0.05)	1726.0	802.8	536.9	1090.9	1015.8
CV (%)	27.1	14.0	17.0	36.4	36.7

** indicates that nitrogen was applied in split*

Conclusion and recommendation

A two-year field experiment was carried in the northwestern parts of Ethiopia for wheat and tef under Nitisols and Vertisols to evaluate the performance of UREA^stabil compared to the conventional urea. The findings of this research denies our prior hypothesis that UREA^stabi could give better yields of tef and wheat at low rates of nitrogen with single applications compared to the conventional urea. Under both soils and for both crops, the application of UREA^stabil did not show a significant yield advantage over the conventional urea. Split application of UREA^stabil showed better yields over a single application. Therefore, there was no evidence in our research that supports the advantage of UREA^stabil over the conventional urea. Nevertheless, N-(n-butyl) is a proven technology to inhibit the activity of urease and hence reduce the loss of nitrogen. However, the rate of the inhibitor under different environments including Ethiopia needs further considerations of research. Moreover, further research on quantifying the nitrogen losses, grain and straw qualities (protein content) and nitrogen recovery using urease inhibitors, nitrification inhibitors and controlled releasing fertilizers should be targeted.

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