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Research Article

# Evaluation of NUE and Rice (*Oryza sativa* L.) Performance Through Application of Urea Stable Fertilizer in Ethiopia

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## Abstract

An experiment based on randomized complete block design was conducted at Fogera and Libokemkem districts from 2017-2019 growing season. Nitrogen is the most yield liming nutrient that can be highly soluble and lost through leaching, volatilization and denitrification. The experiment was conducted to determine the effects of urea stable and convectional urea on rice performance and productivity. The experiment was laid out in randomized complete block design with three replications. The treatments were different rate of urea stable and convectional urea applied at planting and in split: (Control, 69 kg N ha$^{-1}$ from urea stable applied once at planting, 69 kg N ha$^{-1}$ from urea stable in split application, 34.5 kg N ha$^{-1}$ from urea stable in split application and 34.5 kg N ha$^{-1}$ from urea stable in once applied, 103.5 kg N ha$^{-1}$ from urea stable applied once at planting, 103.5 kg N ha$^{-1}$ from urea in split application, 69 kg N ha$^{-1}$ from conventional urea in split application, 103.5 kg N ha$^{-1}$ from conventional urea in split application). The applications of urea stable and conventional urea were significantly improved growth yield and yield components of rice as compared to control. Mean grain yield and biomass yield of rice was significantly affected by nitrogen rate and increased with increasing of nitrogen rate applied from urea stable and conventional urea. Moreover, the highest grain and biomass yield 4.8 t and 10.6 t was recorded from application of the recommended N in urea stable form once at planting in fogera district. Whereas the minimum grain (1.9 t/ha) and biomass yield (4.7 t/ha) was recorded from the negative control. At Libokemkem district the highest grain and biomass yield 3.9 tones and 9.3 t/ha was recorded respectively. But statistically similar from application of 103.5 kg N ha$^{-1}$ applied in split in the form of conventional urea (+ve control). Therefore, there was no evidence in our research that supports the advantage of urea stable over the conventional urea. Hence it is concluded that the application N fertilizers sources from both of urea and urea-stable are equal result obtained in improving of rice productivity and nitrogen use efficiency.

## Keywords

Nitrogen Use Efficiency, Urea Stable, Rice, Conventional Urea

## 1. Introduction

Rice has become a commodity of strategic significance and rapidly growing source of food across many African countries [8]. The total milled rice grain production in sub-Saharan Africa increased from 2 million tons in 1961 to 16 million tons in 2009. About 80% of rice in Africa is produced by small–scale farmers for their own utilization

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and local market [8].

Rice was introduced to Ethiopia in the 1970s and has been cultivated in small pockets of the country [12]. Even though rice is not a traditional staple food in Ethiopia but its feeding system is rapidly adopted by the farmers and preparing different recipes from rice. Currently, Ethiopia is fast emerging as one of the rice-producing countries in sub-Saharan Africa [13]. Gambella, Pawe, Fogera, Metema and Oromia Zone in eastern Amhara National Regional State are suitable for rice production [20]. Out of the total national production of rice in 2008, 40% is produced in the Amhara regional state, 1.14% in Tigray region, 0.41% in Benshangul-Gumz, 7.23 % in Oromia, 1.55 % in Gambella, 13.33% in Somalia, and 27.18% Southern region [13]. The national average productivity of rice in Ethiopia is still however too low about 2.8t $ha^{-1}$ [3].

Grain yield of cereals in the highlands of northern Ethiopia is low mainly due to the low content of essential nutrients. Fertilizer application has commonly done by blanket recommendation of fertilizer rates without soil test and tissue analysis for a specific site. Use of fertilizers in Ethiopia is dominantly based on nitrogen (N) and phosphorus (P). The attention given to other essential nutrients such as sulfur (S) and others is practically none [7].

The value of these inhibitors in mitigating N losses in grazed pasture will depend on their rate of biodegradation persistence in soils [18]. Nitrogen use efficiency of crops include improved cropping system, soil and water management, use of appropriate N fertilizer and application rate. In addition, use of slow N releasing fertilizers, urease inhibitor, nitrification inhibitor, efficient species or genotypes, and disease, insects and weeds control are important to improve the N fertilizer use efficiency of crops [6]. The combination the two however offers the best overall option for both reducing the N losses as well as increasing pasture production and N uptake [19]. However, most of the management such as slow N releasing fertilizers, urease inhibitor and nitrification inhibitors are not being practiced in Ethiopia. For instance, slow nitrogen release urea fertilizers can increase nitrogen use efficiency through either slowing the release or by altering reactions that lead to losses [10]. $UREA^{stabil}$ is one form of slow nitrogen releasing urea.

Nitrogen fertilizer is a determining factor for rice growth and plays a vital role in maintaining rice yield. Leaching, runoff and volatilization are the major N loss pathways in rice growing areas. The use of controlled release fertilizer (CRF) has become common to lessen fertilizer consumption, increase nitrogen use efficiency, and minimize environmental pollution [8]. Conventional fertilization requires frequent applications, whereas a CRF needs only a single application and is thus more labor and time saving. One of the CRFs is UREA stable (US) fertilizer. It is based on urea (46%) with an added urease inhibitor N-(*n-butyl*)-*thiophosphoric triamid* (NBPT). A critical overview is provided on howunderstanding of the physiological and molecular controls of N assimilation under varying environmental conditions in crops has been improved through the use of combined approaches, mainly based on whole-plant physiology, quantitative genetics, and forward and reverse genetics approaches [9]. It helps to reduce losses due to ammonia volatilization during surface application and nitrate leaching. Despite its advantages, this product has not been tested for rice in Ethiopia. Thus, this research was conducted with the objectives of evaluating the nitrogen use efficiencies of rice and its response to US fertilizer. and determining optimum rate of urea stable nitrogen fertilizer for upland rice.

Availability of nitrogen applied as fertilizer to a crop depends not only on the rate but also on the nature of the N fertilizer, soil types and conditions, cropping system, management as well as on temperature and precipitation during the growing season [14].Highly soluble N fertilizers, like urea may be lost from the soil plant system through leaching, $NH_3$ volatilization, denitrification and immobilization or may be fixed on the soil colloids as $NH_4$-N form [1]. Urea has a major disadvantage in that considerable amounts of N can be lost through volatilization which might be resulted in very low N fertilizer use efficiency [2]. 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 [21].

*Objectives*

1. To evaluate the urea stable nitrogen, use efficiencies of rice and its response to urea stable fertilizer and
2. To determine optimum rate of urea stable nitrogen fertilizer for upland rice

## 2. Materials and Methods

The experiment was conducted on farmers' fields for three consecutive years from 2017-2019 in Fogera and Libokemkem districts of Amhara Region. Nine treatments were evaluated and laid out in a randomized complete block design with three replications. Based on EthioSIS soil fertility map, other nutrients such as 5 kg Zn $ha^{-1}$, 2 kg B $ha^{-1}$, 60 kg $K_2O$ $ha^{-1}$ were uniformly applied to all plots at basal. Conventional urea (CU) and urea stable (US) fertilizers were used as a source of N fertilizer, while triple super-phosphate (TSP) was used as a source of P. The recommended P fertilizer (23 kg $P_2O_5$ $ha^{-1}$) was band applied at basal, while N was applied following the different application periods as specified in each treatment (Table 1). The split application of N was made at planting and at tillering. The recommended N used in the study was 69 kg N $ha^{-1}$. Improved upland rice crop variety *NERICA-4* was direct sown in a row with 20 cm spacing and seed rate of 100 kg $ha^{-1}$. The other crop management practices were done as per the recommendations. Analysis of variance (ANOVA) was performed using SAS version statistical software programs [16].

*Description of the Study Area*

*Location*

The experiment was conducted on vertisol of Fogeraand libokemkem districts, South Gondor, Amhara. The experimental site was geographically located with altitude ranges from 1,774 up to 2,410 meter above sea level.

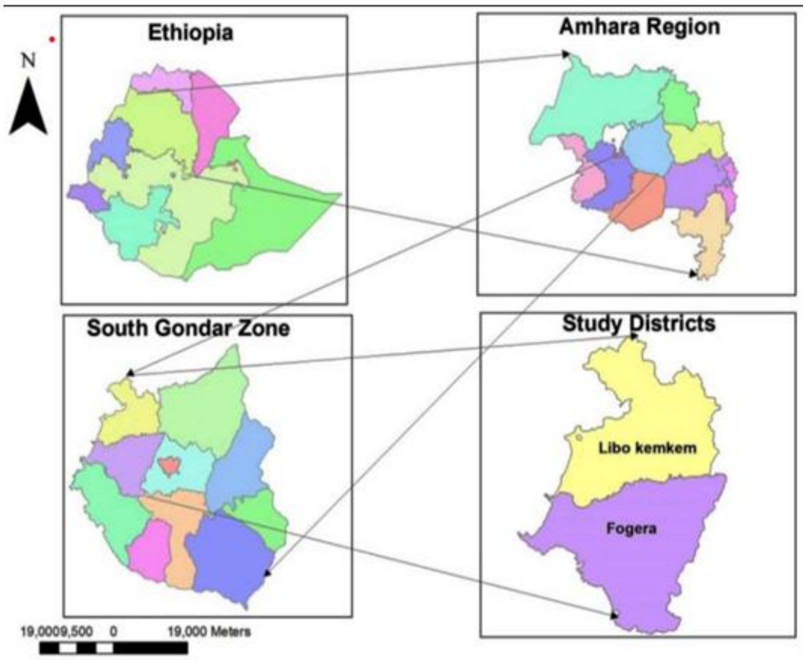


***Figure 1**. Location map of the study areas.*

***Table 1**. Treatment set-up.*

| No | Treatment | N rate (kg ha$^{-1}$) |
|---|---|---|
| 1 | Zero N | 0 |
| 2 | 100% Rec. N (CU) applied in split (100% CU split) | 69.0 |
| 3 | 150% Rec. N (CU) applied in split (150% CU split) | 103.5 |
| 4 | 50% Rec. N (US) applied once (50% US once) | 34.5 |
| 5 | 100% Rec. N (US) applied once (100% US once) | 69.0 |
| 6 | 150% Rec. N (US) applied once (150% US once) | 103.5 |
| 7 | 50% Rec. N (US) applied in split (50% US split) | 34.5 |
| 8 | 100% Rec. N (US) applied in split (100% US split) | 69.0 |
| 9 | 150% Rec. N (US) applied in split (150% US split) | 103.5 |

# 3. Results and Discussion

## 3.1. Plant Height

The analysis of variance showed that plant height was affected significantly ($p < 0.001$) by the main effects of urea stable and conventional urea fertilizer rates. The mean plant height of rice was showed increasing trend with increasing rate of nitrogen applied (Table 3). This indicated the positive effect of N on vigorous vegetative growth and inters- nodal extension due to more availability of N throughout the growing period. Rice plant height was ranged from 55 to 74 cm whereas the lower and higher value of the plant height rice was recorded from control and application of 103.5 kg N ha-$^{1}$ from conventional and urea stable applied at split. This indicates similar effects of nitrogen from urea stable and normal urea on plant height of rice. In line with this, [17] reported that the mean plant height was showed increasing trend with increasing rate of nitrogen applied. [11] Also recorded statistically similar plant height from plot received N from conventional urea and urea with inhibitors. Nitrogen use efficiency in crop plants is the ratio of output (yield) to the applied input (fertilizers) for a processor complex system or the ability of the crop to convert inputs into outputs and has a significant positive association with grain yield in crops [4].

## 3.2. Effect on the Yield of Rice

At Fogera and Libokemkem in the Northern part of Ethiopia, treatment effects were significant for grain yield of rice over three cropping seasons. At Fogera, application of 150% N $ha^{-1}$ (103.5 kg/N ha) from $UREA^{stabil}$ at planting resulted in significantly the highest rice yield of 4.8 t per $ha^{-1}$. In contrast, at Burah the maximum grain yield of 3.9 and 3.8 t/ha was recorded from 150% of the recommended N (103.5 kg/N ha) in both US and CU kg $ha^{-1}$ consecutively. As mentioned earlier, in areas where soil moisture deficit is a limiting factor urea stable could be preferable in terms of yield.

The result showed that there was significant ($p<0.05$) difference among treatments in plant height, grain and dry biomass yields (Tables 2 and 3). At Fogera district (Quhar Micheal testing site), application of 150% (103.5 kg/N ha) of the recommended N in US once at planting gave the highest grain (4.8 t $ha^{-1}$) and biomass yields (10.6 t $ha^{-1}$) (Table 2). However, at Libo kemkem district (Burah testing site), the highest grain and dry biomass yields were obtained from split-application of 150% (103.5 kg/N ha) of the recommended N in both US and CU with very narrow and insignificant difference between the two (Table 3).

## 3.3. Biomass Yield

The result of combined analysis of biomass yield was significantly affected by nitrogen rate applied from urea stable and conventional urea. At Fogera site the mean of over years and location indicates that the maximum biomass 10.6 and 9.7 ton ha-1 respectively was recorded, from the application 103.5 Kg N from urea stable once and split way. In contrast, the minimum 4.7 ton $ha^{-1}$ biomasses were recorded from non-fertilized plot. Whereas Libokemkem, the maximum biomass yield 9.3 and 8.9 tons per ha was recorded from application of N from urea stable and conventional urea at split respectively. Significant increases in biomass yield were from the application of maximum N from both nitrogen sources. Those result in line with [15] that show the maximum rate of fertilizer increases its biomass yield. The best time to determine nutrient accumulation is at flowering or at harvest when accumulation is expected to be at a maximum. Grain, as well as shoot or straw, should be analyzed and their weights per unit area determined to calculate total accumulation [5]. Application of similar rates of nitrogen from urea stable and urea was provided statistically similar biomass yields. In a similar study with wheat as a test crop, [17] reported that application of similar rates of nitrogen from urea stable and urea was provided statistically similar dry biomass yields. In line with this, [17] who also reported non-significant effect of normal urea and urea stable on straw yield when applied at similar rate.

***Table 2.*** *Effect of urea Stable and conventional urea N-fertilizers on the yield and yield components of upland rice at Q/Michael testing site of Fogera district in 2017-2019.*

| Treatments* | 2017 | | | 2018 | | | 2019 | | | Pooled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ph | GY | DBY | Ph | GY | DBY | Ph | GY | DBY | Ph | GY | DBY |
| Zero N | 53d | 1714f | 3258d | 61 | 2608c | 6818b | 48d | 1865c | 4896d | 54e | 1994e | 4743e |
| 100% CU Split | 64c | 2527de | 5871c | 70 | 4795ab | 9943ab | 59ab | 3346ab | 8333abc | 64abc | 3556c | 7738c |
| 150% CU Split | 73ab | 3625b | 8144ab | 68 | 5490a | 11402a | 65a | 3406ab | 8542abc | 69a | 4009bc | 9362b |
| 50% US Split | 64c | 2026ef | 3636d | 64 | 4162b | 9773ab | 52bcd | 2953b | 7865bc | 60cd | 3059d | 6598d |
| 100% US Split | 67bc | 2776cd | 6174c | 67 | 5081ab | 10170ab | 57abc | 3319ab | 8906abc | 64abc | 3726c | 8097c |
| 150% US Split | 69bc | 3296bc | 7803b | 68 | 5406a | 12235a | 66a | 3877a | 9010abc | 68a | 4233b | 9767ab |
| 50% US Once | 56d | 2012ef | 4053d | 67 | 4139b | 7955b | 49cd | 2261c | 9167ab | 57de | 2804d | 6629d |
| 100% US Once | 67bc | 2982cd | 6326c | 65 | 5370a | 11648a | 52bcd | 3389ab | 7604c | 61bcd | 3733c | 8212c |
| 150% US Once | 77a | 4398a | 9091a | 68 | 5826a | 12955a | 54bcd | 3835a | 9479a | 66ab | 4793a | 10637a |
| CV (%) | 5.8 | 11.8 | 10.1 | 8.2 | 11.5 | 14.0 | 8.6 | 11.2 | 8.2 | 7.5 | 12.3 | 11.9 |
| SEM | 3.8 | 332.7 | 607.9 | 5.4 | 551.6 | 1490 | 4.8 | 345.5 | 676.0 | 4.7 | 437.1 | 966.6 |

| Treatments* | 2017 | | | 2018 | | | 2019 | | | Pooled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ph | GY | DBY | Ph | GY | DBY | Ph | GY | DBY | Ph | GY | DBY |
| P value | ≤0.01 | ≤0.01 | ≤0.01 | NS | ≤0.01 | ≤0.05 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 |

Ph= Plant height (cm); DBY= Dry Biomass Yield (kg $ha^{-1}$); GY= Grain Yield (kg $ha^{-1}$). *Means within a column followed by the same letter are not significantly different at 5% probability level: NS=non-significant at p=0.05.

***Table 3.*** *Effect of US and CU N-fertilizers on the yield and yield components of upland rice at Burah testing site of Libokemikem district in 2017-2019.*

| Treatments* | 2017 | | | 2018 | | | 2019 | | | Pooled | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Ph | GY | DBY | Ph | GY | DBY | Ph | GY | DBY | Ph | GY | DBY |
| Zero N | 57e | 1082e | 2614f | 48d | 1299e | 3447g | 61bcd | 1075e | 3160d | 55d | 1152e | 3074e |
| 100% CU Split | 75abc | 3267b | 6678bcd | 59ab | 3956b | 8939bc | 68ab | 2088bc | 6979a | 67b | 3104b | 7532b |
| 150% CU Split | 82ab | 3691ab | 8336ab | 65a | 5214a | 12689a | 71a | 2742a | 5729ab | 72a | 3882a | 8918a |
| 50% US Once | 63de | 1611de | 3245f | 49cd | 2040d | 4773fg | 58d | 1379de | 3889cd | 57d | 1677d | 3969de |
| 100% US Once | 70cd | 2479c | 5541de | 52bcd | 2648cd | 6364de | 66abc | 1648cd | 5174bc | 63bc | 2258c | 5693c |
| 150% US Once | 75abc | 3509ab | 7725abc | 48d | 2915c | 7576cd | 71a | 2262b | 7222a | 66b | 2895b | 7508b |
| 50% US Split | 67cd | 2004c | 4308ef | 52bcd | 2492cd | 5833ef | 59cd | 1563d | 4028cd | 59cd | 2020cd | 4723d |
| 100% US Split | 73bc | 3076b | 6241cd | 57abc | 3943b | 9015b | 66abc | 2069bc | 6319ab | 65b | 3030b | 7192b |
| 150% US Split | 83a | 4087a | 8594a | 66a | 5122a | 12574a | 72a | 2710a | 6910a | 74a | 3973a | 9360a |
| CV (%) | 7.4 | 12.3 | 16.4 | 8.6 | 12.8 | 10.0 | 5.6 | 12.9 | 15.0 | 7.2 | 12.9 | 13.4 |
| SEM | 5.3 | 339.7 | 969.9 | 4.8 | 422.2 | 789.9 | 3.7 | 252.2 | 824.8 | 4.6 | 345.1 | 865.1 |
| P value | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 |

Ph= Plant Height (cm); DBY= Dry Biomass Yield (kg $ha^{-1}$); GY= Grain Yield (kg $ha^{-1}$). *Means within a column followed by the same letter are not significantly different at 5% probability level.

***Table 4.*** *Effect of US and CU N-fertilizers on the NUE of rice at Q/Michael and Bura testing sites in 2017-2019.*

| Treatments* | Quhar Micheal | | | | Burah | | | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | Pooled | 2017 | 2018 | 2019 | Pooled |
| Zero N | - | - | - | - | - | - | - | - |
| 100% CU Split | 36.0bc | 69.5b | 48.5bcd | 51.3bc | 47.3b | 57.3ab | 30.3b | 44.9bc |
| 150% CU Split | 41.2b | 69.6b | 49.1bc | 53.3b | 35.9d | 38.4cd | 23.9bc | 32.7ef |
| 50% US Once | 38.4bc | 73.6b | 48.1bcd | 53.4b | 44.6bc | 57.1ab | 30.0b | 43.9bcd |
| 100% US Once | 55.4a | 122.9a | 65.5ab | 81.3a | 46.7bc | 59.1ab | 40.0a | 48.6b |
| 150% US Once | 55.7a | 120.6a | 75.4a | 83.9a | 58.1a | 72.2a | 45.3a | 58.5a |
| 50% US Split | 30.3c | 52.2b | 41.5cd | 41.3cd | 39.5cd | 49.5bc | 26.2bc | 38.4cde |
| 100% US Split | 33.4bc | 48.1b | 32.9cd | 38.1d | 35.7d | 50.4bc | 26.5bc | 37.5de |

| Treatments* | Quhar Micheal | | | | Burah | | | |
|---|---|---|---|---|---|---|---|---|
| | 2017 | 2018 | 2019 | Pooled | 2017 | 2018 | 2019 | Pooled |
| 150% US Split | 40.2b | 56.3b | 29.9d | 42.1cd | 33.9d | 28.2d | 21.9c | 27.9f |
| CV (%) | 10.9 | 19.5 | 19.9 | 19.1 | 9.4 | 18.6 | 11.53 | 16.5 |
| SEM | 4.5 | 15.0 | 9.7 | 10.6 | 4.0 | 9.6 | 3.51 | 6.9 |
| P value | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 | ≤0.01 |

*Means in a column followed by the same letter are not significantly different at 5% level.

There was also no significant difference (p>0.05) in the residual soil N due to application of US over CU fertilizer (Table 5).

***Table 5.*** *Effects of US-N as compared to CU-N fertilizer on the residual total N (%) of surface soil (0-20 cm) of the study sites after harvesting.*

| Treatment | 2017 | | 2018 | | 2019 |
|---|---|---|---|---|---|
| | Quhar Micheal | Burah | Quhar Micheal | Burah | Quhar Micheal |
| Zero N | 0.08 | 0.08 | 0.05 | 0.05 | 0.10 |
| 100% CU Split | 0.07 | 0.12 | 0.06 | 0.05 | 0.10 |
| 150% CU Split | 0.08 | 0.05 | 0.07 | 0.05 | 0.12 |
| 50% US Once | 0.08 | 0.02 | 0.08 | 0.05 | 0.08 |
| 100% US Once | 0.08 | 0.05 | 0.07 | 0.04 | 0.10 |
| 150% US Once | 0.08 | 0.05 | 0.08 | 0.05 | 0.10 |
| 50% US Split | 0.08 | 0.05 | 0.08 | 0.05 | 0.10 |
| 100% US Split | 0.09 | 0.08 | 0.07 | 0.05 | 0.10 |
| 150% US Split | 0.08 | 0.05 | 0.07 | 0.05 | 0.11 |

## 4. Conclusion and Recommendation

Di-ammonium phosphate and urea have been used as sources of phosphorus and nitrogen fertilizers, respectively for over half a century for the production of different crops in the country. However, since the last few years efforts have been made to diversify fertilizer products in terms of types and amount based on soil fertility status and nutrient requirements of crops. The applications of urea stable and conventional urea were significantly improved growth yield and yield components of rice as compared to control. Mean grain yield and biomass yield of rice was significantly affected by nitrogen rate and increased with increasing of nitrogen rate applied from urea stable and conventional urea. Application of 150% (203.5 N kg/ha) of the recommended N in urea stable form once at planting can be recommended at Quhar Micheal testing site in Fogera district for higher grain yield return from N fertilizer, while, at Burah testing site in Libokemikem district, urea stable fertilizer was not found to have better yield advantage over the conventional urea fertilizer. Therefore, At Libokemkem district, there was no evidence in our research that supports the advantage of urea stable over the conventional urea. Hence it is concluded that the application N fertilizers sources from both of urea and urea-stable are equal result obtained in improving of rice productivity. There was also no significant difference among mean grain yield recorded from application of similar rate and application time of urea stable and conventional urea.

## Abbreviations

CSA Centeral Stastical Agency

## Author Contributions

**Demsew Bekele:** Conceptualization, Formal Analysis, Investigation, Methodology, Software Supervision, Visualization, Writing – original draft, Writing – review & editing

**Abebe Getu:** Data curation, Formal Analysis, Investigation, Methodology, Software, Supervision, Writing – original draft

**Wubayehu Gebremedihin:** Supervision, review & editing

**Helen Asaminew:** Supervision, Writing – original draft

**Belachew Muche:** Supervision, Visualization, Investigation, Writing – original draft

## Conflicts of Interest

The authors declare no conflicts of interest.

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## Research Field

**Demsew Bekele:** Soil Science, plant nutrition, soil characterization, crop management, GIS and remote sensing.

**Abebe Getu:** Soil Science, plant nutrition, soil characterization, crop management, GIS and remote sensing.

**Wubayehu Gebremedihin:** Soil Science, plant nutrition, soil characterization, crop management, Micro biology.

**Helen Asaminew:** Soil Science, plant nutrition, soil characterization, crop management, GIS and remote sensing.

**Belachew Muche:** Irrigation Mangement, Soil Science, plant nutrition, soil characterization, crop management, GIS7.