Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.14, No.2, 2023 www.iiste.org

Evaluation of Nitrogen Fertilizer Sources on Nitrogen Use Efficiency and Maize (Zea mays L.) Yield in in Meki and Adamitulu, Central Rift Valley of Ethiopia

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Abstract
Application of different rates and sources of N fertilizers significantly ($P \leq 0.05$) influenced the entire crop parameters tested except stand count and ear length at both testing sites. The significantly different and maximum grain number per ear (410), 1000 grain weight (276 gm), and grain yield (4033 kg ha^{-1}) were obtained from the application of the lowest N rate (46 kg N ha^{-1}). Maximum grain number per ear (376), 1000 grain weight (216 gm) and grain yield of maize (3653kg ha^{-1}) were received from the application of the lowest rate of N from urea stable (urea treated with urease inhibitor).The agronomic efficiency of N responded positively to the applications of the low rates of N fertilizer from urea stable (46 kg N) applied at planting where the maximum agronomic efficiency (34.63) at Adamitulu and (17.52) at Meki were recorded from plots treated with 46 kg N ha^{-1} of urea treated with urease inhibitor (urea stable). The maximum apparent recovery (AR), partial factor productivity (PFP) and agronomic efficiency (AE) of N was obtained from the lowest rate of N from urea stable (urea coated with urease inhibitor) applied at periods of planting at both study sites. On the other hand, the highest physiological efficiency (PE) of N was observed at 92 kg of N from urea stable applied at time of planting at both study sites. The study shows that the highest economic benefits were recorded from the lowest rate of N (46 kg N ha^{-1}) from urea stable. Hence the maximum net benefits (30368.9 birr) with MRR of (461%) were recorded from the lowest rate of N (46 kg N ha $^{-1}$) from Urea stable at Adamitulu. Similarly, at Meki, the maximum economic response was received from the application of the low rate of N from urea stable where maximum net benefits (27286.9) and MRR (369.34%) were obtained from the application of 46 kg N ha^{-1} at planting time. Therefore, 46 kg N ha^{-1} of urea treated with urease inhibitor is recommended for farmers to maximize their production of maize at Adamitulu and Meki areas.
Keywords: urea stable, Nitrogen use efficiency, maize
DOI: 10.7176/JNSR/14-2-01
Publication date: January 31st 2023

1. INTRODUCTION

Soil is a vital natural resource and must be well managed for sustainable agricultural production (Benton, 2003). In Ethiopia, declining soil fertility presents a major challenge to bring about increased and sustainable productivity in order to feed the ever-growing population of the country. The severe problem of soil degradation in Ethiopia is mainly due to the overexploitation (over-cultivation and overgrazing) of the soil resources which causes billions of tons of soil removal every year and worse loss of the functions and services soil provide. Soil in Ethiopia is thus needs a high attention on soil specific management, which in turn requires a major investigation across the country (Engdawork, 2015). Soil fertility and health management is the key to the development of sustainable agriculture which is concerned with chemical reactions in soil, amount and availability or unavailability of essential plant nutrients, mechanism of nutrition depletion and replenishment in soil (Prasad and Power, 1997). Nitrogen is one of the most limiting plant nutrients in the tropics. Nitrogen mineralization provides a significant proportion of the N necessary for plant and microbial growth, and after water availability, N availability is most likely to limit plant productivity in water-limited ecosystems (Burke et al. 1997). Nitrogen fertilizer has a low efficiency of use in agriculture (10%–50 % for crops grown in farmers' fields, (Balasubramanian et al., 1999). One of the main causes of low efficiency is the large loss of N by leaching, runoff, ammonia volatilization, or denitrification (Raun and Johnson 1999), with resulting contamination of water bodies (Eutrophication) and the atmosphere. The fertilizer loss in crop production creating financial harm to the farmer and limiting yields while food production struggles to stay ahead of population growth is of great importance.

With the limitation on arable land area and the need to minimize the pollution of waters and the atmosphere with reactive N derived from N fertilizer, the only way to continue to feed the increasing population is to increase the efficiency of use of fertilizer N (Cassman et al., 2002). This overview highlights developments in mitigating volatilization from urea with specific focus on the effectiveness and feasibility of urease inhibitors as a mitigation technology. One of those products is UREA stable. It is based on urea (46%) with an added urease inhibitor N-(n-butyl)-Triphosphoric triamide (NBPT). UREA stable is a concentrated nitrogen fertilizer that can be applied as a granular for crops as well as liquid fertilizer through irrigation water for the orchard. Besides, it supposed to have basic advantage of having a combination of rapidly soluble, well absorbable nitrogen with urease inhibitor that helps to improve nitrogen penetration to plant roots by restraining the sorption and fixation of $NH4^+$ in the surface soil layer, which slows the effect of this nitrogen form down. In addition, it helps to reduce its losses due to ammonia volatilization into the atmosphere during surface application.

2. MATERIALS AND METHODS

2.1 Descriptions of the study areas

This study deals with two districts of Oromia regional State, Dugda Bora and Adamitulu Jido kombolcha. East Shewa zone occupies central part of Oromia region. the study areas are located at 8001’to 8025'N Latitude and 38032' to 39004'E Longitude and 7037'-8004'N latitude and 38032'- 39004'E Longitude for Dugda and ATJK respectively. All areas of the district (Dugda) lie within sub-tropical agro climatic zone with a range of temperature 15 to 20OC and rain fall of 700 to 800mm.

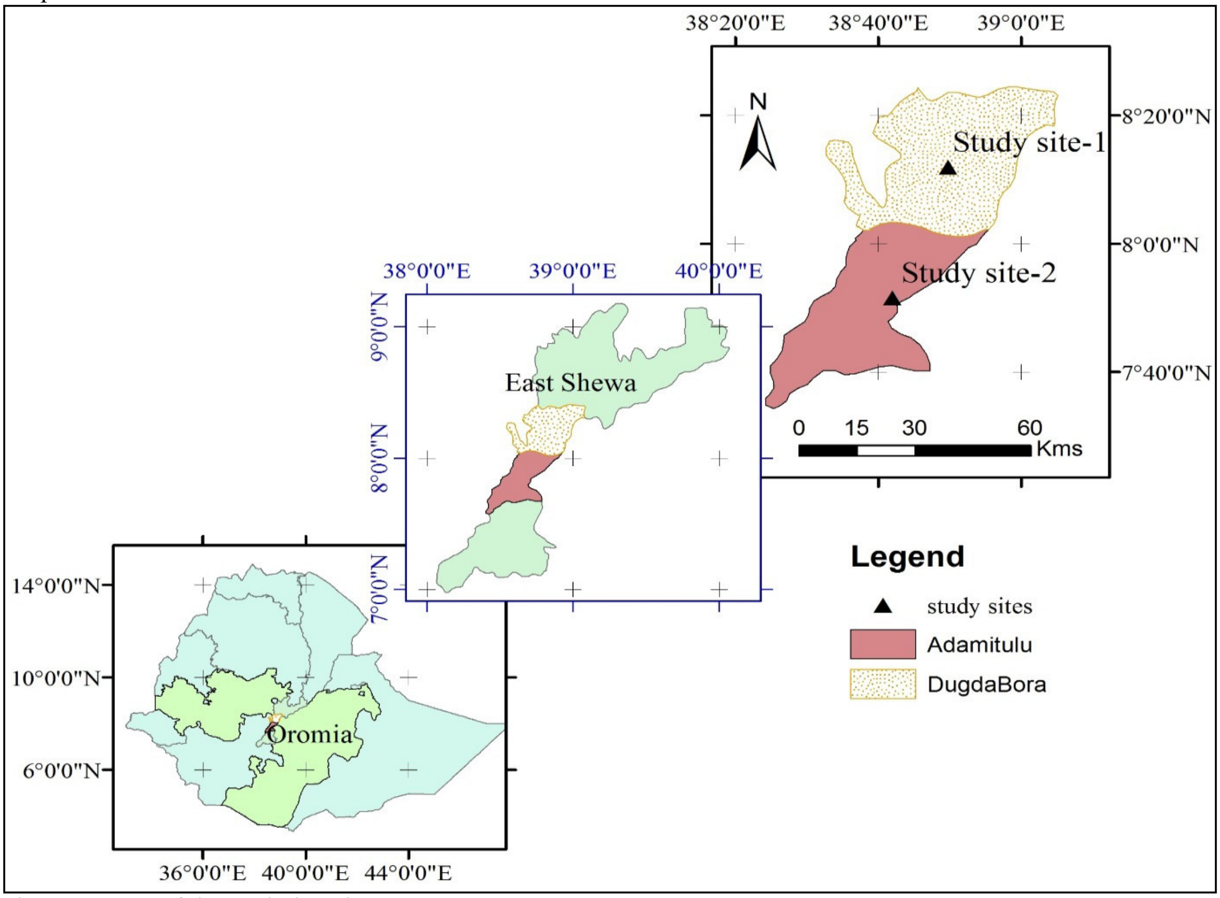


Figure 1. Map of the study locations

2.2 Climate Data

According to the meteorological records of Adamitulu Research Center, the total rainfall during the current (2017) cropping season was about 675 mm, which is lower than the mean annual rainfall of 874 mm of the past 30 years and the average monthly maximum and minimum temperatures of these years were 28.627 and 12.566°C, respectively (Figure 2 & 3 respectively). There was high rainfall during the months of July, September, and August followed by a completely dry periods during the whole of October, November, December and January, a trend that is different from the long-term condition. Meki area receives a mean monthly rainfall of 75.55 mm during the current season (2017) which was higher than the mean monthly rainfall of 58.88 mm (1990-2017). The 29 years’ rainfall data indicates that the maximum rainfall occurs during the months of July and August followed by complete dry periods of October, November and December.

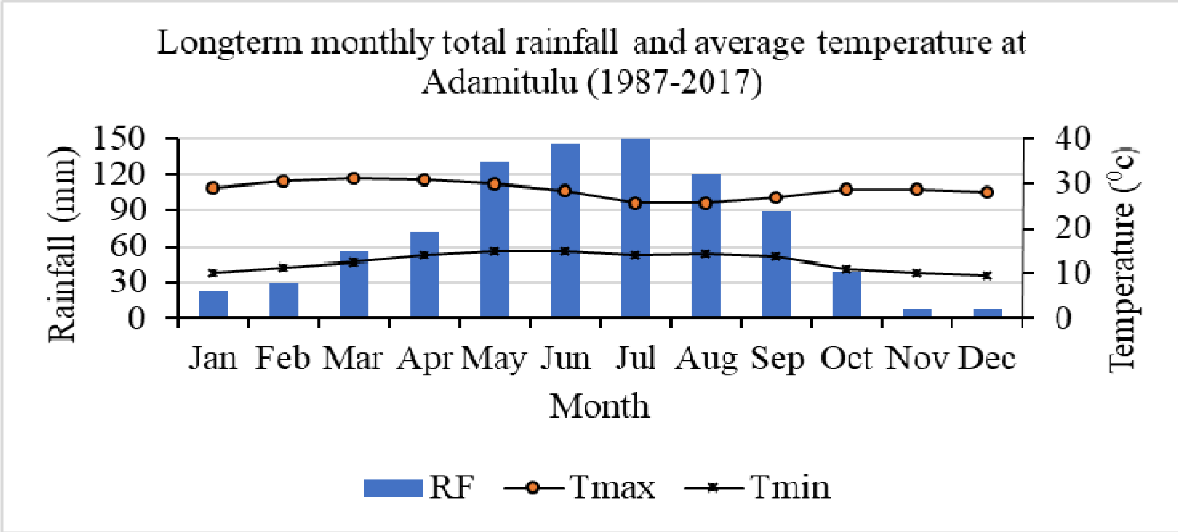


Figure 2. Long term (1987-2017) mean monthly rainfall, mean maximum and minimum temperatures of Adamitulu

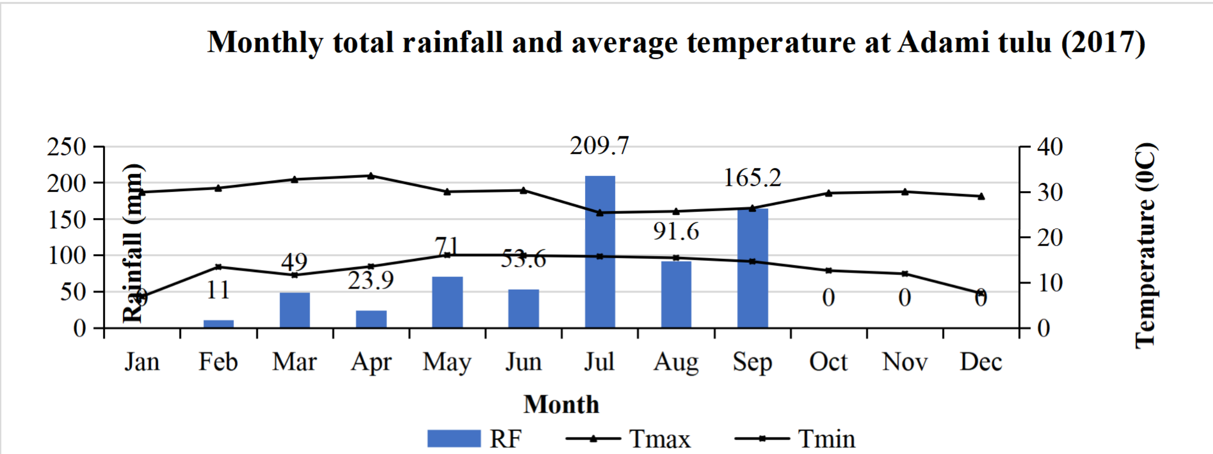
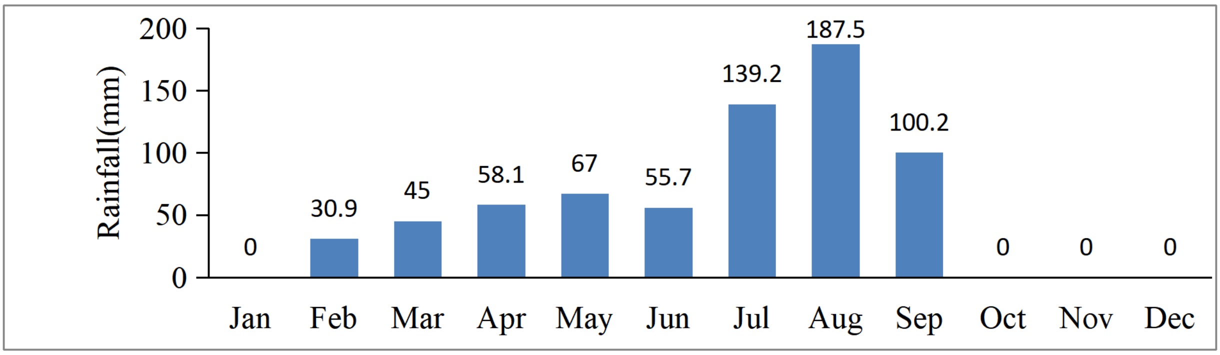


Figure 3. Monthly total rainfall and average temperature



at Adamitulu
Figure 4. Monthly total rainfall at Meki in 2017 cropping season temperature
Figure 5. Average Annual rain fall (mm) at Meki (1990-2017)

3. Result and Discussion

3.1 Maize stand count

Application of different rates and sources of N had no significant effect on stand count data at 4 weeks after sowing at both locations (Adamitulu and Meki) (Tables 2 and 3). This result is in line with the findings of Gebreyes (2005) that the stand count of wheat was not influenced by different rates of N fertilizers. The possible reason for this might be that the rate of N fertilizers applied during planting period might be sufficient for germination and plant establishment since the crop is not affected by external factors like disease, pest and animal damage.

3.2 Plant height

At Adamitulu, the effect of N fertilization on maize plant height was found to be significant (Table 9). The plots which received N fertilizer had increased plant height significantly as compared to the control plot. The plant height was increased consistently with rates of N where the maximum plant height (168 cm) was obtained from the application of the highest N rate (138 kg N ha-1) followed by 150 cm which was obtained from 46 kg N ha-1 and the minimum (130 cm) was from the control plot (Table 9). In the same way, maize plant height at Meki study site has shown a significant difference to the plots treated with 138 kg N ha-1 applied in split as conventional urea fertilizer (Table 10). In agreement with this result at Meki, Amsal et al., 2000, reported a positive and linear response of plant height to N fertilizer application in the central highlands of Ethiopia. Several other studies (Zewdu et al., 1992, Tilahun et al., 1996a; Minale et al., 2005) have also revealed remarkable plant height enhancement in reaction to each incremental dose of N fertilizer.

3.3 Biomass Yield

The results revealed that maize stover dry weight was significantly ($p<0.05$) influenced by N fertilizer rates both at Adamitulu and Meki (Tables 2 and 3). The highest stover yield of maize was obtained from split application of 138 kg N ha-1 as conventional urea both at Adamitulu and Meki, while the lowest biomass was obtained at the control. The straw is a function of leaf size, plant height and stock thicknesses that is often improved through the higher photosynthesis facilitated by more nutrient availability from external and inherent soils. In agreement with this result, Tilahun et al., 1996a, showed straw yield increments of 24 to 29 % for 120 over 60 kg N ha-1 from experiments conducted in the central and southeastern Ethiopia. Moreover, the result from the experiment done on Vertisols of the central highlands of Ethiopia by Selamyihun et al.,1999, showed that straw yield of durum wheat increased significantly with each incremental dose of N. Other reports (Amsal et al., 2000) also indicated that application of N fertilizer significantly enhanced the straw yield of wheat, since N promotes the vegetative growth of the plant. Besides, Taye et al., 2002, reported linear and quadratic responses of straw yield to N rate with mean values ranging from 2324 to 4073 kg ha-1 during favorable growing seasons. In agreement with this report, Amsal et al., 2000, reported that N rate significantly enhanced the straw yield of wheat, since N usually promotes the vegetative growth of a plant. In the same way, Woyema, 2009, and Amanuel et al., 1991, reported that a linear increment in straw yield production was observed with an increase in N rates. This is in agreement with the current study.

Table 1. Different levels and sources of N on yield and yield components of maize at Adamitulu.

Treatments	GY kg ha^{-1}	Bio mass Kg ha^{-1}	1000 seed weight (gm)	Grain no/ear	Ear length	Plant height	Stand count
0N (No Nitrogen)	2440^{c}	6187^{c}	204^{c}	336.67^{c}	11	130^{c}	42
46 kgNha^{-1} USsp	3153^{abc}	6493^{bc}	239^{b}	373^{abc}	12	150^{abc}	44
46 kgNha^{-1} US p	4033^{a}	6753^{abc}	276^{a}	410^{a}	13	150^{abc}	45
92 kgNha^{-1} CU sp	3267^{ab}	6896^{ab}	245ab	370^{bc}	13	150^{abc}	43
92 kgNha^{-1}US sp	3037^{bc}	6975^{ab}	240^{b}	380^{ab}	12	150^{abc}	47
92 kg N ha^{-1}US p	3584^{ab}	6870^{ab}	241^{b}	386^{ab}	12	146^{abc}	46
138 kgNha^{-1}US p	3717^{ab}	7183^{a}	247^{ab}	380^{ab}	13	168^{a}	45
138 kgNha^{-1}CUsp	3656^{ab}	7305^{a}	241^{b}	376^{ab}	12	168^{a}	44
138 kgNha^{-1}USsp	3966^{a}	7189^{a}	265^{ab}	408^{a}	15	167^{ab}	46
CV	15.7	18.38	7.50	5.76	9.85	7.97	2.8
LSD (5 %)	762.7**	2106.2*	6.34**	37.89*	ns	21.14*	ns

Note: Means in a column followed by the same letter are not significantly different at ($p\leq0.05$)
NS= Non-significant, * significant at 5%, **=significant at 1%

Table 2. Different levels and sources of N on yield and yield components of maize at Meki

Treatments	GY kg ha^{-1}	Bio mass Kg ha^{-1}	1000 seed weight (gm)	Grain no/ear	Ear length	Plant height	Stand count
0N (No Nitrogen)	2320.^{c}	4654^{c}	181^{c}	303^{c}	9.3	131^{c}	41
46 kgNha^{-1} USsp	2958^{bc}	4717^{bc}	192^{bc}	330^{bc}	11	151^{b}	42
46 kgNha^{-1} Usp	3653^{a}	5336^{bc}	216^{a}	376^{a}	10.3	158^{ab}	45
92 kgNha^{-1} CU sp	3026^{ab}	4827^{bc}	191^{bc}	333^{bc}	11	162^{ab}	44
92 kgNha^{-1}USsp	3089^{ab}	5454^{abc}	194^{bc}	360^{ab}	11.6	161ab	43
92 kg N ha^{-1}Usp	3234^{ab}	5404^{abc}	201^{abc}	347^{ab}	12	164^{ab}	41
138 kgNha^{-1}Usp	3358^{a}	5768^{ab}	210^{a}	370^{ab}	13.6	166^{ab}	45
138 kgNha^{-1}Cusp	3192^{ab}	6206^{a}	202^{ab}	330^{bc}	12	170^{a}	45
138 kgNha^{-1}USsp	3508^{a}	5841^{a}	215^{a}	374^{a}	13	167^{ab}	44
CV	10.45	10.81	5.69	6.99	18.41	6.72	8.5
LSD (0.05%)	565**	1002.4*	19.74**	42.08*	ns	18.50*	ns

Note: Means in a column followed by the same letter are not significantly different at ($p \leq 0.05$)
NS= Non-significant, * significant at 5%, **=significant at 1%

3.4 Thousand Grain weight of Maize

The results revealed that grain weight of maize was significantly ($p<0.05$) influenced by N fertilizer rates both at Adamitulu and Meki (Tables 9 and 10). The thousand grains weight responded significantly ($P < 0.05$) to the application of 46 kg N ha^{-1} from urea stable at time of planting at Adamitulu. At Meki, in the same way, the thousand seed weight of maize was significantly affected by the treatment that received 46 kg N ha^{-1} from urea stable at planting time. This result is in the contrary to findings of Amsalu et al. (2000) that a positive and linear response of 1000 grains weight to N fertilization. Other reports (Gooding and Davis, 1997), have shown either no improvement or reduced kernel weight due to N fertilization even when yields increased. Zewdu et al. (1992) however has reported non-significant response of 1000 grains weight to application of N fertilizer in the highlands of Ethiopia. The report from Gebre, 2007, has shown an increment of 1000 seed weight in response to the application of 69 kg N ha^{-1}. A number of field and glasshouse trials have reported significant improvement in N response after applying granular urea with Agrotain (Blennerhassett et al., 2007; Zaman et al., 2008) that fully agreed with the current finding. The result of this study, however, did not agree with the findings of Tenaw (2000) who reported no significant effect of N fertilizer on 1000 grain weight of finger millet and maize kernel weight, respectively. Therefore, the lowest dose of N fertilizer from urea stable (urea treated with Agrotain) is recommended for farmers to maximize their production with minimum cost of fertilizer.

3.5 Ear length

In reverse to grain yield, straw yield and grain weight, ear length and stand count of maize did not show significant difference to the applied N rates and sources of N fertilizers both at Adamitulu and Meki study areas (Table 2&3). This result is in contrary to the findings of Gebreyes (2005) that the spike length was significantly ($P < 0.01$) affected by the application of different rates of N fertilizer and exhibited strong linear relationship with fertilizer.

3.6 Number of maize grains per ear

The number of grains per ear also showed a significant difference to the applications of 46 kg N ha^{-1} from urea stable at time of planting at Adamitulu. In similar way, the number of grains per ear has showed a significant difference due to applications of 46 kg N ha^{-1} from urea stable at time of planting at Meki. This result is in line with the finding of Soliman et al., 1999, that grain yield of maize increases with increase in grains cob^{-1} and number of ears. This result shows that the number of grains per Ear has direct relationship to the grain yield obtained from the current study.

3.7 Grain yield

Analysis of variance indicated that treatment effects were significant for maize grain yield at both Adamitulu and Meki study sites in the cropping season. The grain yield responded significantly ($P < 0.05$) to the application of N fertilizer rates (Tables 9). The highest mean grain yield (4033 kg ha^{-1}) was obtained from the minimum doses of N (46 kg N ha^{-1}) from urea stable applied at time of planting at Adamitulu with an increment of 60 % yield advantage over the control treatments (plots with no external N application).

Similarly, a significant difference was observed to the application of the lowest doses of N (46 kg N ha-^{1}) from urea stable at planting at Meki, Hence, the maximum mean grain yield of (3652. kg ha^{-1}) was obtained at half of the recommended rate of N (46 kg N ha-^{1}) from urea stable at time of planting with an increment of 57.52% yield advantage over the control treatments (Table 10). The reason for the better yield at Adamitulu than Meki study location could be attributed to the higher monthly rainfall at Adamitulu than Meki. In the current study, the highest rate of N did not significantly influence the grain yield of maize. This result is in line with Mohammad and Zaman (2010) that the low efficiency of N could be attributed to fast hydrolysis of conventional urea, less optimum soil conditions (extreme low/high soil moisture and temperature) and high application rate. In other report Urea stable applied at 25 kg N/ha exhibited 52% improvement in N response over its high rate of Agrotain treated urea (50 kg N) urea and other urea treatments applied in granular form; while such improvements were only 15% for high rate (Zaman*,* 2010).

This is in line with the current study that the highest N response was obtained from the lowest rate of urea stable (46 kg N ha^{-1}) compared to its high rate of 138 kg N ha^{-1}. In a study by Donner and Kucharik (2008), when the application rate of nitrogen fertilizer was increased by 30%, the maize yield has shown an increment of 4% but the amount of nitrate lost through leaching increased by 53%.

Field experiment results by the department of environment, food and rural affairs in United Kingdom showed that the volatilization loss from conventional urea (urea not treated with) is 58 % while only 7% of N was lost from the urea treated with NBPT. The loss of N from noon volatile ammonium nitrate standard was only 4% of the applied N (Chadwick, 2005).

According to Dawar et.al. 2012, applying urea with Agrotain resulted in even higher herbage growth and N-RE compared with urea alone or other fertilizers. This suggests that delayed hydrolysis in the presence of urea stable (urea treated with Agrotain) improves the bioavailability of urea-N through reductions in plant urease activity, thus providing plants an opportunity to convert the absorbed urea into protein more efficiently. Urea stable or slow releasing urea also provides plants an opportunity to take up more N in either urea or$NH4^{+}$ forms and to convert N into plant protein more efficiently than $NO^{-}3$ (Middleton and Smith, 1979). Zhengping *et al*., 1996, also observed slow urea hydrolysis and a lower accumulation of soil NH4 after applying urea with urease inhibitor to soils under controlled conditions. According to Gebre kiross (2007), Maize yield can be further increased under supplementary irrigation. This shows that it is not only the rate of fertilizer that limit the production of maize crop but the sufficient availability of moisture is a limiting factor in the central rift valley of Ethiopia. Therefore, in areas where moisture is deficient like Adamitulu and Meki, the low doses of urea stable fertilizer could be preferable in terms of yield and economic benefit than conventional urea fertilizer.

4 Nutrient Use Efficiency

4.1 Agronomic Nutrient Use Efficiencies (AEN) of Maize

At Adamitulu, the highest agronomic efficiency (34.63) was recorded from plots treated with 46 kg N ha^{-1} from urea stable at time of planting. This means, 34.63 kg of maize grain was obtained from one kg of N invested from Urea stable at once application. At Meki, the highest agronomic efficiency (17.52) was also obtained from the plots treated with the same rate and source of N (46 kg N ha-1) at once application. This shows that 17.52 kg of maize grain was provided from one kg of N invested from urea stable. (Table 11).

The current study reveals that the highest rate of N fertilizers has resulted in low Nitrogen use efficiency (Agronomic efficiency) of maize. The maximum N use efficiency was obtained from the application of the lowest rate of N from urea stable at both study sites (Adamitulu and Meki). The low nitrogen use efficiency of conventional urea could be attributed to fast hydrolysis of conventional urea, less optimum soil conditions (extreme low/high soil moisture and temperature) high application rate (Zaman *et al.*2010). The same author reported that urea stable significantly increased pasture dry matter (PDM), N response, NRE and pasture N uptake compared to urea alone. Urea stable applied at 25 kg N/ha exhibited 52% improvement in N response over its high rate of urea stable (50 kg N) and other urea treatments applied in granular form; while such improvements were only 15% for high rate. This is in line with the current study that the highest N response was obtained from the lowest rate of urea stable (46 kg N ha^{-1}) compared to its high rates (92 kg Nha^{-1} and 138 kg N ha^{-1}). Similar study from Asossa area revealed significant variation of agronomic efficiency of maize that ranged from2.5 to 19.64 kg ha^{-1} at harvest stage of maize (Bakala, 2017). On the other hand, the decrease in agronomic efficiency with increasing levels of N applied is remarkably different from the report of Gebreyes (2008) who reported higher agronomic efficiency under the application of higher levels of nitrogen. N use efficiency can be increased to 60 to 70% or more with improved management in many cropping systems (Ladha et al. 2005; Raun and Johnson 1999).

4.2 Partial Factor Productivity (PFP_N) of Maize

The highest partial factor productivity (PFP_N) of 87.68 kg grains kg^{-1} N was observed from the application of 46 kg N ha^{-1} urea stable at planting periods at Adamitulu (Table 3). In the same way the highest partial factor productivity of 65.8 kg grains kg^{-1} N was also obtained from the application of 46 kg N ha^{-1} as urea stable at time of planting at Meki (Table 3).

In general, the lower rate (46 kg N ha^{-1}) Urea stable application resulted in higher AE and higher PFP_N. According to Dobermann, 1996, and 2007, under optimal conditions, the PFP typically ranges from 40 to 80 kg kg^{-1}which closely agree with the current finding at Adamitulu. However, according to Cassman et al., (2009), PFP can be increased by increasing the efficiency with which applied nutrients are taken up by the crop and utilized to produce grain.

The agronomic efficiency and partial factor productivity from the same rate of urea stable when applied in split was decreased at both study sites (Adamitulu and Meki). This means time of application has shown a significant influence to the applied N fertilizers from urea stable. This finding is in line with the report of Brad Bernhard and Fred (2016), who stated that application of urea stable resulted in 185 bu Ac^{-1} while decreased to 167 bu Ac^{-1} when the same rate of Agrotain treated urea applied in split. This implies that the plant needs to have a certain amount of fertility at planting to set the trajectory for the rest of the growing season and may not recover if lacking N at an early growth stage. In a study by Donner and Kucharik, (2008), the loss of nitrate through leaching was increased when the application rate of N fertilizer increased.

Table 3. Agronomic efficiency and Partial Factor productivity of maize at Adamitulu & Meki

N applied kg/ha	Adamitulu			Meki- Dugda		
	GY kg ha^{-1}	PFP	AEN	GY kg ha^{-1}	PFP	AEN
0N (No Nitrogen)	2440	-	-	2320	-	-
46 kg N ha^{-1} US in split	3153	68.55^{b}	13.497^{b}	2958	62.64^{b}	24.29^{b}
46 kgNha^{-1} US @Planting	4033	87.68^{a}	32.627^{a}	3653	79.41^{a}	39.384^{a}
92 kgNha^{-1} CU in split	3268	35.52^{cd}	6.407^{b}	3026	33.6^{c}	12.880^{c}
92 kgNha^{-1}US in split	3037	33.01^{cd}	7.993^{b}	3089	35.2^{c}	12.811^{c}
92 kg N ha^{-1}US@ Planting	3584	38.95^{c}	11.427^{b}	3234	34.6^{c}	13.572^{c}
138 kg N ha^{-1}US@Planting	3717	26.93^{d}	8.587^{b}	3358	24.3^{d}	10.754^{c}
138 kgNha^{-1} CU in split	3656	26.49^{d}	8.140^{b}	3192	23.1^{d}	9.790^{c}
138 kg N ha^{-1} US in split	3966	28.74^{cd}	10.390^{b}	3508	25.4^{d}	10.875^{c}
CV		13.99	18.22		8.82	23.87
LSD (0.01)		14.72**	5.49**		6.076**	7.02**

Key: Us= urea stable, Cu= conventional urea

4.3 Nitrogen use efficiency (NUE) of Maize

Efficient fertilizer use can be defined as maximum returns per unit of fertilizer applied (Mortvedt *et al*., 2001). Nitrogen fertilizer is universally accepted as a key component to high yield and optimum economic return. Nitrogen (N) plays a very important role in crop productivity (Ahmad, 2000) and its deficiency is one of the major yields limiting factors for cereal production (Shah *et al*., 2003). Since higher fertilizer use efficiency is always associated with low fertilizer rate, cultural practices meant for promoting integrated nutrient management will help to affect saving in the amount of fertilizer applied to the crops and therefore to improve fertilizer use efficiency (Karim and Ramasamy, 2000). Using Agrotain treated urea could also be another way to improve the fertilizer use efficiency of a crop (Brad Bernhard and Fred E. Belew, 2016).

4.4 Apparent Nitrogen Recovery Efficiency and Nitrogen Harvest Index

4.5 Physiological efficiency of Nitrogen

At Adamitulu, the maximum physiological efficiencies of N (32.87) kg grain per kg total N uptake was recorded at the recommended rate of N from urea stable applied at time of planting (Table 4). Doberman, (2016), reported that the physiological efficiency lies in between 30-60 kg kg^{-1} that fully agreed to the current study. At Meki, the highest physiological Efficiency of N (29.07 kg kg^{-1}) was also recorded from the recommended rate of N (92 kg N ha^{-1}) from urea stable applied at time of planting (Table 4). The lowest rate of N (46 kg N ha^{-1}) from urea stable applied at time of planting resulted in the physiological efficiency of 31.08 and 26.5 kg grain per kg total N uptake at Adamitulu and Meki testing sites respectively. Therefore, the current study reveals that the lowest doses of N from urea stable (urea treated with Agrotain) applied at planting could influence the physiological Efficiency of maize to N fertilizer.

The mean PE of N of 26.49 kg grain per kg total N uptake and 22.75 kg grain per kg total N uptake were recorded at Adamitulu and Meki respectively. (Table 12). Hence, this is low efficiency when compared to the reports from Amsal and Tanner, 2001, i.e. 47.33 kg grain per kg total N for bread wheat grown on Vertisols in central Ethiopia. It is also in the contrary to the result reported by Gebreyes, 2008, is that the physiological efficiency of N increased with an increasing N rate.

4.3.6 Nitrogen harvest index

The ratio of grain N to total crop N, defined as the nitrogen harvest index (NHI), provides an indication of how efficiently the plant converts absorbed N into grain. Hence nitrogen fertilizers applied from different sources of N did not influence the NHI of maize at both study sites (Adamitulu and Meki-Dugda). This implies that the N in the grain was not affected by sources and rates of fertilizers. Likewise reports showed that N supply had no significant effect on either harvest index (HI) or N harvest index within the same water treatments (Chakwizira et al., 2016).

The constant indices across N treatments indicated that dry matter and N accumulation in the grain are closely coupled to the mass and N content of the whole plant (Muchow, 1988). In this study, N showed a slight decrease when the rate of N from urea stable increased from 46 kg N ha^{-1} (0.73 %) to 138 kg N ha^{-1} (0.48) (Table 5). According to the above author, the high response of both HI and NHI to moisture stress, but not to fertilizer N, highlights the importance of soil moisture in crop production due to its influence on N uptake. The NHI was closely related to HI, which suggests that management options to improve the HI of maize crops would also improve the crops' ability to utilize N. Therefore, it can be concluded that NHI and HI of maize could not be influenced by the application of increasing rate of N fertilizers.

Table 5. Apparent recovery, physiological efficiency and harvest Index of nitrogen at Adamitulu and Meki study sites, Central Rift Valley of Ethiopia

Kg N ha^{-1}	Adamitulu					Meki-Dugda				
	GY kg ha^{-1})	PE_N (kg kg^{-1})	RE_N (%)	HI	NHI	GY (kg ha^{-1})	PE_N (kg kg^{-1})	RE_N (%)	NHI	HI
0N (No Nitrogen)	2440	-	-	0.53	-	2220	-	-	-	0.51
46 kg N ha^{-1} US in split	3153	16.25^{c}	30.2^{b}	0.58	0.7	2558	23.48	15.87^{b}	0.6	0.58
46 kgNha^{-1} US @Planting	4033	31.08^{ab}	40.4^{a}	0.66	0.7	3026	26.50	46.74^{a}	0.7	0.65
92 kg N ha^{-1} CU in split	3267	23.55^{bc}	18.3^{cd}	0.62	0.5	3089	12.03	13.15^{bc}	0.8	0.59
92 kgNha^{-1}US in split	2903	25.12^{ab}	18.6^{cd}	0.66	0.6	3234	20.18	13.48^{bc}	0.8	0.62
92 kg N ha^{-1}US@ Planting	3583	32.87^{a}	18.8^{cd}	0.59	0.7	3552	29.07	18.15^{b}	0.7	0.58
138 kg N ha^{-1}US@Planting	3717	31.02^{ab}	16.7^{d}	0.65	0.6	3358	25.99	13.26^{bc}	0.7	0.65
138 kgNha^{-1} CU in split	3656	26.41^{ab}	12.9^{cd}	0.58	0.7	3192	22.91	9.49^{c}	0.7	0.61
138 kg N ha^{-1} US in split	3966	25.66^{ab}	20.6^{c}	0.62	0.6	3042	21.89	16.74^{b}	0.7	0.66
CV		18.35	15.75	20.56	16.2		17.86	16.80	8.77	5.78
LSD (0.05)		8.512*	6.08*	ns	ns		ns	5.402*	ns	Ns

4.4. Partial Budget Analysis

Cost benefit analysis was undertaken with different conventional and stable urea fertilizer types and rates to determine the highest net benefit with acceptable marginal rate of return.

At Adamitulu, the result of the partial budget analysis revealed that the application of 46 kg N ha^{-1} Urea stable fertilizer at planting provided the maximum net benefit of 30368.9 ETB ha^{-1} with MRR of 461.08 % at Adamitulu (Table 13), suggesting that for each birr invested in the production of maize, the farmers could earn birr 4.61 after recovering their cost of production. In the same way, the maximum net return (net benefit) of birr 27286.9 ha^{-1} with MRR of 369.34% (Table 14) were recorded from the investment of 46 kg N ha^{-1} from urea stable applied at planting at Meki testing site. This result suggests that for a birr invested in the production of maize, the farmers could earn birr 3.69 after recovering their cost of production.

The results show that a general decrease in benefit cost ratio with increase in levels of fertilizers. This showed that excess usage of fertilizers was increased cost and decreased grain yield of maize. This implies that profitability of maize production is partly related with the right type and rate of input (fertilizer) usage and the cost incurred for these inputs. Most of the treatments showed the minimum acceptable rate of return, which is less 100% (CIMMYT, 1988). However, higher MRR was recorded at 46 kg N ha-1 both at Adamitulu (461.08%) and at Meki (369.34%), which were dominant over the other treatments. Therefore, application of 46 kg N ha-1 from urea stable at time of planting at both Adamitulu and Meki study area can be recommendable for farmers to maximize maize production. According to Karim and Ramasamy (2000), the higher fertilizer use efficiency is always associated with low fertilizer rate and appropriate cultural practices. Thus, the current study revealed that the application of low doses of Urea stable at time of planting with appropriate cultural practices improved the nutrient use efficiency of maize, which may resulted in high net benefit and high Marginal Rate of Return (MRR) for the production of maize at both Adamitulu and Meki study areas.

Table 6. Partial budget, MRR, and dominance analysis of N fertilizers at Adamitulu.

Rate	Grain Yield	10 % AGY	GFB	TVC	Net benefits	MRR
	Kg ha^{-1}				ET birr	%
0 N (No nitrogen)	2440	2196	19764	0	19764	-
46 N US@ planting	4033.2	3629.5	32668.9	2300	30368.9	461
46 N US in split	3153.2	2837.88	25540.9	2700	22840.9 D	
92 N CU in split	3168.7	2851.83	25666.47	3400	21666.47D	
92 N US split	3267.7	2940.93	26468.4	4000	22268.4D	
92 N US @planting	3583.7	3225.37	29028	4000	24428D	
138kg N US @ planting	3656.3	3290.67	29616	4800	23916D	
138 NCU in split	3717.0	3345.3	30107.7	5700	23807D	
138 kg NUS in split	3966.5	3569.85	32128.7	5700	25528.7D	

Table 7. Partial budget, MRR, and Dominance analysis of N fertilizer at Meki.

Rate	Grain Yield	10 % AGY	GFB	TVC	Net benefits	MRR
Kg ha^{-1}				ET birr		%
0 N (No nitrogen)	2320	2088	18792	0	18792	-
46 N US@ planting	3652.7	2662.2	23962	2300	27286.9	369.30
46 N US in split	2958	3287.4	29586	2700	21262.2D	
92 N CU in split	3089.7	2780.7	25026	3800	21226.7D	
92 N US split	3026	2723	24510	4000	20510.6D	
92 N US @planting	3234	2910.6	26195	4400	21795.4D	
138NUS@ planting	3192	2872.8	25855	5200	20655.2D	
138NCU in split	3325	2992.5	26972	5700	21232.5D	
138 kg NUS in split	3341.7	3007.5	27067	5700	20967.8D	

Key: US= Urea stable, CU= Conventional Urea

Table 8. Partial budget, MRR, and Dominance analysis of N fertilizer at Meki.

Rate	Grain Yield	10 % AGY	GFB	TVC	Net benefits	MRR
Kg ha^{-1}				ET birr		%
0 N (No nitrogen)	2320	2088	18792	0	18792	-
46 N US@ planting	3652.7	2662.2	23962	2300	27286.9	369.30
46 N US in split	2958	3287.4	29586	2700	21262.2D	
92 N CU in split	3089.7	2780.7	25026	3800	21226.7D	
92 N US split	3026	2723	24510	4000	20510.6D	
92 N US @planting	3234	2910.6	26195	4400	21795.4D	
138NUS@ planting	3192	2872.8	25855	5200	20655.2D	
138NCU in split	3325	2992.5	26972	5700	21232.5D	
138 kg NUS in split	3341.7	3007.5	27067	5700	20967.8D	

Key: US= Urea stable, CU= Conventional Urea

5. SUMMARY AND CONCLUSION

Soil pits were used to provide characterization of soil profiles for soil morphological, physical and chemical characteristics in two areas of the central rift valley's agricultural soils. Hence, the soils composite surface soils of Adamitulu (7.7 to 7.8) were moderately alkaline and that of Meki was neutral to slightly alkaline. The profiles and the composite surface soil samples of the areas (Meki and Adamitulu) had very low Organic matter, organic Carbon, available p and available nitrogen content that would limit production of many crops. Hence, there is a need for external application of the above nutrients for both locations. In the contrary, the observed exchangeable K value at Adamitulu was high for the surface horizon where it generally showed a decreasing trend with depth of the profile. This was low when compared to the Exchangeable K contents of the soils of Meki which implies that the soils around Adamitulu need more protection and management practices that can improve the exchangeable K on the exchange site of the soil. However, the soils of the sites are not deficient with micro nutrients like zinc, Cu, Fe and Mn. Therefore, there is no recommendation for the external application of the above soil minerals.

The soil textural class of both the profile and the composite surface soil samples were loamy and did not vary with profile depth except for the bottom horizon (C), which was sandy loam. The soil profile contained more than 40% silt and 50% sand throughout the profile while the clay content of the soil was very low. The silt to clay ratio of the soil observed in the current study sites, was generally high (greater than 0.15) of the study areas were for both the profile and the composite surface soils suggesting low degree of weathering and the soil is at development stages (young soil).

The maximum, 40.4 and 46.74 % N recoveries were recorded from the lowest rate of N (46 kg N ha^{-1}) application from urea stable at time of planting at both Adamitulu and Meki testing sites, respectively. The results revealed that NRE values lie between 0.3 and 0.5 kg kg^{-1} (30 %-50 %) indicating efficient N management. This study revealed, 40 % of the applied fertilizer-N from the lowest rate of N as urea stable at planting was recovered by maize crop at Adamitulu. In the same way, when 46% of the applied N from the same source and rate of N was recovered at Meki. The recorded mean physiological efficiency of N was 26.49 and 22.75 kg ka^{-1} in maize grain at Adamitulu and Meki, respectively. In this study, NHI % was relatively stable at the final harvest, increasing from 0.48 to 0.73% with increasing N application from 46 to 138 kg N ha^{-1}. The nitrogen harvest index was closely related to crop harvest index suggesting that management options to improve the HI of maize crops would also improve the crops' ability to utilize N.

The partial budget analysis revealed that the maximum net benefit and gate farm benefits and marginal rate of return (MRR) were recorded due to the application of the low doses of N (46 kg ha^{-1}) from urea stable during planting periods at both testing sites. The results of the current study showed that urea stable treated plots produced higher N response, higher N use efficiency and higher economic benefits compared to conventional urea. Nitrogen response and response efficiency decreased with higher rates of N fertilizers applied as urea alone urea treated with Agrotain. Therefore, there is considerable potential for improving farm production, profitability and sustainability of maize by using urea stable fertilizer in central rift valley area of Ethiopia. Hence, we recommend application of 46 kg N ha^{-1}urea stable at planting to increase profitability of the farmers by maximizing the grain yield of maize and increasing the nutrient use efficiency of maize at both locations (Adamitulu and Meki), central rift valley of Ethiopia. Furthermore, we recommend the repetition of the experiments for many seasons and more locations to reach at a conclusive recommendation.

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