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Evaluating Yield and Agronomic Efficiency of Maize (*Zea mays* L.) through Application of Urea Stable at High Moisture Condition of Southwestern Ethiopia

Habetamu Getinet[1*] and Obsa Atnafu[2]

[1]*Ethiopian Institute of Agricultural Research, Debre Markos Agricultural Research Center,P.O.Box, 357, Debre Markos, Ethiopia*
[2]*Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Center, P.O.Box 92, Jimma, Ethiopia*

**Corresponding author*

Abstract

Nitrogen is the most yield-limiting nutrient for maize growth and development as in most soils of the study area and it needs effective management option to enhance crop production. Adoption of appropriate management may overcome N lose and enhance its use efficiency in crop plants which are associated with soil and crop management and include appropriate source and timing of application. Thus, afield experiment was done with an objective to determine mineral N fertilizer source and time of application on agronomic parameters and yields of maize on Nitisols of Kersa and Tiro Afeta District Southwestern Ethiopia during 2017/18 cropping season. The experiment was laid out in RCBD having eight treatments with three replications. Soil sample was taken at a depth of 0-20 cm before treatment application. The soil result showed moderately acidic in reaction, sandy clay texture, low in Tot. N and Av.P and medium in K, OM and CEC at both tested sites. The collected data was subjected to ANOVA using SAS 9.3 version software. LSD test was used to separate means at 5% level of significant. Grain yield, Biomass yield and AE were highly affected by time, rate and N source. The highest grain yield (7067.4 kg ha^{-1}atKersa and 8178.1 kg ha^{-1} at Tiro Afeta) and biomass in average (21.5 t ha^{-1}) were obtained from application of 138 kg ha^{-1} N from urea stable in splits while the lowest grain yield (3251.4 and 3145.4 kg ha^{-1}) and biomass yield (14.75and 11.39 t ha^{-1}) were recorded from control at both sites, respectively. The highest Agronomic Efficiency of Nitrogen (41.29 kg kg^{-1}) at Kersa and (52.10 kg kg^{-1}) at Tiro Afeta was responded from plots treated with 46 kg ha^{-1} N and 138 kg ha^{-1} N urea stable respectively. Moreover, application of 138 kg ha^{-1} N from urea stable in splits provided the maximum net benefit of 61701.93 ETB ha^{-1} with Marginal rate of return(MRR)(415.28%) at Kersa and 72198.05 ETB ha^{-1} with MRR (1795.28%) at Tiro Afeta. Therefore, application of 138 kg ha^{-1} N from urea stable (treated with urease inhibitor) in splits is recommended for farmers to maximize maize production thereby reducing nitrogen lose at high soil moisture conditions.

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Keywords

Maize, Nitrogen, Urea stable.

Introduction

Maize (*Zea mays* L.) is one of the main and popular cereal crop cultivated in Ethiopia due to its high value as stable food as well as its stover demand for animal feed, fuel and even for construction purposes (Abebe *et al.*, 2016). It is the most important stable crop in terms of calorie intake in rural families where approximately88%

of maize produced is used as food, in both green cobs and grain (Mandefro *et al.,* 2001). Because of its multiple advantages, it ranks second in production area next to teff while it ranks first in its productivity among major cereal crops (Abate *et al.,* 2015) and it is, therefore, one of the high priority crops to feed the ever-increasing Ethiopian population. Despite the fact that its current productivity is higher than other major cereal crops, still the yield productivity is below its potential and there is also potential yield variability in research fields which produced up to 9.5-12 t ha^{-1} and 6-8.5t ha^{-1} on farmers field whereas the national average productivity is 3.675 tha^{-1}(CSA, 2017). Even many biotic and abiotic factors contribute the presence of this yield gaps, soil fertility depletion and poor nutrient management are the major factors contributing to low productivity (Mourice *et al.,* 2015).

Among the major mineral nutrients the higher grain yield response was recorded due to nitrogen (N)application than any other nutrients at all study sites in maize growing areas of southwestern Ethiopia, which clearly shows that N is the most yield limiting nutrient for maize intensification and hence needs special attention (Tesfaye *et al.,* 2019). Thus, N needs special management technique for crop production, which is one of the main concerns since it is the most important, and primary nutrient for growth and development of the crop and most susceptible to lost via leaching and volatilization (Blumenthal *et al.,* 2008). Therefore, selecting appropriate N source and methods of application can enhance yield productivity and nutrient use efficiencies thereby reduce the environmental pollution trough leaching. Application of Nover the optimum requirement of maize could not increase yield and may lead to an elevated level of nitrate in the soil and susceptibility to nitrate loss by leaching (Gehl *et al.,* 2005). Another research finding also indicated that abundant N supply favors ammonia losses, especially if the supply is in excess of plant requirements. However, the negative losses through leaching and indirect environmental impacts associated with maize production can minimized through efficient N management by adjusting time of application and selecting appropriate sources (Fageria and Baligar, 2005).

Nitrogen concentration in soil is relatively low, and its availability is often a limiting factor for plant growth in natural habitats as well as agricultural crop production. The use of urea and urea-based fertilizers has increased considerably over the past few years and currently accounting for approximately half of the world's agricultural N consumption. It is apparent that currently N use under most smallholder farmers in Ethiopia is very low on the average compared to any standard. On the other hand, N fertilizer is highly soluble and once applied to the soil it is lost through leaching, ammonia volatilization and nitrate denitrification. Thus, urea is an inorganic N source that needs to hydrolyze by the enzyme urease before ammonia volatilized. This hydrolysis of urea can be rapid under certain environmental conditions (Black *et al.,* 1987). The lower N recovery efficiency (NRE) of urea is credited to a number of factors including its fast hydrolysis, uneven spread, high application rates and less optimum soil conditions most probably at high soil moisture and temperature after urea application. In addition to lowering the efficiency of applied N nutrient, ammonia losses pose a potential environmental threat via eutrophication of lakes, rivers and other vegetation and may add to global warming by acting as a secondary source of nitrous oxide (N_2O) in the atmosphere.

Consequently, increasing N-use efficiency has become an important concern to maize producers due to escalating N fertilizer prices and environmental concerns. Previously conventional urea was used as a source of N to obtain optimum harvest in Ethiopia. However, blaming from the users was raised due to its high solubility that increases soil acidity and in high rainfall area loss of N through ammonium volatilization or fixation by clay minerals and leaching.

To minimize this problem and to increase use efficiencies of N, different sources have been tested somewhere else in different countries but not in Ethiopia. One of the products is Urea stable (46%N) with an added urea inhibitor N-(n-butyl)-thiophosphoric triamid (NBPT), which reduces losses due to volatilization, leaching and denitrification (Miraz, 2007). Urea stable (coated urea) is a concentrated N source that can apply as a granular (we have used) or liquid form, which is rapidly soluble, well absorbable that helps to improve N penetration to plant roots by restraining the sorption and fixation of NH_4^+ in the surface of soil layer.

It also helps to reduce its losses via ammonia volatilization to the atmosphere during surface application. Therefore, the experiment was developed (i) to determine optimum nitrogen fertilizer rate under high moisture condition, (ii) to evaluate agronomic efficiency and growth performance of maize and (iii) to determine optimum and economically feasible nitrogen rate for maize production.

Materials and Methods

Description of the study areas

The experiment was conducted on farmer's fields in major maize production areas at Kersa and Tiro Afeta Districts South western Ethiopia during 2017/2018 cropping season. The sites were selected to cover a broad range of major maize growing areas representing high rainfall agro-ecologies. Geographically the sites (Kersa) was located between 7°35′-8°00′N latitudes, 36°46′-37°14′E longitude and altitude that ranges from 1740 to 2660 masl and Tiro Afeta was located between 070 40' 09 3" N latitude and 0370 14' 41.5" E longitude at an altitude of 1750 masl, in southwest direction of Addis Ababa. The ten years (2002-2011) weather information at nearby study area (Jimma Agricultural Research Center) revealed the area receives abi-modal rainfall pattern with average annual rainfall of 1283.4 mm. The rainy season covers April to October where the maximum rainfall received on July and August at both sites. The minimum, maximum and average annual temperature of both sites was 13.5, 28.5 and 21.0°C, respectively. The predominant soil type in Southwestern Ethiopia in general and the study sites in particular is Nitisols according to (FAO, 2001) soil classification having reddish in colour. On average, the soil is deep and relatively highly weathered well-drained, sandy clay in texture and strongly to moderately acidic in reaction.

Treatments, Experimental Design and Procedure

The experiment was conducted at two districts of farmer's fields during 2017/18 cropping season to evaluate growth performance, yield and agronomic efficiency of maize through application of urea stable. The experiment contains eight treatments (control, 92 kg ha^{-1}N from conventional urea, 92 kg ha^{-1}N from urea stable, 92 kg ha^{-1}N from urea stable in splits, 46 kg ha^{-1}N urea stable at planting,138 kg ha^{-1}N from urea stable in splits,138 kg ha^{-1}N from conventional urea in splits and 138 kg ha^{-1}N from urea stable at planting. The recommended rate of N and P are 92 kg ha^{-1} and 30 kg ha^{-1} which was set based on recommendation set for maize on Nitisols of Jimma area (Wakene *et al.*, 2011). Conventional urea, Urea stable and TSP was used as sources for supplying N and P. The recommended rate of P (30kgha^{-1}) was applied at planting to all experimental plots while N was applied according to the treatment set up (Table 1). All cultural practices such as weeding and hoeing were done uniformly for all plots, as per the recommendation given for maize production in the area.

Soil sample was collected from the experimental sites at a depth of 0-20 cm in a zigzag methods using auger before treatment application. The working soil was prepared and analyzed following standard laboratory procedures for some selected soil properties. The experimental fields were prepared using oxen plow in accordance with conventional farming practices followed by farming community in the area where, plowed four times. The gross plot size was 25.6m^2 (6.4m x 4m) that accommodated eight rows as an experimental unit with 14.4m^2 (4.8m x 3m) net plot area. Hybrid (BH-661) maize variety, which is high yielder as compared to other improved varieties was used as a test crop on both sites that was planted in rows with spacing of 0.8m and 0.5m between rows and plants, respectively. Planting was done on early May 2017 where three seeds per hill were planted and after emergence thinned to two plants per hill. During different growth stages of the crop, all the necessary field management practices were carried out as per the practices followed by the farming community around the areas. To avoid boarder effects, both ends of rows and row length of a plot was left during harvesting. Hence, 14.4 m^2 (4.8 m x 3m) of net plot size was used for data collection.

Agronomic Data Collection

All necessary data was collected on plant basis from the harvestable six central rows (14.4m^2) out of eight rows per plot. The crop data collected includes: plant height, leaf area index (LAI), grain and biomass yield.

The height (cm) of ten randomly selected plants per plot were measured from ground level to the point where the tassel started branching when 50% of plants reached tasseling stage and the mean value was taken as plant height.

Leaf area index was determined on ten randomly selected plants per plot with primarily calculating largest leaf area dividing the average of leave by each plant area and the mean value taken as LAI per plant for each plot.

Grain and biomass yield was collected at harvesting from the net plot area of 14.4 m^2 and converted into kilogram per hectare basis. Grain yield was adjusted to 12.5% moisture level, which is the standard moisture content of cereals; whereas the above ground biomass yield was calculated as the sum of the grain and stover yields. Agronomic efficiency (AE) was calculated as grain yield of each fertilized treatment minus grain yield of control divided by the quantity of fertilizer applied as follows:

$$AE = \frac{\text{Grain yield of fertilized plots} - \text{Grain yield of control plots}}{\text{Fertilizer applied(kgha}^{-1}\text{)}}$$

Economic Analysis

As farmers attempt to evaluate the economic benefits of the yield, partial budget, dominance analysis and marginal rate of return, (MRR) was done to identify the rewarding treatments. Yield from on-farm experimental plots was adjusted downward by 10% i.e., 5% for management difference and 5% for plot size difference, to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment. Average market grain price of maize (ETB 10.50 kg^{-1}), farm-gate price of urea fertilizer (ETB 14.8 kg^{-1}) and Urea stable (ETB 16.95 kg^{-1}) was used for economic analysis.

Statistical Analysis

The collected agronomic and yield related data was subjected to analysis of variance (ANOVA) appropriate to randomized complete block design (RCBD) using statistical analysis system (SAS Institute, 2012) 9.3 version software computer program following the procedures described by (Gomez and Gomez, 1984). Mean separation of significant treatments were carried out using the least significant difference (LSD) test at 5% probability level.

Results and Discussion

Soil Physico-chemical Properties before Planting

Soil samples was collected from the experimental sites using augur at a depth of (0-20 cm) and analyzed for some selected soil properties before treatment application as shown (Table 2). The soil was sandy clayey in texture and moderately acidic in reaction (Tekalign, 1991). The bulk density values were within normal range of mineral soils at both sites. According to the finding of Bogale (2014) total N was rated as low whereas Ava. Pat Kersa was rated as medium and low at Tiro Afeta Landon (1991). According to (Horneck *et al.*, 2011) exchangeable K was rated from high to very high at Kersa and Tiro Afeta, respectively and OM were medium contents in the soil. According to Hazelton and Murphy (2016), CEC of the experimental site was rated as medium. Generally, the result of showed the soils of the study sites had poor chemical fertility.

Growth Parameters

Plant height

There was highly significant variation ($P<0.01$) among N source on maize plant height at both sites. Application of 138 kg ha^{-1}N from urea stable in splits stable in splits recorded the highest plant height (296.67cm) and at Tiro Afeta the highest plant height (306.00cm) was recorded from application of 92 kg ha^{-1}N from urea stable in splits. On the other hand, the shortest plant height (264.33cm and 231.00cm) were recorded from unfertilized plots at kersa and Tiro Afeta, respectively, which might have due to low soil fertility level in the study area because Plant growth and development might be retarded significantly if any of nutrient elements is less than its threshold value in the soil or not adequately balanced with other nutrient elements (London, 1991). This result was in agreement with the finding of (Amsal and Tanner, 2000) who reported that a positive and linear response of plant height to N fertilizer application in the central highlands of Ethiopia.

Leaf Area Index (LAI)

The maximum LAI (2.36 at Kersa and 2.00 at Tiro Afeta) was recorded from plots treated with 138Kg ha^{-1} N from urea stable in splits while least leaf area index (1.07) in average was recorded from control plots at both sites (Table 3). The reason for an increase in leaf area index for those treatments might be due to development of more expanded leaves produced in response to slow release of N from urea stable in maize growth period. This suggest that availability of N increased leaf size in an attempt to maximize light interception and maximize the overall plant economy for acquisition of resources needed for growth and development there by it has a primary importance in increasing yield. The result is in line with Oscar and Tollenaar (2006) from Ontario, Canada who reported that leaf area index of maize increased with the application of higher rate of N and decline in much prominent in low rate of N.

Stem girth(Stem diameter)

The ANOVA showed that there was a highly significant ($P< 0.01$) effect of N rate on stem girth. The maximum stem diameter (3.10cm) at kersa was recorded due to supplying 92 kg ha^{-1}N from urea stable in splits and at Tiro Afeta (2.87cm) was obtained from application of 92 kg ha^{-1}N from urea stable once at plantings, while minimum stem girth (2.52cm and 2.23cm) was recorded from control. Stem girth is an important growth parameter, which influence carbon storage and its subsequent utilization for grain filling and it contributes significantly to grain yield of maize because it controls both number of grains per cob and grain size.

Maize Grain yield

Analysis of variance on grain yield of maize showed that application of 138 kg ha^{-1} N from urea stable in two splits was responded significantly higher compared with the remaining treatments. Accordingly, grain yield ranged from 3251.4kg ha^{-1} to 7067.4kg ha^{-1} at Kersa and 4769.4kg ha^{-1} to 8178.1 kg ha^{-1}at Tiro Afeta recording the lowest grain yield from the control while the highest obtained from application of 138 kg ha^{-1} N from urea stable in two splits. The highest yield obtained due to urea stable application might be delayed hydrolysis in the presence of urea stable (urea treated with agrotain) that improves the bioavailability of N through reductions in plant urease activity, thus providing plants an opportunity to convert the absorbed urea into protein more efficiently. Urea stable also provides an opportunity to take up more N in either urea or NH_4^+ forms and to convert N into plant protein more efficiently in its life span (Middleton and Smith, 1979). This result agreed with (Zhengping *et al.*, 1996) who reported that slow urea hydrolysis and a lower accumulation of soil NH_4^+ after applying urea with urease inhibitor to soils under controlled conditions whenever the soil contains appropriate moisture. This shows that it is not only the time and source of N that limit the production of maize crop but also the sufficient availability of moisture is a limiting factor. Therefore, in areas where moisture is sufficient like Kersa and Tiro Afeta, supplying of urea stable fertilizer could be preferable in terms of yield and economic benefit than conventional urea fertilizer. The low yield in unfertilized plots on the other hand might have been due to reduced leaf area development resulting in lesser radiation interception and, consequently, low efficiency in the conversion of solar radiation (Sallah *et al.*, 1998). Compared to application of 138 kg ha^{-1} N from conventional urea in two splits, mean grain yield was increased by 5% and 15.8 % due to application of 138 kg ha^{-1} N from urea stable in splits at Kersa and Tiro Afeta, respectively. This increment in grain yield due to application of slow release of N plant nutrients is an indicator of low soil fertility level in the study area for maize production.

Biomass yield

With regard to biomass yield, the highest value (21.67 t ha^{-1} and 21.42 t ha^{-1}) were obtained from application of 138 kg ha^{-1} N from urea stable in two splits while the lowest biomass yield(14.75 t ha^{-1} and 11.39t ha^{-1}) were recorded from control plots at Kersa and Tiro Afeta, respectively. Compared with application of 138 kg ha^{-1} N from conventional urea, mean biomass yield was increased by 4.6 and 14.5% due to application of 138 kg ha^{-1} N from urea stable in splits at Kersa and Tiro Afeta, respectively. Since biomass is a function of yield and yield contributing parameters including leaf size, plant height and stock thicknesses, which often improved through higher photosynthesis, facilitated by more nutrient availability from external and inherent soils. In agreement with this result, by Selamyihun *et al.*, (1999) showed that biomass yield of durum wheat increased significantly with each incremental dose of N.

Agronomic Efficiency

At Kersa, the highest agronomic efficiency of nitrogen (AEN) (41.29kg kg^{-1}) was recorded from plots treated with 46 kg ha^{-1}N from urea stable applied at planting indicating, 41.29 kg of maize grain was obtained from one kg of N invested from urea stable at once application. At Tiro Afeta, the highest AEN (52.10kg kg^{-1}) was obtained from plots treated with 92 kg ha^{-1}N from urea stable applied in splits indicating 52.10 kg of maize grain was provided from one kg of N invested from urea stable (Table 5). The current result revealed that the highest rate of N fertilizer has resulted in low Nitrogen AE of maize. On the other hand, the maximum N use efficiency was obtained from application of the lowest rate of N from urea stable at both study sites. The low NUE of conventional urea might attributed due to fast hydrolysis of conventional urea, less optimum soil conditions with high application rate (Mohammad *et al.*, 2010) that supports the current finding where the highest N response was obtained from the lowest rate of urea stable (46kg ha^{-1}N at Kersa and 92kg N ha^{-1}N at Tiro Afeta). Nitrogen plays a very important role in crop productivity and its deficiency is one of the major limiting factors for cereal production.

Table.1 Treatment set up at Kersa and Tiro Afeta experimental sites in 2017/18cropping season

Treatments	N-rate (Kg ha^{-1})	Split form (kg ha^{-1})	Once applied
T1= Control (no supply of nitrogen)	0	0	0
T2 = Rec. N from Cu in two splits	92	31/61	-
T3 = Rec. N from Us applied once at planting	92	-	92
T4 = Rec. N from Us applied in two splits	92	30/62	-
T5 = Half of rec. N from Us applied at planting	46	-	46
T6 = Half more than rec. N from Us applied in two splits	138	46/92	-
T7 = Half more than rec. N from Cu applied in two splits	138	46/92	-
T8 = Half more rec. N from Us applied at planting	138	-	138

Where: Us = Urea stable and Cu = Conventional urea

Table.2 Soil physico-chemical properties of the experimental sites before planting

Soil properties	Kersa	Tiro Afeta	Rating	Soil properties	Kersa	Tiro Afeta	Rating
Textural class	S. Clay	S. Clay	Sandy Clay	T. N (%)	0.18	0.17	Low
B.D (gm cm^{-3})	1.25	1.12	Optimum	Av. P (mg kg^{-1})	9.90	3.55	Low
pH (1: 2.5H_2O)	5.50	5.10	Moderate acidic	CEC (cmol (+) kg^{-1})	15.91	13.16	Medium
OM (%)	4.75	2.76	Medium	Exchangeable K	264.64	625.40	High

OM = Organic matter, T. N=Total nitrogen, Av. P = Available phosphorus, pH = power of hydrogen, B.D = Bulk density, S. clay = Sandy clay, CEC = Cation exchange capacity, K = Potassium.

Table.3 Mean value of plant height and leaf area of maize

Treatments	Plant height (cm)		Leaf Area Index		Stem girth (cm)	
	Kersa	Tiro Afeta	Kersa	Tiro Afeta	Kersa	Tiro Afeta
0 N (No Nitrogen)	264.33d	231.00c	1.10d	1.04d	2.52c	2.23d
92 kg ha^{-1} N Cu	285.33abc	283.67ab	1.78c	1.65bc	2.89ab	2.77abc
92 kg ha^{-1} N Us at planting	275.73bcd	292.00ab	1.79c	1.61bc	2.78abc	2.87a
92 kg ha^{-1} N Us in split	294.60a	306.00a	1.85bc	1.65bc	3.10a	2.77abc
46 kg ha^{-1} N Us at planting	291.67ab	265.67bc	1.78c	1.49c	2.98ab	2.83ab
138 kg ha^{-1} N Us in split	296.67a	296.67ab	2.36a	1.74abc	2.99ab	2.67c
138 kg ha^{-1} Cu in split	285.33abc	279.33ab	1.83bc	1.93ab	2.72bc	2.71bc
138 kg ha^{-1} N Us in split	273.73cd	301.67ab	2.06b	2.00a	3.03ab	2.81abc
LSD (0.05)	16.20	37.05	0.25	0.34	0.35	0.15
CV (%)	3.30	7.50	7.72	11.97	6.88	3.21

Means within a column followed by the same letter are not significantly different from each other at $p < 0.05$. ^{NS} not significant at $P > 0.05$, * significant at $P < 0.05$, and **significant $P < 0.01$

Table.4 Mean value of maize grain and biomass yield at Kersa and Tiro Afeta in 2017/18

Treatments	Grain Yield (kg ha^{-1})		Biomass Yield (t ha^{-1})		Harvest Index (%)	
	Kersa	Tiro Afeta	Kersa	Tiro Afeta	Kersa	Tiro Afeta
0 N (No Nitrogen)	3251.40e	3145.40d	14.75c	11.39e	20.99c	27.49d
92 kg ha^{-1} N Cu	5716.20c	7918.9ab	19.53ab	19.74abc	29.44a	40.05ab
92 kg ha^{-1} N Us at planting	4345.0d	5648.20c	15.68c	17.14cd	29.85a	32.68c
92 kg ha^{-1} N Us in split	5969.3bc	7938.2ab	19.69ab	20.38ab	30.25a	37.61ab
46 kg ha^{-1} N Us at planting	5151.0cd	4769.40c	19.48ab	15.74d	25.05b	31.69c
138 kg ha^{-1} N Us in split	7067.40a	8178.10a	21.67a	21.42a	31.02a	41.04a
138 kg ha^{-1} Cu in split	6715.7ab	6884.50b	20.68ab	18.71bc	31.09a	36.61b
138 kg ha^{-1} N Us in split	5253.0cd	7133.6ab	17.72bc	18.49bc	30.29a	38.59ab
LSD (0.05)	930.81	1204.10	3.46	2.64	3.14	3.86
CV (%)	9.78	10.66	10.58	8.44	6.28	6.17

Means within a column followed by the same letter are not significantly different from each other at P< 0.05. ^{NS} not significant at P> 0.05, * significant at P< 0.05and **significant P< 0.01.

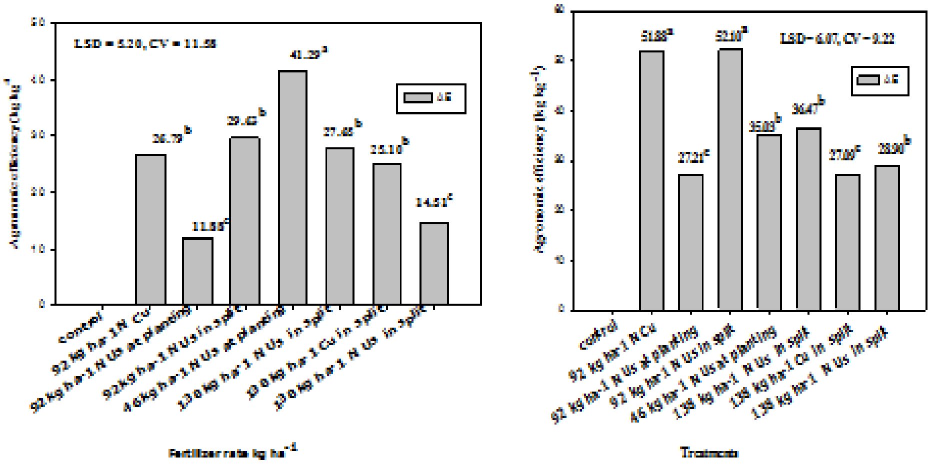
Table.5 Partial budget, marginal rate of return and dominance analysis of N fertilizer at Kersa

Treatments	GY (Kg ha^{-1})	Adj.GY (Kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
Control	3251.4	2926.3	30725.7	0	30725.7	-
46 kg ha^{-1} N Us at planting	5151.0	4635.9	48676.9	1695	46981.9	
92 kg ha^{-1} N Cu	5716.2	5144.6	54108.1	2960	51148.1	
92 kg ha^{-1} N Us at planting	4345.0	3910.5	41060.3	3390	37670.3	D
92 kg ha^{-1} N Us in split	5969.3	5372.4	56409.9	3390	53019.9	-
138 kg ha^{-1} Cu in split	6715.7	6044.1	63463.4	4440	59023.4	
138 kg ha^{-1} N Us in split	7067.4	6360.7	66786.9	5085	61701.9	415.3
138 kg ha^{-1} N Us in split	5253.0	4727.7	49640.9	5085	44555.9	D

Table.6 Partial budget, marginal rate of return& dominance analysis of N fertilizer at Tiro Afeta

Treatments	GY (Kg ha^{-1})	Adj.GY (Kg ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})	MRR (%)
Control	3145.4	2830.9	29724.0	0	29724.03	-
46 kg ha^{-1} N Us at planting	4769.4	4292.5	45070.8	1695	43375.8	
92 kg ha^{-1} N Cu	7918.9	7127.0	6414.3	2960	3454.3	D
92 kg ha^{-1} N Us at planting	5648.2	5083.4	53375.5	3390	49985.5	
92 kg ha^{-1} N Us in split	7938.2	7144.4	75015.9	3390	71625.9	-
138 kg ha^{-1} Cu in split	6884.5	6196.1	65058.5	4440	60618.5	D
138 kg ha^{-1} N Us in split	8178.1	7360.3	77283.1	5085	72198.1	1795.3
138 kg ha^{-1} N Us in split	7133.6	6420.2	67412.5	5085	62327.5	D

Fig.1 Agronomic efficiency of maize at Kersa (left side) and Tiro Afeta (right side).



Since higher fertilizer use efficiency is always associated with low fertilizer rate, cultural practices for promoting integrated nutrient management might 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 (Bradand Fred, 2016)because using urease and nitrification inhibitors reduced N losses and increased N use efficiency by crops which supports the current study.

Partial budget Analysis

An increase in output will always raise profit so as long as the marginal rate of return is higher than the minimum acceptable marginal rate of return (MRR) which is 100% in developing countries (CIMMYT, 1988). The partial budget analysis showed fertilizer application at rate of 138 kg ha^{-1}N from urea stable applied in two splits provided the maximum net benefit (61701.93 ETB ha^{-1}) with MRR (415.28%) at Kersa (Table 6), suggesting that for each birr invested in the production of maize, the farmers could earn birr 4.15 after recovering their cost of production. Similarly, the maximum net benefit of birr (72198.05 ETB ha^{-1}) with MRR (1795.27%) were recorded from the investment of 138 kg ha^{-1}N from urea stable applied in two splits at Tiro Afeta testing site(Table 7). This result suggests that for a birr invested in the production of maize, the farmers could earn 17.95 birr after recovering their cost of production. According to CIMMYT (1988), if the treatment fills the minimum acceptable MRR, the treatment having high net benefits will select for recommendation. Therefore, application of 138 kg ha^{-1}N from urea stable in two splits at both Kersa and Tiro Afeta study area can be recommendable for farmers to maximize maize production.

Increasing maize yield in the country becomes an essential component of modern agriculture to keep pace with the increasing population. From the results of the present study, it can concluded that it is possible to increase maize yield on average by about 15.69 percent using an economic optimum level of 138 kg ha^{-1}N from urea stable. Compared to the effectiveness of different nitrogen sources, applying urea stable has a significant effect on yield over conventional urea at the same rate of fertilizer application both in terms of grain and biomass yields because conventional urea lost to the atmosphere by ammonia volatilization, a reaction mediated by the activity of the urease enzyme before absorbed by plants. Therefore, increasing N-use efficiency has become an important concern to maize producers due to escalating N fertilizer prices and environmental concerns.

The partial budget analysis revealed that the maximum net benefit and marginal rate of return (MRR) was obtained from application of 138 kg ha^{-1}N from urea stable applied in splits at both testing sites. The results 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 use efficiency decreased with higher rates of N fertilizer applied as urea treated with Agrotain. Therefore, there is considerable potential for improving farm production, profitability and sustainability of maize by using urea stable. Hence, we can recommended that application of N at a rate of 138 kg ha^{-1}from urea stable applied in splits is better to increase profitability of the farmers by maximizing the grain yield of maize and increasing nutrient use efficiency at both experimental locations (Kersa and Tiro Afeta).

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