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Yield Response of Maize to N-(N-Butyl) - Thiophosphoric Triamide) (NBPT) Stabilized Urea and Application Time in Moisture Stressed Area of the CRV of Ethiopia

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Abstract: The effectiveness of Urease inhibitors was evaluated in moisture stressed area of the Central Rift Valley of Ethiopia on maize (*Zea mays* L.) at Dugda and Adami Tulu Jido Kombolcha (ATJK) districts. Different levels of Urease inhibitors fertilizer with conventional Urea fertilizers were evaluated for two consecutive cropping seasons (2015-2016). The experiment was laid out in randomized complete block design and replicated three times. The result revealed that at ATJK district the application of 64kg/ha Urease inhibitors at planting significantly boosted the maize grain yield (4057 kg ha^{-1}). At Dugda the application of 192kg/ha Urease inhibitors gave the highest yield (3332 kg ha^{-1}) though, statistically insignificant at $p<5\%$. At ATJK a unit kg of N application in the form of Urease inhibitors at planting was increased in maize grain yield by 17.61 kg from plot received 64 kg N ha^{-1}. At Dugda the nitrogen use efficiency of maize lower than ATJK, the application of the same rate gave only 9.58 kg of grain /kg of N. The partial budget analysis also showed that the application of 64 kg N ha^{-1} gave a maximum marginal rate of return 198.5 and 62.29 % at ATJK and Dugda districts respectively. At Dugda this rate gave lower than the minimum acceptable rate of return.

Key words: Stabilized Urea · Conventional Urea · Nitrogen Use Efficiency · Marginal Rate of Return

INTRODUCTION

Nitrogen (N) is often the most limiting nutrient for crop yield in many regions of the world and it is one of the main inputs for cereals production systems. In Ethiopia, for the last five decades Urea and Di-ammonium Phosphate (DAP) were used as a source of nitrogen and phosphorus fertilizers to obtain optimum harvest. The increase of agricultural food production worldwide over the past four decades has been associated with a 7-fold increase in the use of N fertilizers [1].

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 [2]. Highly soluble N fertilizers, like urea may be lost from the soil plant system through leaching, NH_3 volatilization, de-nitrification and immobilization or may be fixed on the soil colloids as NH_4-N form [3]. 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 [4]. 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 [5].

Different mechanisms which can improve the nitrogen fertilizer 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].

Urea undergoes hydrolysis via the urease enzyme in soil, causing increases in the soil pH in the surrounding area of the granules and resulting in NH_3 losses. The average N losses 16% and can reach 40% or more worldwide in hot and humid conditions. The use of urease inhibitors is an effective way to reduce NH_3 losses through volatilization. Among commercially available urease inhibitors, merely N-(n-butyl) thiophosphoric triamide (NBPT) has been used globally, being the most

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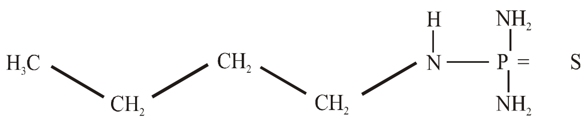
successful. In comparison to urea, NBPT-treated urea reduces NH_3 loss by around 53% [7]. However, most of the management options, such as slow N releasing fertilizers, urease inhibitor and nitrification inhibitors are not being practiced in Ethiopia. For instance, slow nitrogen release urea fertilizers can increase nitrogen use efficiency through either slowing the release rate or by altering reactions that lead to losses [8]. Urease inhibitors are one form of slow nitrogen releasing urea.



The nitrogenous fertilizer Urease inhibitors are urea enriched with the inhibitor of urease NBPT (N-(n-butyl) - thiophosphoric triamide). It reduces losses due to volatilization, leaching and denitrification. Thus, appropriate source of N fertilizer, rate and time of application may improve N fertilizer use efficiency of crops. However, the rate and time of application of slow nitrogen releasing fertilizer like Stabilized Urea (NBPT) have not been well investigated in Ethiopia on yield and nitrogen use efficiency of maize. The effect of the application of Stabilized Urea in moisture stressed area like Dugda and ATJK have not been evaluated. Therefore, this study was initiated with the following objectives to determine optimum NBPT nitrogen fertilizer rate and application time for maize under low moisture condition and evaluate the nitrogen use efficiency of maize under low moisture conditions in CRV of Ethiopia:

MATERIALS AND METHODS

Field experiments were conducted on farmers' fields in the 2015 and 2016 crop growing seasons on two different locations situated N 7°52'29.9'' and E 38°42' 42'' 1644 masl, 172 km away from the capital Adiss Abeba and N 8°10' 26'' and E 38°50' 44'' 1665 masl, 130 km away from the Adiss Abeba at Adami Tulu Jido Kombolcha (ATJK) and Dugda districts respectively.

The treatments were:

- Control- without N.
- 64 kg N ha^{-1}N from Stabilized Urea (NBPT) applied at planting.
- 128kg N ha^{-1} from conventional Urea in split.
- 128kg N $ha^{-1}$from Stabilized Urea (NBPT) applied at planting.
- 192kg N ha^{-1} from Stabilized Urea (NBPT) applied at planting.
- 192kg N ha^{-1} from Stabilized Urea (NBPT) in split.

Treatments were laid out in randomized complete block design with three replications. The conventional Urea and Stabilized Urea (NBPT) were the sources of N for nitrogen fertilizer and triple supper-phosphate (TSP) for phosphorus fertilizer. Phosphorus fertilizer was applied in band at planting time and N was applied as per the treatment set-up. Maize (Melkassa 2 variety) was used as a test crop and Plot size 5.0 m by 3.75 m (5 rows) and 3 harvestable rows, planted in rows 75 cm row spacing and 25 cm between plants. Other agronomic practices were applied as per the recommendations for maize.

At agronomic maturity, maize plants within the three central rows of each plot in a net plot area of 11.25 m^2 were harvested for grain yield determination. Maize grains were adjusted to 12.5% moisture content. NAE was determined using the following formula by Dobermann [9]:

$$NAE\ (kg\ kg^{-1}) = (YN_f - YN_0) / N_r \qquad (1)$$

where YN_f is the grain yield of the fertilized plot (kg), YN_0 is the grain yield of the unfertilized plot (kg) for each replicate and N_r is the quantity of N fertilizer applied (kg).

Statistical Analysis: The data were subjected to analysis of variance using the general linear model procedure (PROC GLM) of SAS statistical package version 9.0 software program, [10]. The total variability for each trait was quantified using pooled analysis of variance over years using appropriate models. Means for the effects of N fertilizer treatments (n = 6) were compared using the MEANS statement with the least significant difference (LSD) test at the 0.05 level of probability [11].

Partial Budget Analysis: As farmers attempt to evaluate the economic benefits of shift in practice, partial budget analysis 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 8.00 kg^{-1}), farm-gate price of urea fertilizer (ETB 14.95 kg^{-1}), Stabilized Urea (NBPT) (ETB 16.95) and labour valued at ETB 60.00 per person-day were used for fertilizer application.

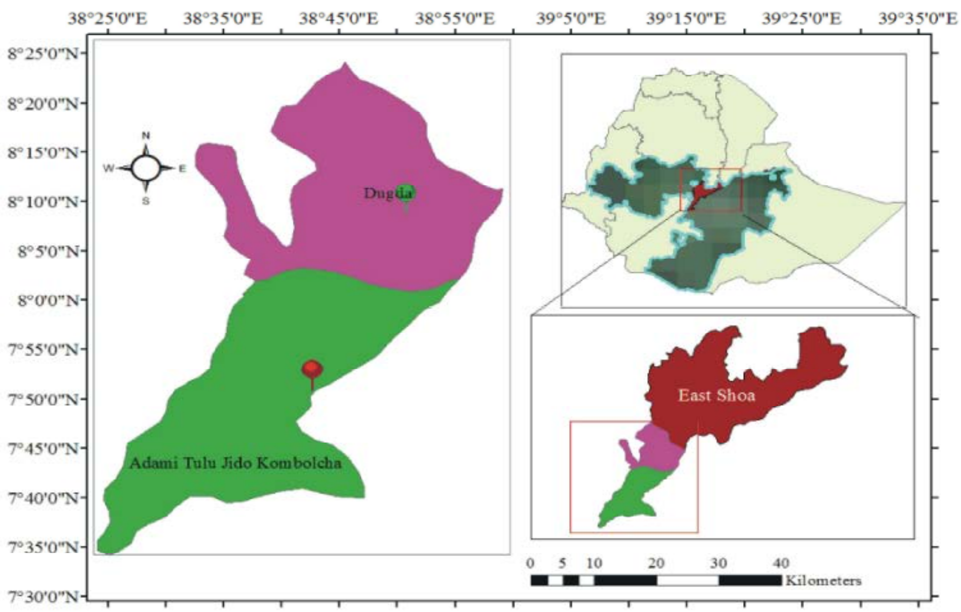


Fig. 1: Map of testing sites

RESULTS AND DISCUSSION

Grain Yields of Maize: At ATJK and Dugda in the central rift valley of Ethiopia, treatment effects were significant for grain yields of maize over two cropping seasons. At Adami Tulu, application of 64 kg N ha^{-1} from Stabilized Urea (NBPT) at planting resulted in significantly higher maize grain yield of 4, 057 kg ha^{-1}. In contrast, at Dugda the maximum grain yield of 3, 332 kg ha^{-1} was achieved from the addition of 50% over the recommended rate (192 kg N ha^{-1}) in the form of Stabilized Urea (NBPT) (Table 1). However, differences among treatments were not statistically significant, except compared with the control. As mentioned earlier, in areas where rainfall scarcity is a problem and soil moisture deficit is a limiting factor Stabilized Urea (NBPT) could be preferable in terms of yield.

Nutrient Use Efficiency: Nutrient use efficiency is the amount of increased yield obtained in kg from addition of one kg of nutrient [12]. The higher nitrogen use efficiency were recorded for plots treated with 64 kg followed by 128 kg N ha^{-1} in the form of Urease inhibitors at planting. The lowest at 192 kg N ha^{-1} in the form of Urease inhibitors at planting and in split respectively (Fig. 1). Thus, a unit kg of N application in the form of Urease inhibitors at planting caused increase in maize grain yield by 9.58 kg from plots treated with 64 kg N ha^{-1} and 6.69 kg from plot treated 128 kg N ha^{-1} in the form of Urease inhibitors at planting at Dugda district.

At ATJK the highest nitrogen use efficiency were recorded for plots that received 64 kg in the form of Urease inhibitors at planting followed by 128 kg N ha^{-1} in the form of conventional Urea in split. The lowest at 192 kg and 128 kg N ha^{-1} in the form of Urease inhibitors at planting respectively (Fig. 1). Therefore, a unit kg of N application in the form of Urease inhibitors at planting caused increase in maize grain yield by 17.61 and 9.58 kg from plots treated with 64 kg N ha^{-1} and 5.75 kg from plot treated 128 kg N ha^{-1} conventional Urea in split at both ATJK and Dugda districts respectively.

The highest nitrogen use efficiency in both districts were recorded at the lowest dose of Urease inhibitors this is because urea stabilizer (NBPT) is more effective in retarding urea hydrolysis in alkaline soil [13] and hence improve the nitrogen use efficiency.

Partial Budget Analysis for Maize: At Dugda, the result of the partial budget analysis revealed that the application of 64 kg ha^{-1} Urease inhibitors fertilizer at planting provided the highest net benefit of 19, 233.82 ETB ha^{-1} with MRR of 62.29% which is lower than 100% the minimum acceptable rate of return (MARR) according to CYMMIT[14] (Table 2). Thus, the application of lower doses of Urease inhibitors may result in high net benefit and MRR for the production of maize. At Adami Tulu, the same rate of Urease inhibitors provided the highest net benefit of 26, 484.3 ETB ha^{-1} with MRR of 198.51 (Table 3), suggesting for each birr invested in the production of maize, the farmers could earn birr 1.98 after recovering their cost of production.

Table 1: Maize grain yield (kg ha^{-1}) as affected by different N fertilizer sources and rates at different agro-ecologies and soil types in 2015 and 2016 cropping seasons

Treatment	Adami-Tulu	Dugda
Without N	2930[b]	2436[b]
64 N kgha^{-1} from Urease inhibitors applied at planting	4057[a]	3049[ab]
128 N kgha^{-1} from Urea in split	3666[a]	3184[ab]
128 N kgha^{-1} from Urease inhibitors applied at planting	3505[ab]	3292[a]
192 N kgha^{-1} from Urease inhibitors in split	3986[a]	3332[a]
192N kgha^{-1} from Urease inhibitors applied at planting	3592[ab]	3231[a]
LSD (<0.05)	666.6	788.6
CV (%)	15.58	26.9

Note: Means in a column followed by the same letter are not significantly different at p<0.05. CV= Coefficient of variability, LSD= List significant difference

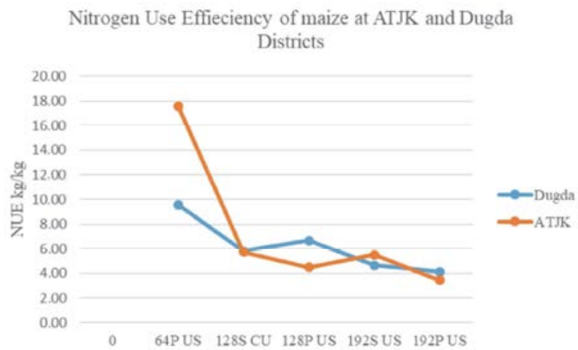


Fig. 1: Nitrogen use efficiency of Maize at ATJK and Dugda
CU = Conventional urea, p-@planting, s-in split, US = Urease inhibitor,

Table 2: Partial budget, marginal rate of return and dominance analysis of Urease inhibitors fertilizer on maize at Dugda

	kg ha^{-1}		ETB ha^{-1}			
N Rate kgha^{-1}	GY	10% AGY	GFB	TC V	N Benefit	MRR %
0 No N	2436.2	2192.58	17540.64	0	17540.64	
64 US p	3048.9	2744.01	21952.08	2718.261	19233.82	62.29
128 CU s	3183.9	2865.51	22924.08	4880	18044.08	D
128 US p	3291.8	2962.62	23700.96	5256.522	18444.44	D
192 US p	3231.4	2908.26	23266.08	7734.783	15531.3	D
192 US s	3332.4	2999.16	23993.28	8034.783	15958.5	D

Table 3: Partial budget, marginal rate of return and dominance analysis of Urease inhibitors fertilizer on maize at ATJK

	kg ha^{-1}		ETB ha^{-1}			
N Rate kgha^{-1}	GY	10% AGY	GFB	TC V	N Benefit	MRR %
0 No N	2930.3	2637.27	21098.16	0	21098.16	
64 US p	4057.3	3651.57	29212.56	2718.261	26494.30	198.51
128 CU s	3666.2	3299.58	26396.64	4880	21516.64	D
128 US p	3504.8	3154.32	25234.56	5256.522	19978.04	D
192 US p	3592	3232.8	25862.4	7734.783	18127.62	D
192 US s	3985.8	3587.22	28697.76	8034.783	20662.98	D

CONCLUSIONS AND RECOMMENDATIONS

At Adami Tulu, application of 64 kg N ha^{-1} from Urease inhibitors at planting resulted in significantly the highest maize grain yield. At Dugda the maximum grain yield was achieved from the addition of 192 kg N ha^{-1} in the form of Urease inhibitors in split.

Thus, similar to the grain yields, application of 64 kg N ha^{-1} as Urease inhibitors at planting resulted in the highest net return and MRR and also high nutrient use efficiency at ATJK, at Dugda this rate gave the highest net return, MRR and also high nutrient use efficiency and thus this rate could be recommended for maize production at both ATJK and Dugda districts.

The N levels investigated in this study were considerably higher than the recommended N fertilizer rates both Urease inhibitors and conventional urea should have been compared with the recommended N fertilizer rate for maize production.

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