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# Maize Nitrogen Use Efficiency and Yield as Affected by Fertilizer Nitrogen Form and Rate of Application in the Guinea Savanna Agro Ecological Zone of West Africa

**Kodjovi Sotomè Detchinli and Jean Mianikpo Sogbedji***

School of Agronomy, University of Lome, Lome, Togo

***Corresponding author***

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**A B S T R A C T**

Maximizing nitrogen (N) use efficiency is needed to enhance maize (*Zea mays* L.) production in the coastal western Africa. We assessed the effects of N fertilizer rate and form of application on the yield and N use efficiency under maize in a 2-yr study (2014-2015) with four growing seasons conducted at the Agronomic Research Station of the University of Lome in Togo. The N rates of application included: no fertilizer N application (control, T1) and application of 30, 60 and 90 kg N ha$^{-1}$ labeled as T2, T3 and T4, respectively. Two forms of N fertilizer were used including ordinary urea (OU) and urea super granule (USG). Nitrogen fertilizer in the USG form proved superiority over the OU form under low (30 kg ha$^{-1}$) and high (90 kg ha$^{-1}$) N rates of application, but the two N forms performed similarly under an intermediate N application rate of 60 kg ha$^{-1}$. Using N fertilizer at low and high rates (30 to 90 kg N ha$^{-1}$) in the form of USG and only at an intermediate rate of 60 kg N ha$^{-1}$ should be advised towards improved maize grain yield, maximal N fertilizer use efficiency and optimal economic profit in the region.

## Introduction

Presumably because maize is one of the main staple foods crop in coastal Western Africa, its production has received tremendous supports since the early 1970', primarily through heavy subsidies on mineral fertilizers. Atchou (1988) and MAEP (2013) reported subsidies by the national governments and the international community ranging from 50 to 84% of fertilizers' real prices to foster maize production. Probably because of these supports, fertilizer use efficiency under the soil, weather, and cropping conditions in the region were of little concern. The low increase in average maize grain yield from 850 to 1500 kg ha$^{-1}$ since the last three decades (DRDR, 1988; ITRA, 2007) may have resulted in part from a lack of fertilizer use efficiency.

Of the fertilizer nutrients applied to crops in the world in general, and particularly in West Africa, N is the most important in terms of amounts applied (Christianson and Vlek, 1991; Zhang *et al.,* 2012). In the region, N constitutes slightly more than 50% of all nutrients used (Bumb, 1989). However, N is also one of the most difficult fertilizer nutrients to manage as a result of the fact that (i) plant available N is water soluble and therefore, easily translocated in the soil by percolating water and (ii) the amounts of N in the soil solution are constantly changing because of soil adsorption, microbial immobilization, and mineralization (Christianson and Vlek, 1991; Sogbedji *et al.,* 2001). The amount of soil N that is available for crop growth can therefore change dramatically over a short period of time, and this phenomenon makes it difficult to develop a recommendation for N fertilizer requirements on a site-specific basis.

The concern associated with fertilizer N greatly varies over the world. In industrialized countries such as the USA, Canada, and most European countries, it is more of environmental concern because of the potential impact of agricultural sources of N on ground and surface water supplies (Inskeep *et al.,* 1996; Yiridoe *et al.,* 1997). In the developing countries on the other hand, the environmental impact may not be a primary concern, but rather, the challenge is the optimization of small amounts of fertilizer N affordable by resource-poor farmers (Atchou, 1988; IFDC, 2013). In either developing or developed countries, fertilizer use efficiency appears to be the appropriate solution to the problems associated with the use of fertilizer N in agriculture (Christianson and Vlek, 1991). Studies (Bock, 1984; Zhang *et al.,* 2012; Alireza and Habibi, 2013) discussed several approaches to assessing fertilizer N efficiency including the use of isotopically labeled N fertilizer and N-treated versus non-N-treated plots. Another measure of fertilizer N efficiency is defined agronomically: it is the measure of the increase in grain yield obtained for a given amount of fertilizer added (i.e., kg grain/kg N) and it answers the farmer's question of how much extra food and or cash he will produce if fertilizer is used. This suggests that determination and analysis of crop yield and associated economic profits under various N fertilization schemes may help identify N management practices towards economic optimum crop productions.

Unfortunately, N use efficiency in most crops is low, and in many trials, less than 50% of the applied N is found in the crop at harvest (Arora and Juo, 1982; Raun and Johnson, 1999; Zhang *et al.,* 2012). In an extreme case in experiments conducted in Niger, West Africa, only 20% of fertilizer N was recovered (Christianson *et al.,* 1990). Poor N use efficiency can be caused by a number of loss mechanisms including leaching, ammonia volatilization, denitrification, and biological immobilization (Jemison *et al.* 1994; Sogbedji *et al.,* 2000). The extent and relative importance of each mechanism depends greatly on crop and fertilizer management as well as soil and climatic factors. Several studies (Jemison *et al.,* 1994; Raun and Johnson, 1999; Rehman *et al.,* 2011) suggested that to avoid N losses and increase the nutrient use efficiency, better management practices are needed, not only for high-input systems, but also under modest fertilization. They found that the method, number, and timing of application, and the chemical form used, are some of the factors that can be manipulated to better match N availability to crop needs. Under the current West African conditions of increasing population, food insecurity, limited access and affordability of production inputs, degraded lands and competing land use demands and unstable climate, it has become more important than before to effectively secure nutrient use efficiency in agriculture if improved livelihood of the population is to be achieved.

The objectives of this study were (i) to quantitatively assess the combined effects of N fertilizer rate and form of application on maize grain yield and N use efficiency and (ii) to determine and compare the economic return of various rate-form combinations of N application. The study aimed at providing technically, socio-economically and environmentally justified N managements schemes that sustain improved maize production in coastal Western Africa.

## Material and Methods

### Experimental Site

The study was conducted at the University of Lome Research Station near Lome, Togo (6°22'N, 1°13'E; altitude = 50 m). The soil type was a rhodic Ferralsol locally called "Terres de Barre" that developed from a continental deposit (Saragoni *et al.*, 1991). This soil type covers part of the arable lands in Togo, Benin, Ghana, and Nigeria (Louette, 1988) and is commonly used for maize production in coastal Western Africa. It is a well-drained soil, very low in organic matter (< 10 g $kg^{-1}$) and K (< 0.2 meq $100g^{-1}$), and has total P contents ranging from 250 to 300 mg $kg^{-1}$, cation exchange capacity of 3 to 4 ceq $kg^{-1}$, and pH of 5.2 to 6.8 (Louette, 1988; Tossah, 2000). Sand content is approximately 80% at the 0 to 0.20 m depth, and decreases to less than 60% at the 0.50 to 1.20 m depth (Sogbedji, 1999). The experimental site has a slope of less than 1%. The site is located in the guinea savanna agro ecological zone where the rainfall regime allows for two maize growing seasons, one from April to July and another from September to December with annual precipitation typically ranging from 800 to 1100 mm. The experimental site was under a 1-yr grass fallow prior to this study.

At the onset of the experiment (at maize planting in April), initial soil properties including total C and N contents, exchangeable bases ($Ca^{++}$, $Mg^{++}$, $Na^{+}$ and $K^{+}$), pH, total cation exchange capacity (CEC) and particle size distribution were measured for the first 20 cm soil layer (0-20 cm depth) on the experiment site from twenty four composite soil samples using the standard methods of the International Institute for Tropical Agriculture (IITA, 2014). The soil of the experimental site was moderately acidic with a pH of 6.70 and very low total C and N contents of 0.73 and 0.06%, respectively (Table 1). The soil texture results showed that the soil was sandy, with a total sand content of 80% for the top 20 cm soil profile, indicating that the site was a well-drained soil with low and fairly low P and K contents of 12.60 and 74.20 mg $kg^{-1}$, respectively. The CEC was low (2.90 cmol $kg^{-1}$) with exchangeable bases $Ca^{++}$, $Mg^{+}$, $Na^{+}$ and $K^{+}$ of 28.80, 8.20, 6.90 and 4.23 cmol $kg^{-1}$, respectively (Table 1). Overall, the soil properties indicated that the experimental site was low in inherent fertility as demonstrated earlier by Tossah (2000), and, therefore, will require additional fertilizer for optimum maize grain yield. It was thus expected that maize crop would respond to fertilizer application on the site.

### Crop and Soil Management

A 2-yr period (four growing seasons, 2014-2015) split-plot experiment was established with three replicates. Two forms of N fertilizer were the main plot effects and four fertilizer levels were at the subplot level. The site was manually plowed and 6 main plots (10 x 8 m) and 24 subplots (4 x 3 m) were laid out in a spatially-balanced complete block design (van Es and van Es, 1993). Spatially-balanced complete block (SBCB) designs are a model-based approach that guarantees that the experiment is insensitive to trends, spatial correlation, or periodicity in the research domain (van Es *et al.*, 2004).

It aims to equalize variances among treatment contrasts and allows for conventional statistical analysis methods. The forms of N fertilizer include: (i) urea in the ordinarily sold form (OU) and (ii) urea in the form of super granule (USG). The two forms of urea are shown in figure 1. The four rates of N fertilizer application include: T1 (0 kg N $ha^{-1}$), T2 (30 kg N $ha^{-1}$), T3 (60 kg N $ha^{-1}$) and T4 (90 kg N $ha^{-1}$). All subplots were fertilized with 60 kg P $ha^{-1}$ and 60 kg K $ha^{-1}$.

Fertilizer P and K rates were manually applied as $P_2O_5$ and $K_2O$, respectively, two weeks after maize planting (just after the first weeding) while N rates were applied five weeks after planting. All fertilizers were manually point-placed at approximately 8 cm depth. Maize (Ikenne, the most commonly used improved variety) was planted in April and harvested in July during the first growing season, and was planted in September and harvested in December during the second season at a density of 50,000 plants $ha^{-1}$. The crop was manually weeded three times during each growing season.


**Fig. 1** Urea super granule, USG (left) and ordinary urea, OU (right)

### Data Collection

Maize grain yield was determined under each treatment from four 3-m long rows of maize from the center of each sub-plot that were harvested and adjusted to 14% moisture content for the two growing seasons in 2014 and the first season in 2015. Maize grain yield data for the second growing season in 2015 were simulated with a regression model developed on the basis of a 20-yr period (1995–2014) of historical field-measured yield data (Sogbedji, personal communication). Maize grain yield data were analyzed using the general linear mixed model with rep and rep*fertilizer form as random, and fertilizer rate and fertilizer form as fixed effects. Significant effects were followed by multiple comparisons adjusted with a Bonferoni correction. The MIXED procedure in

Statistical Analytical System (SAS, 2014) was used to run the analysis.

Mean maize grain yield data were used to calculate the N agronomic efficiency Index using the approach of Fathi (1996) represented by the following equation:

N agronomic efficiency Index = (A-B) / C (1)

Where A is grain yield of plant that obtains a fertilizer, B is grain yield of plant that obtains a minimum amount of fertilizer and C is the consumed fertilizer.

## Economic Analysis

The economic return as cash profit from maize grain production in the 2-yr period (four growing seasons) under each of the four fertilizer treatments was estimated through a partial budget analysis. Output consisted of the amount of cash corresponding to the cumulative maize grain produced in the four seasons, which was assumed to be sold at 160 F CFA (US$0.32) $kg^{-1}$, the average sale price in the country.

The inputs consisted of the costs associated with each fertilization treatment, including those for soil preparation, seed, crop planting and related tasks, fertilizer purchase and application, crop weeding and crop harvesting and associated tasks. Labor costs were determined to be 2 000 FCFA (US$4.0) per person day, and fertilizer costs were based on current prices which were determined to be 220 FCFA (US$0.46) $kg^{-1}$ for ordinary urea, 250 FCFA (US$0.50) $kg^{-1}$ for USG and 460 FCFA (US$0.92) $kg^{-1}$ for $P_2O_5$ and $K_2O$.

Estimates of labor for each fertilization treatment in a growing season are presented in table 2, and are based on labor records from the experiment.

## Results and Discussion

### Maize Grain Production

Maize grain yield data are presented in table 3. In the first year, grain yield from all combinations of N fertilizer rate-form of application ranged from 4.70 to 8.75 and 3.28 to 5.38 Mg $ha^{-1}$ during the first and the second growing seasons, respectively. In the second year, grain yield ranged from 3.69 to 6.26 and 2.75 to 4.08 Mg $ha^{-1}$ during the first and the second growing seasons, respectively. The yield depression in the second growing season (typically 30 to 35% on average) as compared with the first growing season presumably resulted from lower rainfall in the second season (Table 4) that may have hampered an effective use of the applied nutrients. Indeed, the 5-yr average rainfall data for the 1990 to 2014 period ranged from 402 to 535 and 124 to 182 mm for the first and the second seasons, respectively, indicating that the first season has 200 to 230% more rainfall than the second season (Table 4).

Amouzou *et al.* (2013) demonstrate the evidence of climate change and variability leading to a significant reduction of the second growing season rainfall as compared to that of the first season in the region. Furthermore, other studies (Poss *et al.*, 1988; Sogbedji *et al.*, 2006; Laba and Sogbedji, 2015) report 40 to 60% maize grain yield decrease in the second season as compared with yield in the first season primarily as a result of lower rainfalls in the second season, and advised cautions in the use of inputs particularly fertilizers for maize cropping in the second season. The lower maize grain yield in the first growing season during the second year (2015) in comparison to yield in the corresponding season of the first year (2014) primarily resulted from the fact that 2015 is a particularly dry year with 280 mm rainfall in the first season versus 405 mm in 2014 and an average of 438 mm for the 1990 to 2014 period (Table 4).

Maize grain yield was responsive to N fertilizer rate of application but the magnitude of the response varied with the N form used, which indicates that the effects of N rate and form and their interaction were measurable. During the first year under OU, grain yield in both the first and second growing seasons was significantly lower under treatments T1 and T2 (3.28 to 4.77 Mg ha$^{-1}$) than yield under T3 and T4 (4.39 to 7.80 Mg ha$^{-1}$), and followed a similar pattern on an annual basis (Table 3).

Under USG, maize grain yield was lowest under T1 (4.70 Mg ha$^{-1}$), intermediate for T2 and T3 (6.52 and 7.57 Mg ha$^{-1}$), highest for treatment T4 (8.75 Mg ha$^{-1}$) in the first season and followed a similar trend on an annual basis. In the second growing season, grain yields were similar under T2, T3 and T4 but higher as compared with yield for T1 (Table 3). The lack of discrimination among treatments T2, T3 and T4 in the second growing season might most likely be a result of insufficient rainfall that presumably prevented a proper dissolution of USG and thus an efficient N use.

In both the first and second growing seasons, maize grain yield was consistently higher or similar under USG as compared to yield under OU. This resulted on an annual basis, in 42.8 and 25.7% yield increase under T2 and T4 with USG as compared to yield under corresponding application rates with OU, and yearly mean total yield being 15% higher for USG than for OU (Table 3). These results demonstrate that in terms of maize grain yield in the region, N fertilizer in the form of USG proved superiority over the OU form under low (30 kg ha$^{-1}$) and high (90 kg ha$^{-1}$) N rates of application with similar yield performance of the two forms for an intermediate rate of 60 kg ha$^{-1}$.

In the second year, maize grain yield under OU was in general lowest for T1 (3.69 Mg ha$^{-1}$), intermediate for T2 and T3 (4.25 and 4.68 Mg ha$^{-1}$) and highest for T4 (5.58 Mg ha$^{-1}$) during the first growing season, and similar for T2, T3 and T4 (3.04 to 3.73 Mg ha$^{-1}$) during the second season (Table 3). A similar trend was observed in grain yield under USG with yield being lowest under T1 (3.69 Mg ha$^{-1}$), intermediate for T2 and T3 (4.87 and 4.71 Mg ha$^{-1}$) and highest for T4 (6.26 Mg ha$^{-1}$) during the first growing season, and similar for T2, T3 and T4 (3.36 to 4.08 Mg ha$^{-1}$) during the second season. Yearly cumulative yield under both OU and USG followed an identical pattern to that of the seasonal data set (Table 3). Unlike the first year, within-season and annual grain yields in the second year were similar for the different combinations of N rate and form of application (Table 3) mainly as a result of the fact that the second year was particularly dry with 280 mm rainfall against 405 mm for the first year in the first growing season (Table 4).

On a 2-yr basis, cumulative maize grain yields for USG under treatments T2, T3, and T4 were 28.6% higher, similar and 19.1% higher as compared with yields under corresponding treatments for OU, respectively (Table 3). Across N fertilizer rates of application, mean 2-yr cumulative yields were 11.3% higher under USG than for OU. These results, again demonstrate the superiority of the USG form of N over the OU form in terms of maize grain yield under low (30 kg ha$^{-1}$) and high (90 kg ha$^{-1}$) N rates of application in the region, but the two N forms performed similarly under an intermediate N application rate of 60 kg ha$^{-1}$.

Studies comparing maize N fertilizer use efficiency under the two forms of N (USG and OU) are typically inexistent. IFDC (2013) conducted 1-yr trials in northern Togo that involved several N fertilizer rates crossed with USG and OU; it finds that the USG form of N proved superiority in increasing maize grain yield by 34, 30 and 27% with N application of 30, 60 and 90 kg N $ha^{-1}$, respectively, with an average of 30% over the OU form of N. Our results in general especially those in the first year reasonably agreed with results reported by IFDC (2013) regarding the superiority of USG over OU at N fertilizer application rates of 30 and 90 kg $ha^{-1}$ but disagreed in that our findings did not show any yield difference between the two N forms at the application rate of 60 kg $ha^{-1}$.

## Nitrogen Agronomic Efficiency Index

The N agronomic efficiency index values experienced seasonal variation, being consistently higher (2.33 to 60.67) during the first growing season than values (1 to 58) for the second growing season (Table 5), presumably mainly as a result of lower rainfall in the second season (Table 4). This pattern of the index data sets strengthened statements by Poss *et al.* (1988) and Laba and Sogbedji (2015) who advise cautions in the use of inputs particularly fertilizers for maize cropping during the second season in the region. The index values were also typically lower in the second year than in the first year primarily because the second year was particularly dry.

Mean N agronomic efficiency index values in both the first and second growing seasons and in each of the two years were consistently higher (17 to 60.67 and 8.83 to 58 for the first and second seasons, respectively) under USG as compared with values (2.33 to 51.67 and 1 to 26.83 for the first and second seasons, respectively) for OU (Table 5). In the first growing season, 2-yr average N agronomic efficiency index values under USG for T2, T3 and T4 were 376.19% higher, similar and 63.86% higher as compared with corresponding N application rates under OU, respectively, with an overall mean index value under USG 77.83% higher than hat for OU. During the second season, 2-yr average N agronomic efficiency index values under USG for T2, T3 and T4 were 634.37% higher, similar and 64.11% higher as compared with corresponding N application rates under OU, respectively, with an overall mean index value under USG 116.33% higher than hat for OU.

In the first growing season within the OU form of N, agronomic efficiency index values were lowest, highest and intermediate for T2, T3 and T4, respectively, in the first year (Table 5). In the second year, index value under T4 was higher than that for T3 but similar to the value for T2. On a 2-yr average basis, the index values were lowest, highest and intermediate for T2, T3 and T4, respectively. Within the USG form of N, index values were similar for T3 and T4 but lower as compared to the value under T2 in the first year, and in the second year, the index values were highest, lowest and intermediate for T2, T3 and T4, respectively.

On a 2-yr average basis, the index values were similar for T3 and T4 but lower as compared to the value under T2. In the second growing season within the OU form of N, agronomic efficiency index values were lowest, highest and intermediate for T2, T3 and T4, respectively, in the first year and on a 2-yr average basis but in the second year the index values were similar for the three treatments (Table 5).

Within the USG form of N, the index values were similar for T3 and T4 but lower as compared to the value under T2 in the first year and on a 2-yr average basis but in the second year the index values were highest, lowest and intermediate for T2, T3 and T4, respectively. These results indicate that the OU form of N should be used only with intermediate to high rates, while the USG form can be used even at low rate. Zang *et al.* (2011) studied N fertilizer use efficiency under maize and report efficiency index values ranging from 12.52 to 69.17. Nitrogen efficiency index values from our study were between 1 and 60.67 and thus agreed reasonably well with those of Zang *et al.* (2011) as well as values of 24.7 to 45.7 published by Rehman *et al.* (2011). Furthermore, our results in most cases agreed with other studies (Pikul *et al.*, 2005; Rehman *et al.*, 2011; Alireza *et al.*, 2013) who find that N use efficiency was significantly lower with high fertilizer rates than with low or medium rates.

**Table.1** Soil properties at the onset of the experiment

| Parameter | Value |
|---|---|
| pH ($H_2O$) | 6.70 |
| Total C (%) | 0.73 |
| Total N (%) | 0.06 |
| $NO_3$-N (mg $kg^{-1}$) | 2.30 |
| Labile P (mg $kg^{-1}$) | 12. 60 |
| Available K (mg $kg^{-1}$) | 74.20 |
| Exchangeable bases (cmol $kg^{-1}$) | |
| Ca++ | 28.80 |
| Mg++ | 8.20 |
| Na+ | 6.90 |
| K+ | 4.23 |
| Total CEC (cmol $kg^{-1}$) | 2.90 |
| Sand content (%) | 80.0 |
| Silt content (%) | 7.0 |
| Clay content (%) | 13.0 |

**Table.2** Estimated labor associated with a season of maize crop under each fertilizer treatment

| | T1 | T2 | T3 | T4 |
|---|---|---|---|---|
| | | ___person day $ha^{-1}$____ | | |
| Soil preparation | 30 | 30 | 30 | 30 |
| Planting and related tasks | 35 | 35 | 35 | 35 |
| Weeding | 90 | 90 | 90 | 90 |
| Fertilizer application | 10 | 20 | 20 | 20 |
| Harvesting and related tasks | 70 | 70 | 70 | 70 |
| Total labor | 235 | 245 | 245 | 245 |
| Total labor cost[¶] (F CFA[§]) | 470 000 | 490 000 | 490 000 | 490 000 |

¶ Total cash based on the cost of 2000 F CFA per person-day.

§ On average 1US$ = 500 F CFA.

**Table.3** Mean maize grain yields (Mg $ha^{-1}$) for each growing season, year and the entire period of the experiment

| Fertilizer Treatment | Year 1 | | | Year 2 | | | Year 1 + Year 2 |
|---|---|---|---|---|---|---|---|
| | $GS^T$ 1 | GS2 | Total | GS1 | GS2 | Total | Total |
| **Ordinary Urea (OU)** | | | | | | | |
| T1 | 4.70a | 3.28a | 7.98a | 3.69a | 2.75a | 6.44a | 14.42a |
| T2 | 4.77a | 3.31a | 8.08a | 4.25ab | 3.04ab | 7.29ab | 15.37a |
| T3 | 7.80b | 4.89b | 12.69b | 4.68bc | 3.27ab | 7.95b | 20.64b |
| T4 | 6.85b | 4.39b | 11.24b | 5.58c | 3.73b | 9.31c | 20.55b |
| **Mean** | **6.03** | **3.97** | **10.00** | **4.55** | **3.20** | **7.75** | **17.75** |
| **Urea Super Granule (USG)** | | | | | | | |
| T1 | 4.70a | 3.28a | 7.98a | 3.69a | 2.75a | 6.44a | 14.42a |
| T2 | 6.52b | 5.02b | 11.54b | 4.87b | 3.36ab | 8.23b | 19.77b |
| T3 | 7.57b | 4.77b | 12.34b | 4.71b | 3.28ab | 7.99b | 20.33b |
| T4 | 8.75c | 5.38b | 14.13c | 6.26c | 4.08b | 10.34c | 24.47c |
| **Mean** | **6.89** | **4.61** | **11.50** | **4.88** | **3.37** | **8.25** | **19.75** |

T Growing season

Means within the same column not followed by letters or followed by the same letter are not significantly different at $\alpha = 0.05$. The comparisons were adjusted by a Bonferoni correction for multiple comparisons.

**Table.4** Five-year average cropping season and annual rainfall (mm) for the period 1990 -2014 and seasonal rainfall (mm) for the 2014 and 2015 years

| | 1990-1995 | 1996-2000 | 2001-2004 | 2005-2009 | 2010-2014 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|
| $GS^T$1 | 402 | 407 | 420 | 535 | 459 | 405 | 280 |
| GS2 | 182 | 124 | 137 | 153 | 178 | 158 | - |
| Annual | 654 | 668 | 656 | 808 | 715 | 762 | - |

T Growing season

**Table.5** Mean nitrogen agronomic efficiency Index under each of the fertilization treatment

| Fertilizer Treatment | GS[T]1 | | | GS2 | | |
|---|---|---|---|---|---|---|
| | Year 1 | Year 2 | 2-yr Average | Year 1 | Year 2 | 2-yr Average |
| **Ordinary Urea (OU)** | | | | | | |
| T1 | - | - | - | - | - | - |
| T2 | 2.33a | 18.67ab | 10.50a | 1.00a | 9.67a | 5.33a |
| T3 | 51.67b | 16.50a | 34.08b | 26.83b | 8.67a | 17.75b |
| T4 | 23.89c | 21.00b | 22.44c | 12.33b | 10.89a | 11.61c |
| **Mean** | **25.96** | **18.72** | **22.34** | **13.39** | **9.74** | **11.56** |
| **Urea Super Granule (USG)** | | | | | | |
| T1 | - | - | - | - | - | - |
| T2 | 60.67d | 39.33c | 50.00d | 58.00d | 20.33b | 39.17d |
| T3 | 47.83b | 17.00a | 32.42b | 24.83b | 8.83a | 16.83b |
| T4 | 45.00b | 28.56d | 36.78b | 23.33b | 14.78c | 19.06b |
| **Mean** | **51.17** | **28.30** | **39.73** | **35.39** | **14.65** | **25.02** |

T Growing season
Means within the same column followed by the same letter are not significantly different at $\alpha = 0.05$.

**Table.6** Partial budget analysis (F CFA $ha^{-1}$) for each of the treatments for the 2-yr period

| | **Total Output** | **Total Input** | **Balance** |
|---|---|---|---|
| **Ordinary Urea (OU)** | | | |
| T1 | +2 307 200 | -2 341 300 | -34 100 (-US$68.20) |
| T2 | 2 459 200 | 2 478 720 | -19 520 (-US$39.04) |
| T3 | 3 302 400 | 2 536 140 | 766 260 (US$1532.52) |
| T4 | 3 288 000 | 2 593 560 | 694 440 (US$1388.88) |
| **Mean** | **2 839 200** | **2 487 430** | **351 770 (US$703.54)** |
| **Urea Super Granule (USG)** | | | |
| T1 | +2 307 200 | -2 341 300 | -34 100 (-US$68.20) |
| T2 | 3 163 200 | 2 486 560 | 676 640 (US$1353.28) |
| T3 | 3 252 800 | 2 551 800 | 701 000 (US$1402) |
| T4 | 3 915 200 | 2 617 060 | 1 298 140 (US$2596.28) |
| **Mean** | **3 159 600** | **2 499 180** | **660 420 (US$1320.84)** |

## Partial Budget Analysis

Results of the balance of inputs (total costs associated with maize production under each fertilization treatment) and corresponding outputs (cash values of maize grain yield) for the four growing seasons (two years) are presented in table 6. Because maize grain was assumed to be sold at the same price, the outputs' trend was the same as that of yields. Under OU, on a 2-yr period basis, outputs under T4 T3 and T2 were 42.51, 43.13 and 6.59% higher as compared with T1, respectively; those under T4 and T3 were 33.70 and 34.29% higher as compared with T2, respectively, while the output under T4 was 0.44 % lower than that under T3.

Under USG, on a 2-yr period basis, outputs under T4, T3 and T2 were 69.69, 40.98 and 37.10% higher as compared with T1, respectively; those under T4 and T3 were 23.77 and 2.83% higher as compared with T2, respectively, while output under T4 was 20.36% higher than that under T3. Inputs associated with each treatment were identical for both the first and the second growing seasons within each N fertilizer form. With OU, inputs for T4, T3 and T2 were 10.77, 8.32 and 5.87% higher as compared with T1, respectively; inputs under T4 and T3 were 4.63 and 2.32% higher as compared with T2, respectively, while input under T4 was 2.26% higher than that under T3. With USG, inputs for T4, T3 and T2 were 11.78, 8.99 and 6.20% higher as compared with T1, respectively, inputs under T4 and T3 were 5.25 and 2.62% higher as compared with T2, respectively, while input under T4 was 2.56% higher than that under T3.

On a per hectare basis under OU, the balance was positive for T4 and T3, indicating that there was profit or net gain of 694 440 FCFA (US$1388.52) and 766 260 FCFA (US$1532.52), respectively, with gain under T4 being 9.37% lower than that for T3.

The balance was negative for T1 and T2, indicating that these treatments resulted in net loss (Table 6) and thus should not be recommended. Under USG, the balance was positive for T2, T3 and T4 with net gains of 676 640 FCFA (US$1353.28), 701 000 FCFA (US$1402) and 1 298 140 FCFA (US$2596.28), respectively. Profits under T4 and T3 were 91.85 and 3.60% higher as compared with T2, respectively, while profit under T4 was 85.18% higher than that under T3. Across N rates on a 2-yr period basis, profit under USG (660 420 FCFA = US$1320.84) was 87.74% higher than that under OU (351 770 FCFA = US$703.54).

## Conclusion

Under the current conditions of degraded lands and climate change and variability in coastal western Africa, maize cropping should not be undertaken without N fertilizer. Insufficient seasonal rainfall severely challenges maize cropping in the second growing season of the year and thus investment in N fertilizer for maize production in the region should be limited. Nitrogen fertilizer in the USG form proved superiority over the OU form in terms of maize grain yield under low (30 kg $ha^{-1}$) and high (90 kg $ha^{-1}$) N rates of application in the region, but the two N forms performed similarly under an intermediate N application rate of 60 kg $ha^{-1}$. Using N fertilizer at low and high rates (30 to 90 kg N $ha^{-1}$) in the form of USG and only at an intermediate rate of 60 kg N $ha^{-1}$ should be advised towards improved maize grain yield, maximal N fertilizer use efficiency and optimal economic profit. The USG technology appeared to be an alternative in rain fed maize cropping based fertilization to improving the crop yield through maximal N fertilizer use efficiency. However, further field demonstrations are needed to validate such a performance thereby putting the technology into a scaling-out process for adoption.

## References


Alireza, E., Habibi, F. 2013. Evaluation of nitrogen use efficiency in corn (*Zea mays* L.) varieties. *World Appl. Sci. J.*, 21(1): 63–68.

Amouzou, K.A., Ezui, K.S., Sogbedji, J.M. 2013. Impacts of climate variability and soil fertility management strategies on maize grain yield on ferrralsols in Coastal Western Africa. *J. Renew. Agricult.*, 1(3): 44–52.

Arora, Y., Juo, A.S.R. 1982. Leaching of fertilizer ions in a kaolinitic Ultisol in the high rainfall tropics: leaching of nitrate in field plots under cropping and bare fallow. *Soil Sci. Soc. Am. J.*, 46: 1212–1218.

Atchou, Y.K. 1988. Problèmes relatifs à l'utilisation des engrais au Togo. In: Tsibaka, T.B., Baanante, C.A. (Eds.). Fertilizer policy in tropical Africa, 1988. Workshop proceedings, Lome, Togo, April 1988. IFDC, IFPRI. Pp. 84–93

Bock, B.R. 1984. Efficient use of nitrogen in cropping systems. In: Hauk (Ed.), Nitrogen in crop production, American Society of Agronomy, Madison, Wisconsin. Pp. 273–294.

Bumb, B.L. 1989. Global fertilizer perspective, 1960–1995, Technical Bulletin T-35, International Fertilizer Development center (IFDC), Muscle Shoals, Alabama.

Christianson, C.B., Bationio, A., Henao, J., Vlek, P.L.G. 1990. Fate and efficiency of N fertilizer applied to millet in Niger. *Plant Soil*, 125: 221–231.

Christianson, C.B., Vlek, P.L.G. 1991. Alleviating soil fertility constraints to food production in West Africa: Efficiency of nitrogen fertilizer applied to food crops. In: Uzo Nokwunye, A. (Ed.). Alleviating soil fertility constraints to increased crop production in West Africa.1991. Kluwer Academic Publishers, in cooperation with IFDC.

DRDR, 1988. Direction Régionale du Développement Rural: rapport annuel du service de vulgarisation. Lomé, Togo.

Fathi, K. 1996. New outlook on nutrient use efficiency (with emphasis on element nitrogen). Integrated research Ramin Agricultural Higher Education. Shahid Chamran University. Iranian Crop Science Congress reform Articles. Pp. 283–266.

IFDC, International Fertilizer Development Center, 2013. Mainstreaming pro-poor fertilizer access and innovative practices in West Africa. IFAD Technical Assistance Grant No. 1174 report. Muscle Shoals, Alabama, USA.

IITA, International Institute of Tropical Agriculture, 2014. Automated and semi-automated methods of soil land plant analysis. IITA, Ibadan, Nigeria.

Inskeep, W.P., Wraith, J.M., Wilson, J.P., Snyder, R.D., Macur, R.E., Gaber, H.M. 1996. Input parameter and resolution effects on prediction of solute transport. *J. Environ. Qual.*, 25: 453–462.

ITRA, Institut Togolais de Recherche Agronomique, 2007. Situation de référence sur les principales céréales cultivées au Togo: maïs, riz, sorgho, mil. Lomé: Institut Togolais de Recherche Agronomique. Pp. 9–38.

Jemison, J.M. Jr., Fox, R.H. 1994. Nitrate leaching from soil measured with zero-tension pan lysimeters as influenced by nitrogen fertilizer rate and manure application. *J. Environ. Qual.,* 23: 347–343.

Laba, B.S., Sogbedji, J.M. 2015. Identification of land degradation and climate change resilient soil and crop management strategies for maize production on West African ferralsols. *Int. Invent. J. Agricult. Soil Sci.,* 3(2): 13–20.

Louette, D. 1988. Synthèse des travaux sur la fertilité des terres de barre au Bénin et au Togo. CIRAD, Montpelier, France.

MAEP, Ministère de l'agriculture, de l'élevage et de la pêche, République togolaise, 2013. Etude du secteur des engrais au Togo en vue de la formulation d'un mécanisme adéquat de subvention publique et du renforcement du réseau de distribution par le secteur privé. Rapport final. Version définitive. Octobre 2013. MAEP, Lomé, Togo, 156 Pp.

Pikul, J.L., Hammack, L., Riedell, W.E. 2005. Corn yield, nitrogen use and corn rootworm infestation of rotations in the northern corn belt. *Agron. J.,* 97: 854–863.

Poss, R., Saragoni, H., Imbernom, J. 1988. Bilan hydrique simulé du maïs au Togo méridional. *Agron. Trop.,* 43(1): 18–29.

Raun, W.R., Johnson, G.V. 1999. Improving nitrogen use efficiency for cereal production. *Agron. J.,* 91: 357–363.

Rehman, A., Saleem, M.F., Safdar, M.E., Hussain, S., Akhtar, N. 2011. Grain quality, nutrient use efficiency, and bioeconomics of maize under different sowing methods and NPK levels. *Chilean J. Agricult. Res.*, 71(4) October-December 2011: 586–593.

Saragoni, H., Olivier, R., Poss, R. 1991. Dynamique et lixiviation des éléments minéraux. *Agron. Trop.*, 45: 259–273.

SAS, Statistical Analysis System Institute, 2014. Base SAS 9.4 Procedures Guide. SAS Institute, Cary, NC, 2014.

Sogbedji, J.M. 1999. Maize nitrogen utilization and nitrate leaching modeling in Togo and New York. Ph.D. Thesis, Cornell University, New York, USA.

Sogbedji, J.M., van Es, H.M., Hutson, J.L. 2001. N fate and transport under variable cropping history and fertilizer rate on loamy sand and clay loam soils: I. Calibration of the LEACHM model. *Plant Soil,* 229(1): 57–70.

Sogbedji, J.M., van Es, H.M., Tamelokpo, F.A. 2006. Optimizing N fertilizer use for maize on ferralsols in Western Africa. *Revue Togolaise des Sci.,* 2: 2–18.

Sogbedji, J.M., van Es, H.M., Yang, C.L., Geohring, L.D., Magdoff, F.R. 2000. Nitrate leaching and nitrogen budget as affected by maize nitrogen rate and soil type. *J. Environ. Qual.,* 29: 1813–1820.

Tossah, B.K. 2000. Influence of soil properties and inorganic inputs on phosphorus cycling in herbaceous legume-based system in the West African derived savana. Ph D dissertation No 428, Catholic University, Leuven, Belgium.

van Es, H.M., Gomes, C., Sellmann, M., van Es, C.L. 2004. Spatially-balanced designs for experiments on autocorrelated fields. In: 2004 Proc. Am. Statistical Assoc., Statistics & the Environment Section [CDROM], Alexandria, VA.

van Es, H.M., van Es, C.L. 1993. Spatial nature of randomization and its effect on the outcome of field experiments. *Agron. J.*, 85: 420–428.

Yiridoe, E.K., Voroney, R.P., Weersink, A. 1997. Impact of alternative farm management practices on nitrogen pollution of groundwater: Evaluation and application of CENTURY model. *J. Environ. Qual.*, 26: 1255–1263.

Zhang, J., Li, Z-H., Li, K., Huang, W., Sang, L-H. 2012. Nitrogen use efficiency under different field treatments on maize fields in Central China: A lysimeter and $^{15}$N study. *J. Water Resour. Prot.,* 4: 590–596.