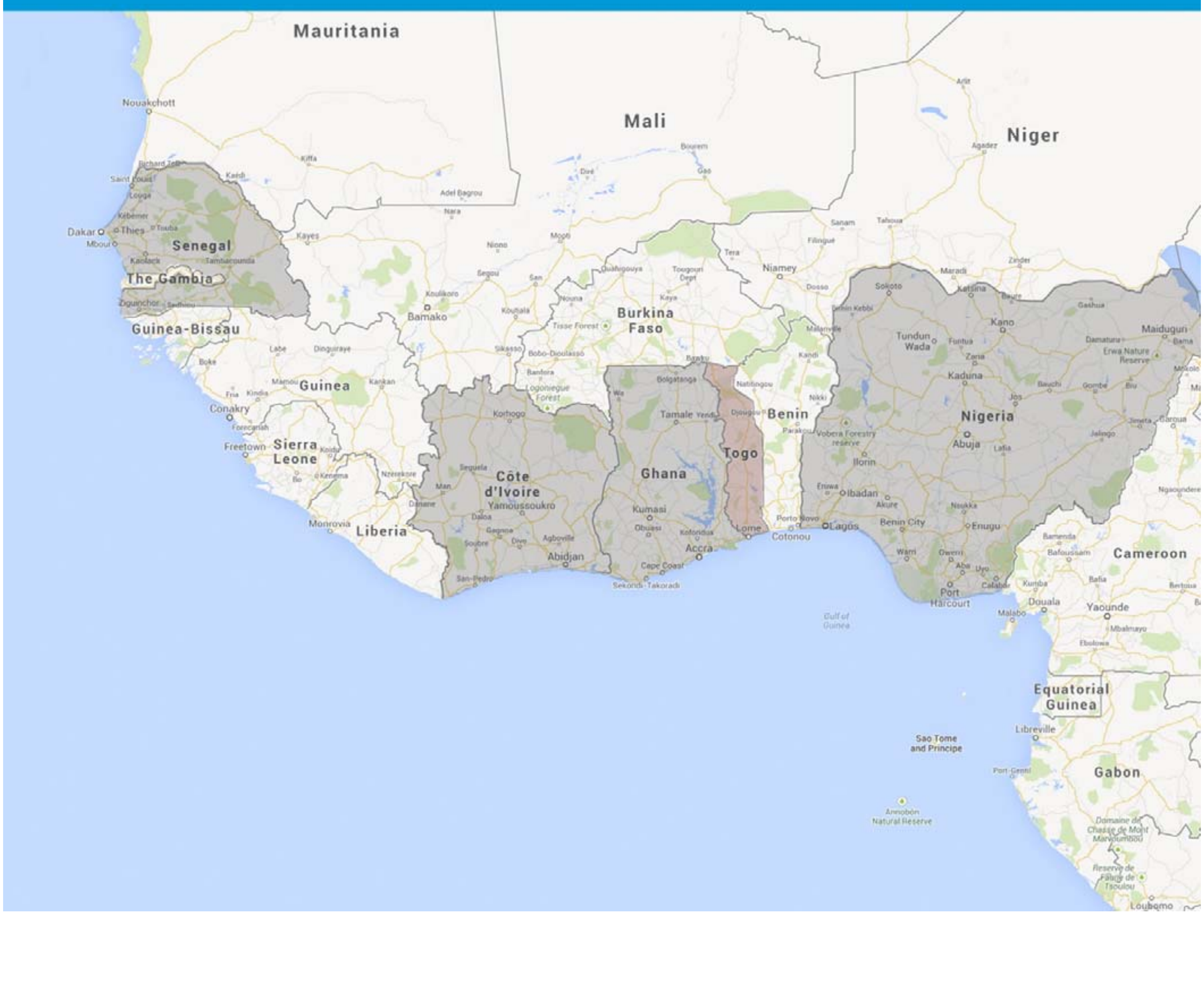
The Quality of Fertilizer Traded in West Africa: Evidence for Stronger Control

TOGO REPORT



The Quality of Fertilizer Traded in West Africa: Evidence for Stronger Control

Togo Report

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Foreword

One of the key pieces of the integration of the economies of West African States is the development of regional markets. Considering the overriding role agriculture plays in the development of these economies, strengthening agricultural inputs and produce markets is central to West Africa's economic integration. This is clearly articulated in the agricultural policy UEMOA adopted in 2000 and reaffirmed subsequently in 2005 in the ECOWAS agricultural policy. The liberalization of national economies in the 1980s and 1990s aimed to unleash the power of the private sector to drive economic development through greater participation in economic activities. Many now recognize that, in each country, this was done without a definition of the "rules of the game" and, in most cases, without proper recognition that national markets are too small to attract significant private sector investments to fill the gap the withdrawal of the public sector created. It was therefore not surprising that in all countries, concern emerged over the quality of products being offered for sale, particularly fertilizers.

In their effort to facilitate the development of a regional agro-input market, the ECOWAS and UEMOA Commissions made the adoption of market-friendly regional regulatory frameworks that institute the quality control of agro-inputs traded one of the priorities in the implementation of their regional agricultural policy. For fertilizer, this effort is also part of the implementation of the regional strategy for promoting fertilizer use that the Commissions adopted in 2006, prior to the Africa Fertilizer Summit.

This report is a contribution to national and regional efforts aimed at intensifying the use of inorganic and organic fertilizers, an input African Heads of States and Governments declared, at the Summit held in Abuja in 2006, "a strategic commodity in achieving the African Green Revolution to end hunger." The report also reminds policymakers that while promoting greater fertilizer use, it is equally important to effectively control its quality to promote fair competition among sellers. This would ensure that farmers get what they paid for because they will use fertilizers only if these fertilizers are of good quality. Finally, the study will serve as a baseline for assessing the performance of the quality control and regulatory mechanism that is being instituted with the adoption of the regional framework.

Although many individuals and organizations contributed to the design and completion of this study, the support, guidance and cooperation of fertilizer importers and agro-dealers in the target countries were critical. Similarly, the funding support of DGIS through MIR Plus, a joint ECOWAS and UEMOA project implemented by IFDC, was equally critical. The ECOWAS Commission and IFDC gratefully acknowledge these supports.

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Acronyms and Abbreviations

AGRA	Alliance for a Green Revolution in Africa
AOAC	Association of Official Analytical Chemists
AS	Ammonium Sulfate
CAADP	Comprehensive Africa Agriculture Development Programme
DAP	Diammonium Phosphate
DGIS	(*Directoraat Generaal voor Internationale Samenwerking*) Directorate-General for International Cooperation
DTG	Departure from Total Grade
DTNC	Deviation from Total Nutrient Content
DWL	Departure from the Weight in the Label
ECOWAS	Economic Community of West African States
ECFDF	Empirical Cumulative Frequency Distribution Function
EFDF	Empirical Frequency Distribution Function
FAO	Food and Agriculture Organization of the United Nations
GADD	Ghana Agro-Dealer Development
GAEC	Ghana Atomic Energy Commission
GDP	Gross Domestic Product
ICP-OES	Inductively Coupled Plasma Optical Emission Spectrometry
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
kg	kilogram(s)
MDG	Millennium Development Goal
MIR	Marketing Inputs Regionally
mt	metric ton(s)
NEPAD	New Partnership for Africa's Development
ReSAKSS	Regional Strategic Analysis and Knowledge Support System
SGS	*Société Générale de Surveillance*
SSP	Single Superphosphate
TL	Tolerance Limits
UEMOA	*Union Économique et Monétaire Ouest Africaine* (West African Economic and Monetary Union)
USA	United States of America

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Executive Summary of the Regional Report

The Commissions of the Economic Community of the West African States (ECOWAS) and the West African Economic and Monetary Union (UEMOA) are developing a regional legal framework for controlling the quality of fertilizer traded in West Africa. The main purpose of this framework is to safeguard the interests of farmers against nutrient deficiencies, adulteration, misleading claims and short weight as well as to contribute to the creation of an enabling environment for private sector investment in the fertilizer industry. To determine the basis for assessing the effectiveness of this framework once it is implemented, the ECOWAS and UEMOA Commissions initiated, through the Marketing Inputs Regionally (MIR) Plus project, a study to assess the quality of fertilizer traded in West Africa as well as factors influencing fertilizer quality.

The study was carried out by trained inspectors from the national fertilizer regulatory services in five West African countries – Côte d'Ivoire, Ghana, Nigeria, Senegal and Togo. The sampling methodology consisted of two steps. The first step focused on obtaining a random sample of 5 to 10 percent of fertilizer dealers in each country either from maps (Ghana and Nigeria) that geo-reference the location of each dealer or from lists of dealers available at the ministry in charge of agriculture (Côte d'Ivoire, Senegal and Togo). The second step was the collection of random samples of fertilizers from each of dealers selected in the first step. Fertilizer sampling and collection were conducted following an agreed-upon protocol. In addition, pretested questionnaires were used to record conditions of storage, physical attributes of fertilizers and characteristics of markets and dealers.

A total of 2,037 fertilizer samples was collected from 827 wholesalers, government depots and retailers of various sizes in the five countries. The distribution of these fertilizer samples is a good representation of the relative importance of the different fertilizer products in the five countries. Urea and the NPK 15:15:15 blend were the only products collected from each of the five countries. Urea, the compound NPK 15:15:15, the compound NPK 16:16:16, the compound NPK 23:10:5, the blend NPK 15:15:15 and ammonium sulfate account for 79 percent of the samples collected.

The chemical analyses of the fertilizer samples focused on determining the content of primary plant nutrients (total nitrogen, available phosphorus and soluble potassium). However, analyzing samples for secondary nutrients (calcium, magnesium and sulfur) was considered, but only the sulfur content in the samples of Sulfan collected in Ghana was analyzed.

Statistical analyses described in Section 1 were applied to data on nutrient content, physical attributes and characteristics of markets and dealers, and storage conditions to determine the quality of the different fertilizer products and to associate fertilizer quality with market and dealer characteristics. To be meaningful, the nutrient content compliance was analyzed with inferential statistical methods only for the fertilizer products with at least 23 samples and these accounted for 93 percent of all the samples collected in the study. Fertilizers that were collected with a sample size lower than 23 were analyzed only descriptively. Nutrient content compliance was assessed based on newly adopted ECOWAS standards.

Blends and Compounds Present Cases of Poor Quality, but This is Most Severe for Blends

The chemical analyses carried out show that NPK fertilizers manufactured through blending present the most frequent cases of poor quality compared with compound products. More specifically, 51 percent of the 106 samples of the 15:15:15 blend were out of compliance with the newly adopted ECOWAS tolerance limits for nutrient content deviations. Similarly, other products that failed to meet the ECOWAS quality standards were 86 percent of the 90 samples of the 20:10:10 blend, 12 percent of the 30 samples of the 6:20:10 blend, 96 percent of the 27 samples of the 15:10:10 blend, 31 percent of the 23 samples of Asaase Wura (0:22:18+9CaO+7S+5MgO) and 26 percent of the 27 samples of Cocoa Feed (0:30:20).

In contrast to the blended products, the only compound products that failed to meet the ECOWAS quality standard were 4 percent of the 534 samples of urea, 10 percent of the 356 samples of the compound 15:15:15, 16 percent of the 162 samples of AS (21:0:0+24S), 15 percent of the 162 samples of compound 16:16:16, 1 percent of the 103 samples of compound 23:10:5 and 4 percent of the 90 samples of Sulfan (24:0:0+6S). While the proportions of non-compliant samples observed in the compound products are lower than the ones observed in blended products, these can still be considered high for imported products. This result confirms the finding of a previous assessment IFDC carried out in West Africa in 1995 indicating that 10 of the 29 samples of NPK compounds examined were nutrient-deficient.

Of the 10 samples of single superphosphate (SSP) collected from several locations in Nigeria, seven of them were found to contain no phosphorus (P_2O_5) but contained mainly quartz (SiO_2). The chemical and X-ray mineralogical analyses indicate that the samples with no phosphorus come from spurious materials without fertilizer characteristics that are commercialized as SSP.

Country-to-Country Comparisons Show Variable Product Quality

Country-to-country comparisons made between Côte d'Ivoire, Ghana and Togo for the 15:15:15 blend and between Ghana, Nigeria and Togo for the 15:15:15 compound show a great deal of variability between countries. The overall out-of-nutrient content compliance probability of the 15:15:15 blend was the highest in Côte d'Ivoire (0.87), followed by Ghana (0.42) and Togo (0.06). For the 15:15:15 compound, the overall out-of-nutrient content compliance probability was the highest in Nigeria (0.16), followed by Ghana (0.10) and Togo (0.03). The low proportion of non-compliant samples observed in Togo may be attributed to the fact that, of the three countries, Togo might be expected to have low variability in the importation sources and a relatively simple distribution chain due to government control of importation and distribution.

Nutrient Deficiencies in Blended Products are Not Simply an Issue of Segregation

The analysis indicated that the main reason for nutrient content deficiencies in Asaase Wura is the uneven distribution of nutrients in the fertilizer bags caused by granule segregation. Nutrient content deficiencies are also attributed to segregation of the fertilizer components used in the bulk blend for half of the NPK 15:15:15, two-thirds of the Cocoa Feed and one-third of the NPK 6:20:10 samples. These results suggest that the high proportion of nutrient-deficient cases found in these products can be avoided by using fertilizers of uniform granule size for the manufacture of these blends and by utilizing appropriate equipment and procedures to make the blends.

The effect of segregation in the NPK blends 15:10:10 and 20:10:10, which have the highest proportion of non-compliant samples, is found to be minimal. This indicates that the lack of nutrient compliance in these products is caused primarily by insufficient nutrient input in the blend manufacture. Reduction of nutrient content along the distribution chain could be another explanatory factor, but evidence of such cases was not documented in this study for these products.

Evidence of Adulterated Products in the Collected Samples is Weak

Trained inspectors reported evidence of adulteration in 31 of 134 (23 percent) samples collected in Côte d'Ivoire but only 14 of 414 (3.4 percent) samples from Nigeria. However, the only cases of completely proven adulteration are the seven samples of SSP from Nigeria that were found to have no P_2O_5 content or any of the minerals that carry P in phosphate rock. While high percentages of nutrient deficient samples in some NPK blends found in some countries could be interpreted as fraud during manufacturing or along the distribution chain, this is not substantiated by findings of this study; the lack of or poor control of blending procedures and use of inadequate blending equipment are also possible explanations.

Short Weight Fertilizer Bags are Common in the Market

An analysis of the weight of 1,055 fertilizer bags collected from all five countries indicates that there is a 41 percent chance that the bag weight does not comply with the ECOWAS tolerance limit in Nigeria, a 28 percent chance in Côte d'Ivoire, 13 percent in Senegal, 12 percent in Ghana and 7 percent in Togo. The two probable reasons for underweight bags are deliberate acts of underweighting and poor process control during the bagging of imported products or during rebagging along the distribution chain.

Market Characteristics are Associated with the Quality of Products

A statistically significant association between market characteristics and fertilizer quality categories (good or bad) was found only for NPK 15:15:15 blends when samples from all countries were combined. This was probably because under this scenario (aggregating samples), there is enough variability in the samples collected between the two categories ("Bad" and "Good") for this particular product. The rural markets are associated with a significantly higher percentage (87.5 percent) of "Good" quality fertilizer than the urban markets (56.5 percent). Statistical analysis results also showed that permanent markets tend to have a significantly higher percentage of "Good" quality NPK 15:15:15 blends than periodic markets. Similarly, markets with a high concentration of agro-dealers tend to have a significantly higher percentage of "Good" quality products than isolated agro-dealers.

When data were analyzed by country, the pattern of the associations between market characteristics and fertilizer quality differed from the pattern identified when the aggregated data from the five countries were analyzed. This was either because some associations could not be evaluated due to insufficient sample size or because of insufficient quality variability within fertilizers with appropriate sample size. With country-level analysis, a statistically significant association between market characteristics and fertilizer quality categories (good or bad) was found only for the 15:15:15 blend in Ghana and for the 15:15:15 compound in Nigeria. In Nigeria, the urban markets showed significantly higher frequency of good quality than the rural markets. In Ghana, the permanent markets and the dealers that sell mainly to large-scale farmers presented significantly higher frequency of good quality than temporary markets and dealers that sell mainly to small-scale farmers, respectively.

Licensing and Knowledge of Fertilizers Matter

Statistical analysis performed on 106 samples of the NPK 15:15:15 blend and agro-dealer characteristics reveals that agro-dealers with "good knowledge about fertilizers" are more likely to sell a higher percentage of "Good" quality products than others. Similarly, analyses carried out with the 624 samples of NPK 15:15:15 blend, 15:15:15 compound and 16:16:16 compound show that the agro-dealers with a license for selling fertilizer are more likely to sell a higher percentage of "Good" quality fertilizers than non-licensed agro-dealers. In addition, the analysis also indicates that the agro-dealers that predominantly sell fertilizer to large-scale farmers are more likely to sell a higher percentage of "Good" quality products than the agro-dealers who sell fertilizer mainly to small-scale farmers. Wholesalers have a significantly higher percentage of "Good" quality fertilizers than retailers.

Physical Attributes of Fertilizers are Associated with Product Quality as Well

The qualitative assessment of granule integrity (presence of fine particles and dust) with aggregated data from all five countries indicated that all the blended fertilizers had at least 50 percent of the samples classified at medium- or high-level categories for the presence of fine particles. Eighty percent of the samples of the blended NPK 15:10:10 were categorized at the high-level category for the presence of dust. Among the compound fertilizers, 16:16:16, 15:15:15, 23:10:5 and Sulfan also presented more than 50 percent of the samples classified in the categories of medium or high for the presence of fine particles. Paradoxically, granule integrity was poorer for the 15:15:15 compound than for the 15:15:15 blend. Unfortunately, this lack of granular integrity has a negative impact on the quality of fertilizer. The observed frequent and severe granule degradation identified can be attributed to excessive manipulation of the fertilizer bags associated with their manual and individual handling. There is also a clear tendency of complex distribution chains (Nigeria and Ghana) to present higher frequency and severity of granular degradation than simple distribution chains (Togo).

As expected, the study found a strong association between high moisture levels and high caking levels for both the blended fertilizers and the compound fertilizers. In addition, the importance of appropriate bagging was underscored by findings in Senegal where 41 percent of the bags were found to be outer woven without plastic inner lining, and 61 percent of the samples presented medium to high degrees of urea caking. Low frequency of caking in urea was closely associated with the use of laminated bags or bags with plastic lining in Ghana, Nigeria and Togo.

Among the physical attributes of fertilizer considered in the study, the moisture content and the segregation showed significant relationships with nutrient content quality only in the NPK 15:15:15 blend.

Effective Implementation of the Adopted ECOWAS Fertilizer Regulatory System is Critical

The study results clearly suggest that effectively implementing the adopted ECOWAS fertilizer regulatory system is likely to ensure that products supplied to the market meet high quality standards. The system calls for licensing of agro-dealers as well as inspection, sampling and analysis of fertilizers at importation points and along the distribution chain.

Assessing the Economics of Fertilizer Quality Deficiencies for Farmers and National Economies is Needed

The study found high frequencies of poor-quality fertilizer in the target countries. These deficiencies have a direct effect on revenues at the farmer and country levels. Analyzing these effects will be an important contribution.

Addressing the Quality Challenges of the Blends is Needed

The fact that blends show the most frequent and severe cases of poor quality suggests that it is imperative to identify the origin of their quality problems and to propose appropriate solutions. In addition, there is a clear need to enhance the manufacturing knowledge and equipment for manufacturing blends.

Building the Capacity of Agro-Dealers is Necessary

The study results equally suggest the need to train distributors on the appropriate storage and handling of fertilizer products as well as their physical and chemical properties. Doing so will contribute to reducing the effect of physical attributes of fertilizer on product quality.

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Introduction

With the exception of Cape Verde and, to a lesser degree, Senegal, the agricultural sector has a dominant position in the national economies of the Economic Community of West African States (ECOWAS) member countries.[1] Agriculture accounts for 25 to 65 percent of the gross domestic product (GDP) and employs an average of 40 to 77 percent of the active population, making it the main source of employment and revenue for the majority of the population. Moreover, agriculture generates up to 66 percent of export revenues in many countries and its growth stimulates demand from other economic sectors.

A performance assessment carried out by the Regional Strategic Analysis and Knowledge Support System (ReSAKSS) in 2009 shows that in West Africa, more than half of a 1 percent reduction in poverty at national and rural levels can be attributed to growth in the agricultural sector. Consequently, the agricultural sector is the cornerstone of any food security and poverty reduction strategy in the region, particularly for the rural population. This sector is unfortunately characterized by low productivity on the majority of farms, especially for food crops. This low productivity level stems largely from the fact that soil nutrients that are absorbed by crops are not sufficiently replaced by external sources, leading to an impoverishment of soils that are already naturally poor.[2]

Indeed, fertilizer consumption, estimated to be about 1.5 million metric tons (mt) per year at the regional level, is low and variable from one country to the other. Fertilizer is primarily used on cash crops with an organized subsector. Its supply is dominated by imports, either of raw materials that often are fertilizers themselves, which are blended locally to produce NPK blend fertilizers, or of finished compound granulated fertilizer products. With an average of less than 8-9 kilograms (kg) of nutrients used annually per hectare (ha) of arable land, fertilizer consumption in West Africa is among the lowest in the world.

The Food and Agriculture Organization (FAO) of the United Nations [3] estimates that the average fertilizer application rate should increase from the current 8-9 kg/ha/year to 23 kg/ha/year by 2015 to meet the objective of 6 percent annual growth in agricultural production that was set by the Comprehensive Africa Agriculture Development Programme (CAADP), a framework the New Partnership for Africa's Development (NEPAD) adopted in

[1] Agriculture accounts for 12 percent of Cape Verde's GDP and less than 18 percent of Senegal's, compared with at least 65 percent and 51 percent for their tertiary sectors, respectively.

[2] These soils have often developed from heavily leached, old rocks. Their carrying capacity tends to be very low, either because of low water availability or low nutrient availability (Roy, A.H., and J.H. Allgood. 1999. "IFDC's Experience in Development Programmes in Developing Economies with Special Reference to Africa," FSAA Journal).

[3] FAO. 2004. "Fertilizer Development in Support of the Comprehensive Africa Agriculture Development Programme," 23ème conférence régionale, FAO.

2003. According to ReSAKSS[4] and the International Food Policy Research Institute (IFPRI),[5] even with an annual growth rate of 6 percent, most West African countries will not achieve the first Millennium Development Goal (MDG) of halving poverty and hunger by 2015; an increase in the consumption of fertilizers to 23 kg/ha/year by 2015 will be insufficient as well. Recognizing that the use of fertilizers is vital to achieve the African Green Revolution, particularly in view of the rapid population growth and rate of urbanization as well as the declining soil fertility, Member States of the African Union pledged, at the Africa Fertilizer Summit held in June 2006, "…to increase the level of fertilizer use from the current annual average of 8 kilograms of nutrients per hectare to at least 50 kilograms per hectare by 2015."

In 2006, prior to the Africa Fertilizer Summit and in collaboration with the West Africa Economic and Monetary Union (UEMOA), ECOWAS adopted a fertilizer strategy[6] with the general objective of promoting their increased and efficient use with a view to sustainably improving agricultural productivity. This regional strategy hinges on four pillars or specific objectives:

1. Improve the physical environment for the optimal use of fertilizers.
2. Improve the institutional, regulatory and business environment of the regional fertilizer market.
3. Stimulate effective demand.
4. Stimulate supply.

Through the second specific objective, which is to improve the regulatory, institutional and business environment of the regional market of fertilizers, ECOWAS is focusing on creating favorable conditions for the development of the fertilizer sector. Indeed, West African national fertilizer markets are underdeveloped and too narrow to generate a sufficient dynamism and competitiveness. The extension of national markets to the ECOWAS region through the harmonization of national regulatory frameworks is likely to further stimulate private investment in this sector. The effective implementation of a regional framework that harmonizes national regulatory frameworks governing the production and trade of fertilizers and instituting and organizing quality control will protect farmers and render fertilizer trade more attractive to private investment by expanding national markets beyond national borders and by stimulating fair competition with quality products.

The liberalization of the importation and distribution of fertilizers in several West African countries without appropriate control led to the emergence of quality problems in products traded in the region. These problems could impede efforts to boost agricultural productivity and to restore or maintain soil fertility. There are very few systematic studies on the quality of fertilizers marketed in West Africa. The most recent,[7] which dates back to 1995 and was conducted by IFDC, showed that although in general the physical attributes of marketed fertilizers were acceptable, 43 percent of products were nutrient deficient and 58 percent were deficient in weight. However, the study found no evidence of the common forms of

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[4] Johnson, M., et al. 2008. "Regional Strategic Alternatives for Agriculture-Led Growth and Poverty Reduction in West Africa," ReSAKSS Working Paper No. 22.

[5] IFPRI. 2009. *ECOWAP/CAADP Implementation: Agricultural Growth and Poverty Reduction Performance and Outlook Synthesis of National Agricultural Investment Programs*.

[6] ECOWAS. 2006. *Stratégie Régionale de Promotion des Engrais en Afrique de l'Ouest*.

[7] Visker, C., Rutland, D. and K. Dahoui. 1995. "The Quality of Fertilizer in West Africa (1995)," IFDC. *Miscellaneous Fertilizer Studies No. 13*.

adulteration.[8] There are several cases that confirm that these problems persist[9] in markets and, consequently, a considerable quantity of fertilizers traded in West Africa is of poor quality. These quality problems will increase if the market should continue growing without effective control; significant environmental hazards may also occur. In addition, only quality products can enable farmers to maximize the returns from their investments and encourage them to continue using fertilizers.

The urgency of adopting a regional legal framework is therefore a priority for ECOWAS and UEMOA in the context of the implementation of the regional fertilizer strategy adopted in 2006. To support the development of this framework and to serve as a basis for assessing the impact of the regional regulatory framework following its adoption and implementation, ECOWAS and UEMOA initiated in 2010 an assessment of the quality of fertilizer traded in West Africa as well as factors that influence the quality of fertilizers in the region through the Marketing Inputs Regionally (MIR) Plus project.[10]

This report presents the main findings of this assessment for Togo. Comparisons with other countries involved in this study were intentionally avoided. However, these are highlighted in the summary of this report, which is the same as the summary provided in a separate cross-country, regional report [11] that was produced using the same data set to provide a regional perspective on the extent of quality problems associated with fertilizers traded in West Africa. The conclusions and recommendations in this report are also similar to the ones provided in the regional report.

[8] These forms are to: (a) change the appearance of the product; (b) add "miracle" substances; and (c) sell an outright fake product. These problems are typically found at the retail distribution level. The 1995 study was conducted only at port and wholesaler levels.

[9] In Nigeria, for example, Zimbabwean farmers in Kwara State purchased considerable quantities of compound NPK fertilizers (12-12-11, 20-10-10 and 15-15-15) in 2006. Laboratory analysis results from Zimbabwe and South Africa showed that these fertilizers instead contained 11.7-1.4-5.8, 16.2-1.3-3.8 and 15.5-1.38-7.2, respectively.

[10] The MIR Plus project is a joint ECOWAS-UEMOA project implemented by IFDC with the overall objective of facilitating the development of a regional agro-input market in West Africa in support of the implementation of their regional agricultural policies.

[11] ECOWAS, UEMOA and IFDC. 2013. *The Quality of Fertilizer Traded in West Africa: Evidence for Stronger Control*, Special IFDC Publication SP-42.

Section 1. Methodology

1.1. Data and Sample Collection

In July 2010, a consultative meeting was held with technical partners from national services responsible for fertilizer control from a sample of countries in West Africa (Côte d'Ivoire, Ghana, Nigeria, Senegal and Togo). The purpose was to determine the data to be collected and to discuss a methodology for an assessment of the quality of fertilizers traded in the region. The sampling methodology used is diagrammed in Figure 1 and it consists of two steps: (1) obtaining a random sample of fertilizer dealers or distributors in each country and (2) collecting random samples of fertilizers from each of the warehouses or shops included in the sample of distributors in the first step.

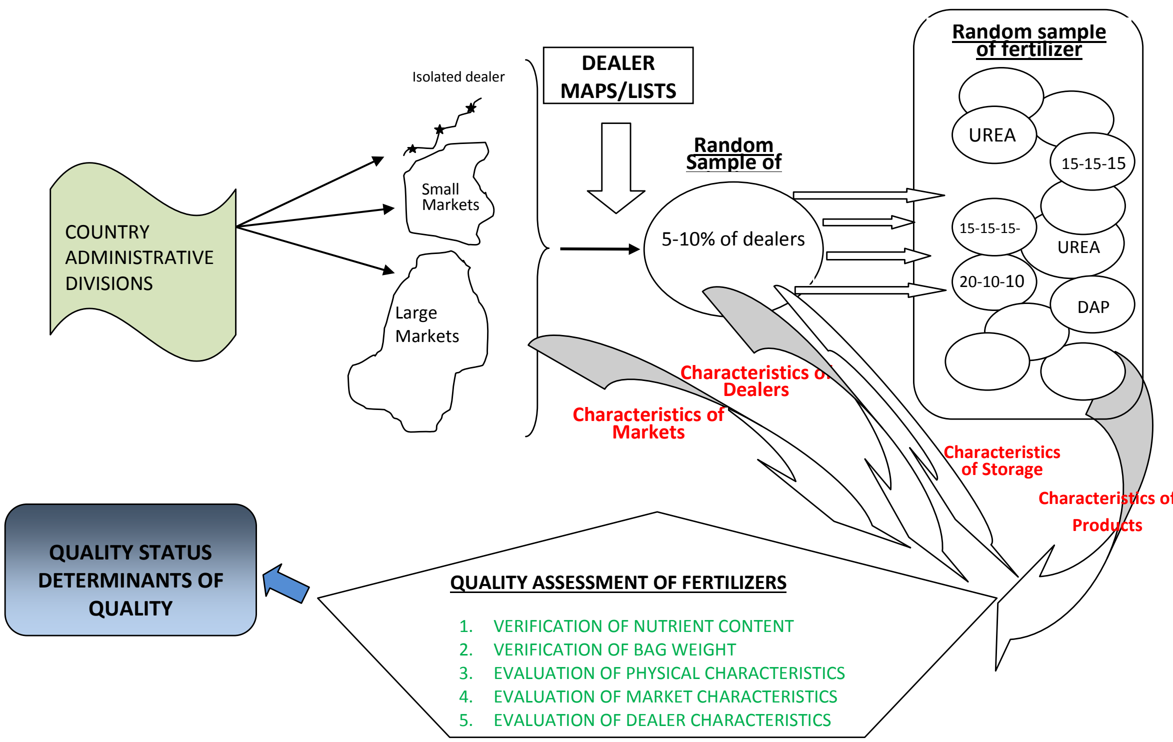


Figure 1. General Methodology for the Quality Assessment of Fertilizers Commercialized in the ECOWAS Countries

1.1.1. Sampling of Fertilizer Dealers

Information about the location and characteristics of the fertilizer markets was collected for the different administrative divisions in each country. After identification and characterization of the markets, an inventory of dealers inside each market was conducted. The purpose of the dealer inventory was to identify and delimit the population of dealers to sample. The dealer population was defined using maps[12] (Ghana and Nigeria) that geo-reference the location of each dealer within the different markets or with lists of dealers that were available at the ministry of agriculture (Côte d'Ivoire, Senegal and Togo). In each

[12] These maps were developed by the Alliance for a Green Revolution in Africa (AGRA)-funded agro-dealer development projects implemented by IFDC.

country, a sample of dealers was obtained by randomly selecting 5-10 percent of the dealers from the maps or the lists. Special care was taken to make sure that the sample followed the same geographical distribution patterns as the population of fertilizer dealers. Classification of dealers by market size was done *ex post facto* during data analysis.

1.1.2. Random Sampling of Fertilizers and Collection of Data

When the study teams visited the dealers that were part of the sample, they recorded the characteristics of markets and dealers in a pretested main questionnaire (Table A.1 in Appendix A). Inside the dealer's warehouse or shop, the field personnel sampled every type of fertilizer found following specific procedures for sampling, collecting, inspecting and labeling every fertilizer sample. Characteristics of the fertilizer sampled were recorded in the main questionnaire (Table A.1) and in the questionnaire for physical attributes (Table A.2 in Appendix A). Together with the fertilizer sample collection at each dealer or distribution point that was selected in the first step of the methodology, the inspectors recorded the following information in Table A.1 and Table A.2:

- Characteristics of the market (country, state or region, town, type of market, concentration of dealers, periodicity of the market).
- Identification and characteristics of the dealer (fertilizer owner or attendant, knowledge about fertilizers, training in fertilizer, possession of license, type of customer, business status and size).
- Characteristics of storage (approximate dimensions, ventilation, temperature, product handling equipment, use of pallets, height of stacks, general housekeeping).
- Characteristics of fertilizer products (type, category of supplier, quantity in hands, bag type, bag weight, evidence of quality problems).
- Qualitative assessment of physical attributes (segregation, estimated amount of filler and impurities, granule integrity [fines and dust], caking, moisture content).

In each of the distribution points visited, fertilizer products were sampled, labeled and packed using the sampling protocol described in Appendix A. Samples from a country or group of countries were taken to a central location where they were reduced to about 100 grams (g) each using a riffle (Figure A.4) for chemical analysis of nutrient content.

1.2. Chemical and Physical Analyses of Fertilizer Samples

1.2.1. Selection of the Laboratory

Laboratories with experience in the analysis of soil, plant, water and fertilizer operating in the region were considered to analyze the fertilizer samples. Based on information available at IFDC and past experiences, two of these laboratories stood out: the SGS Environmental Laboratory of Tema in Ghana and the Ghana Atomic Energy Commission (GAEC) laboratories in Accra. Project technical personnel visited the two laboratories and agreed on the following process to select one of them to perform the analysis.

1. Assessment of the laboratory's familiarity with and/or agreement on the procedures: Each of the laboratories was given a copy of the draft analysis manual ECOWAS was developing[13] for member States to assess if they were comfortable with the procedures described in the manual for analyzing the samples. The procedures are based on the methods of the Association of Official Analytical Chemists (AOAC) and are similar to

[13] This manual had been technically validated by experts from the ECOWAS member States in a regional workshop. It has been submitted for final adoption by the ECOWAS Commission.

those used in the laboratory selected for reference analyses (i.e., IFDC laboratory in Alabama, USA).

2. Estimation by each of the laboratory of the time required to complete the analysis: To determine this, it was agreed that the two laboratories should take into account that samples were to be analyzed in batches of 100-150 and will submit an interim report to project technical staff at the end of the analysis of each batch. The analysis of the next batch of samples is dependent on the quality of the results presented in the interim reports.
3. Estimation of the total cost of the analysis: The laboratories were asked to submit a cost proposal for analysis to project technical staff.
4. Testing phase: Before embarking on the analysis of the samples, the two laboratories were asked to analyze five samples that project technical staff provided to test their familiarity with the procedures. These test samples include NPK products (obtained both through physical blends and compound granulation) from the study's collection. They were also given five fertilizer materials of known nutrient content from the Magruder Fertilizer Check Sample Program.

After undergoing the aforementioned process, the SGS Environmental Laboratory at Tema, Ghana, was selected to analyze the samples. Samples from the Magruder Fertilizer Check Sample Program were used as standards by this laboratory for validation-calibration of their methodologies.

1.2.2. Chemical Analysis of Fertilizers

Given the limited resources available for this assessment, the priority in the chemical analysis of the fertilizer samples focused on determination of their primary plant nutrient content: total nitrogen (N), available phosphorus (P_2O_5) and soluble potassium (K_2O). However, a few samples were considered for determination of secondary nutrients: calcium (Ca), magnesium (Mg) and sulfur (S). The nutrient content of samples was determined using analytical methods that are summarized in Appendix B.

1.2.3. Physical Analysis of Fertilizers

In each country, prior to the field work, the project technical staff trained members of the sampling teams on the qualitative evaluation of the fertilizer physical attributes described below. The training consisted of explaining the concepts associated with each physical attribute and how to use the qualitative scale for each. The qualitative scales and the format to record fertilizer attributes are presented in Table A.2.

1.2.3.1. Segregation

Segregation is the physical separation of granules from the different components of bulk blends due to their granule size differences. Uneven distribution of the blend components can occur due to shaking during transportation and handling in warehouses and shops. Segregation is the result of small granules moving downward between spaces left by larger granules. The larger the granule size differences, the larger the segregation could be. The qualitative evaluation of segregation in the fertilizer samples was conducted using a scale with the categories: none, low, medium and high.

1.2.3.2. Granule Integrity

Granule integrity refers to the capability of the fertilizer granules to remain whole, resisting fracture or abrasion. Poor granule integrity may indicate manufacturing deficiencies, excessive handling or product aging. The lack of granule integrity is estimated through quantification of fines (particles smaller than the original granule size) and dustiness. Fines are defined as the portion of the sample that visually appears to have particles smaller in size than the bulk of the sample. The determination for fines was made by observing the samples and assigning the sample a category from the scale: none, low, medium or high.

Dustiness is defined as the level of visible dust present as the sample is being poured into a resealable plastic bag; the quantity of dust can be estimated by the amount of dust deposited at the bottom of the plastic bag after shaking. In this study, dustiness was qualitatively rated as: none, low, medium or high.

1.2.3.3. Moisture Content

The moisture content was qualitatively assessed by observation, feeling and examination of the fluidity of the fertilizer sample. NPK fertilizers tend to become darker than their original color when they have absorbed moisture from the environment. Medium to high humidity of a fertilizer can be felt when touched. Similarly, fertilizer granules with medium to high humidity do not flow freely; they can get clogged in the sample probe. To preserve the original moisture content, each sample was packed in two plastic bags with perfect sealing. Moisture content was qualitatively rated as adequate, medium or high.

1.2.3.4. Caking

Caking occurs when the individual granules of the product fuse to form larger aggregates. In extreme cases of caking, entire bags become one solid body. Caking usually takes place when the fertilizer product comes in contact with water or when it is stored at high relative humidity. Another factor contributing to caking is the pressure exerted by stacked bags. Caking was qualitatively assessed through observation and by feeling the fertilizer bags and rated as none, low, medium or high.

1.2.3.5. Impurities and Fillers

Impurities are foreign substances that become mixed with the fertilizer during deficient manufacturing procedures or as a result of management practices that compromise quality. When products are spread on the ground (a practice among small retailers to dry, break conglomerates and make blends), they may be contaminated with soil, plant materials or other materials. The difference between fillers and impurities should not be confused. Fillers are materials added to fertilizers to help in the uniform distribution of nutrients within a given volume of the fertilizer product. Impurities are foreign substances that are mixed with the fertilizer during deficient manufacturing procedures or as a result of management practices that compromise quality. Fillers are present in relatively large quantities and tend to be uniformly distributed in the entire volume of fertilizer. Impurities are present in small quantities and their distribution is not uniform.

Large amounts of fillers in blended NPK products may be a sign of product adulteration. Usually, the compound granulated NPK products and crystalline products such as urea, ammonium sulfate and potassium chloride (KCl) do not have fillers; the presence of fillers in bags of these products may be evidence of adulteration. The presence of fillers or impurities in the fertilizer was recorded as “yes” or “no” in the questionnaires.

1.3. Data Analysis and Interpretation

Fertilizers that were collected with a sample size lower than 23 were analyzed only descriptively. For the fertilizer products with at least 23 samples, inferential statistical analyses were applied on data about nutrient content, bag weight, physical attributes and characteristics of markets, dealers and storage conditions to determine the quality of the different fertilizer products and to associate fertilizer quality with market, dealer and physical characteristics. Then, the quality problems were interpreted as a result of manufacture deficiency, mismanagement, adulteration or a combination of these three categories. The complete statistical methodology was applied separately to data collected from each of the five countries to produce national reports and to aggregated data from all countries (regional report).

1.3.1. Nutrient Content Compliance

For a single nutrient fertilizer, the tolerance limits (TL)[14] ECOWAS adopted require compliance to the individual nutrient content criterion (Appendix C). For NPK fertilizers, compliance with both the individual nutrient content and with the content of all nutrients combined is required. A fertilizer is deemed "nutrient deficient" if the deviation for the content of at least one of the individual nutrients is below the individual nutrient content TL and if the total deviation in nutrient content (hereafter referred to as total deviation) for all nutrients combined is below TL[15]. The total deviation for all nutrients combined is calculated from the addition of deviations for nutrients with content lower than the label specification (negative deviations); compensation from nutrients with content higher than specified to balance deficiency of another nutrient is not allowed. For example, in a 15:15:15 sample that showed total N, P_2O_5 and K_2O contents to be 15, 13.8 and 14, respectively, only deviations in nutrient content associated with the P_2O_5, and K_2O are added to calculate the total deviation for all nutrients combined. In this example, the total deviation for all nutrients combined is -2.2.

The guarantee[16] for phosphate is measured in terms of available phosphate, which is phosphate soluble in water, plus phosphate soluble in neutral ammonium citrate; the guarantee for nitrogen is in terms of total nitrogen; and the guarantee for potassium is in terms of soluble potash.

The assessment of nutrient compliance is commonly made through the count of cases not meeting standards set in the regulations. This approach has limitations for expression of quality in probabilistic statements and for evaluations of hypotheses that involve different sets of fertilizer samples. Alternatively, for continuous variables such as individual nutrient content, total nutrient content, deviations from total nutrient content of the fertilizers or the weight of the fertilizer bags, the empirical cumulative frequency distribution function (ECFDF) is used to develop probabilistic statements about nutrient content compliance or for the fertilizers to be out of compliance. The ECFDF allows to observe and infer about the behavior of the entire population of individual nutrient content (or deviation from total nutrient content) values and to develop probability statements of nutrient content out of compliance with respect to specific tolerance limits or intervals of tolerance limits. On the

[14] The term "tolerance limits" means allowances for variations inherent in the collection, preparation and analysis of a fertilizer sample. It does not include an allowance for manufacturing variation.

[15] These deviations are calculated as follows: nutrient content obtained from the analysis - nutrient content guaranteed.

[16] A guarantee for a nutrient is the percentage of that plant nutrient claimed on the label.

ECFDF, by using values lower than the tolerance limit, different degrees of severity of out-of-compliance content and their probabilities can be estimated. The ECFDF is also a valuable tool to compare the behavior of complete populations, such as when countries or types of manufacture are compared with respect to nutrient content compliance of specific fertilizer products. Probability values are directly obtained from the graphical representation of the ECFDF.
The ECFDF is depicted by a continuous ascending line in a coordinated system in which the nutrient contents resulting from chemical analysis or the weight differences are in the abscissa and the cumulative frequencies of occurrence (percent) are in the ordinate. The dotted lines on the ECFDF indicate the percentage of samples associated with the values for total nitrogen, available P_2O_5 or soluble K_2O content or bag weight that are below the TL. The probability values are directly obtained by transforming the percentage frequency into probability values between 0 and 1.

The diagnostic about the nutrient content compliance of fertilizers commercialized in the ECOWAS sub-region was made using the regulation adopted by ECOWAS whose tolerance limits are specified in Appendix C. The out-of-nutrient content compliance is expressed in probability statements following this procedure:

A. **Determination of probability for "out of compliance of individual nutrient contents":** p_N, p_P, or p_K (Table 1) are obtained from the ECFDF developed for individual nutrients contained in each fertilizer. ECFDFs were built using the appropriate tolerance limits depending on whether the fertilizer contains a single nutrient or multiple nutrients. Values from the ECFDF are expressed in probability using the expression:

    P (Individual Nutrient Content measured $\leq$ x) = p

    Where x = Nutrient Content guaranteed – TL – 0.1 and p is a probability with values in the range 0 to 1.

    A nutrient content is out of compliance when it has a deficit of at least TL + 0.1..

    Example: The probabilistic statement for a 15:15:15 out of compliance for total nitrogen content is P (Total Nitrogen measured $\leq$ 13.8) = p

B. **Calculation of the probability that "at least one of the nutrients is out of compliance":** $p_{(N+P+K)}$ (Table 1) is done by adding the individual nutrient content probabilities obtained in the first step. This probability for an NPK fertilizer is the sum of the probabilities for nitrogen out of compliance (p_N) plus the probability for phosphorus out of compliance (p_P) plus the probability of potassium out of compliance (p_K). $p_{(N+P+K)} = p_N + p_P + p_K$. When the addition of the probability for out of compliance from individual nutrients is higher than one, a probability equal to one is adopted as the probability of at least one of the nutrients out of compliance

C. **Calculation of the probability for "out of compliance of deviations from total nutrient content":** p_{DTNC} (Table 1) was obtained from the ECFDFs for deviations from total nutrient content. Using the following expression:

    P(DTNC $\leq$ - 2.6) = p

    Where DTNC is the deviation from total nutrient content and 2.6 is the TL for total nutrient content compliance with value of 2.5 plus 0.1. The 0.1 is added because for the DTNC to be out of compliance, it has to be lower than the TL.

D. **Calculation of the probability for "overall out-of-nutrient content compliance":** p_{ooc} (Table 1) for a fertilizer is obtained as the product of the probability for out of compliance of at least one of the nutrients times the probability for out of compliance of deviations from total nutrient content: $p_{(N+P+K)} * p_{DTNC}$.

E. **Calculation of probability of segregation:** p_{SEG} (Table 1) for blended fertilizers was obtained from the ECFDFs for the deviations from the total grade in the blended fertilizers, using the expression P(-2.5 $\leq$ DTG $\leq$ 2.5) = p where DTG is departure from total grade and 2.5 is the tolerance limit for total nutrient content. Total grade (TG) is the addition of the individual grades of the NPK components. For example, the TG of a 15:15:15 is 45.

1.3.2. Bag Weight Verification

Prior to sampling fertilizer products, a random sample of fertilizer bags was selected, and individual bags were weighed for the verification of the weight declared on the fertilizer label in each fertilizer shop or warehouse included in the dealer's random sample. The departure from weight on the label was recorded in the survey questionnaire (Table A.1), and the data were used for development of the ECFDF per country. The ECFDF graphs have the departure from the weight on the label (DWL) in the abscissa and the cumulative frequency (percent) in the ordinate. The probability statements for DWL were made using the following general expression:

$$P(DWL \leq 1.0) = p$$

The tolerance limit adopted by ECOWAS for weight departure from the label specified net weight is 1 percent of the bag weight. For 50-kg bags, the tolerance is 0.5 kg. Unfortunately, during data collection, bag weights in this study were recorded without decimals. Consequently, the probabilities for bag weight out of compliance (Table 3) were determined using 1 kg per 50-kg bag as the tolerance limit.

1.3.3. Evaluation of Fertilizer Physical Attributes

Given the discrete nature of the fertilizer physical attribute variables, the probabilistic statements associated with the different categories of the physical attributes were obtained from the empirical frequency distribution function (EFDF), which is represented by a bar graph with the physical attributes categories in the abscissa and the frequencies (percent) in the ordinate. In this case, the probability statements have the following form:

$$P(\text{Physical Attributes} = c) = p$$

Where c is the category of the physical attributes and p is the probability value obtained directly from the frequency associated with a category in the EFDF figure.

Segregation of the bulk blend fertilizers was estimated qualitatively through observation by inspectors of the samples collected. Through the use of the total grade concept for blended fertilizers, the probability of segregation was calculated in the manner described in 1.3.1.

1.3.4. Factors Influencing Fertilizer Quality

Factors considered in this analysis are characteristics of fertilizer markets, characteristics of fertilizer distributors, characteristics of storage conditions and characteristics of fertilizer products. These characteristics are listed in the questionnaire presented in Table A.1 (Appendix A) that inspectors used to record the data and information needed.

From the evaluation of nutrient content compliance, a categorical variable named "Quality" with two categories ("Bad"[17] or "Good") was developed. When a fertilizer presented nutrient content deviation below the tolerance limit, the "Quality" variable took the category value "Bad"; otherwise, it took the category value "Good."

[17] In this study, a fertilizer is classified as "Bad" due to no nutrient content compliance. This does not mean that the product is bad in itself; it is a good product with different nutrient content, which is why the regulation requires that such fertilizer be relabeled.

Two-way contingency tables of each of the characteristic's variables listed in the questionnaire (Table A.1) against the "Quality" variable developed ("Bad" or "Good") were constructed to identify possible relationships. A Chi-square test was then applied to test the hypothesis of independence between the "Quality" variable and each of the variables defining the aforementioned characteristics. The significant results from Chi-square, identified by probabilities equal to or lower than 0.1, indicate a possible relationship between characteristics of markets, dealers, storage and products with the nutrient content of the fertilizers. Only products with a large number of samples and enough variability between the categories of the characteristics tested for association were included in this analysis. Fertilizers in which the nutrient content compliance is dominantly "Bad" or dominantly "Good" do not allow to test the association hypotheses between nutrient content quality and factors such as characteristics of markets, dealers and products.

Section 2. Results and Discussion

2.1. Distribution of Fertilizer Samples

A total of 168 fertilizer samples were collected throughout Togo (Appendix D) and largely from government depots using the methodology presented in Section 1. These samples represent eight identified fertilizer products and three that were not identified. Their distribution by grade is shown in Figure 2.

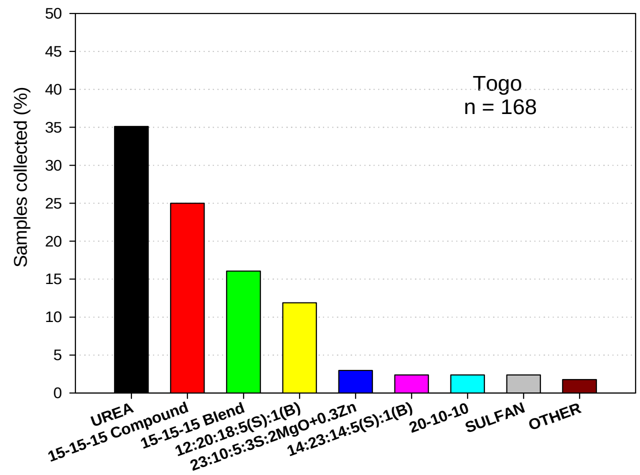


Figure 2. Breakdown of Fertilizers Samples by Product in Togo

Samples of urea, NPK 15:15:15 compound, NPK 15:15:15 blend and NPK 12:20:18+5S+1B blend had the highest occurrence frequencies with 35.1 percent, 25.0 percent, 16.0 percent and 11.9 percent, respectively. They are followed by other products in much smaller proportions: NPK 23:10:5+3S+2MgO+0.3Zn compound (five samples), NPK 14:23:14:+5S+1B blend (four samples), NPK 20:10:10 blend (four samples), Sulfan (four samples) and three other samples of unidentified products.

It is clear that the total number of samples collected in Togo is low and this is partly because the sampling was performed toward the end of the planting season. For example, very few samples of fertilizer grades for cotton (NPK+S+B) and cocoa (NPK 20:10:10) were collected, even though the production of these cash crops is quite significant in the country. Nevertheless, apart from these two grades, the distribution of fertilizer samples presented in Figure 2 is a good representation of the relative importance of the most common fertilizer products used in Togo.

2.2. Fertilizer Nutrient Content Compliance

Inferential statistical methods were used to analyze the nutrient content compliance for 128 samples representing the three fertilizer products listed in Table 1. This corresponds to 76.2 percent of all samples collected in Togo. The other fertilizers sampled had sample sizes that were too small (1-20) to be included in this statistical analysis[18] and were therefore

[18] The sample size threshold used for the inclusion of fertilizer products in the inferential statistical analysis was 23. Fertilizer products with less than 23 samples were only analyzed descriptively due to the low reliability of ECFDFs built with less than 20 observations.

analyzed descriptively (Table 2). The probabilities presented in Table 1 were obtained from Figure 3.

Table 1. Probability for Out-of-Nutrient Content Compliance of Fertilizer Products Sampled in Togo

			Probability of out of compliance for							
			individual nutrient content			content of at	deviations from total nutrlent	overall nutrient content	Probability of segregation
			$P(NC^1 \leq x^2)$			$_N + p_P + p$	$P(DTNC^3 \leq -2.6)$	$p_{(N+P+K)} * p_{DTNC}$	$P(-2.5 < DTG^4 \leq 2.5) = p$
Fertilizer	Manufacture Type	# of Samples	Total N p_N	P_2O_5 p_P	K_2O p_K	$p_{(N+P+K)}$	p_{DTNC}	p_{OOC}	p_{SEG}
15:15:15	BLEND	27	0.18	0.03	0.16	0.37	0.15	0.06	0.76
15:15:15	COMPOUND	42	0.04	0.12	0.06	0.22	0.12	0.03	
UREA	COMPOUND	59	0			0		.	

[1] NC:Nutrient Content; [2] x=Nutrient Content in Label - TL - 0.1; [3] DTNC: Deviation from Total Nutrient Content ;
[4]DTG: Departure from Total Grade

2.2.1. NPK 15:15:15 Blend and Compound

Figure 3 compares the nutrient content compliance of the two types of manufacture in NPK 15:15:15, namely the blend identified by the interrupted line and the compound by the solid line. The probabilities of out of compliance for individual nutrients (P_N, P_P and P_K) are from Figure 3A-C. The probabilities for out of compliance of deviations from total nutrient content (P_{DTNC}) are derived from Figure 3D, and the probability of segregation of the blend (P_{SEG}) is from Figure 3E.

2.2.1.1. NPK 15:15:15 Blend

Table 1 shows that 37 percent of the 27 samples of the NPK 15:15:15 blend collected in Togo were out of compliance for at least one of the primary nutrients. The overall out-of-nutrient content compliance probability (P_{OOC}) of 0.06 (Table 1) indicates that 6 percent of these samples were out of compliance both with respect to the individual nutrient content and with respect to the total nutrient content as defined in the adopted ECOWAS Regulation.[19]

The 0.76 probability of segregation (P_{SEG}) suggests that in 76 percent of the 27 samples of NPK 15:15:15 blend collected, the individual nutrient content deficiencies of this fertilizer can be attributed to segregation of the fertilizer components used in the bulk blend. Indeed, diammonium phosphate (DAP), prilled urea and KCl are the most common components of NPK blends in West Africa. The large granule size disparity between DAP and prilled urea results in the tendency of DAP granules to become located at the top of the bags and prilled urea granules at the bottom of the bags. In addition, because KCl granules are more fragile than DAP or urea granules, they tend to degrade, and smaller KCl particles move toward the bottom of the fertilizer bags. These two phenomena, together with the manual handling of bags, explain the frequent cases of segregation in these types of fertilizers. Therefore, when segregation occurs in blended products, nutrients carried in small granules tend to become

[19] A supporting regulation adopted in application of the ECOWAS *Regulation C/REG.13/12/12 relating to fertilizer quality control in the ECOWAS Region* mandates that, to be acceptable, any deviation of the measured values of primary nutrient content from the values claimed on the label of complex fertilizers and NPK blends shall be an amount not exceeding 1.1 units for individual nutrients and 2.5 percent for all nutrients combined.

located in the lower portion of the bags and those carried in large granules tend to remain at the top of the bags.

This non-uniform distribution of nutrients in fertilizer bags experiencing segregation is reflected in samples taken from the bags using the standard methodology for sampling granulated fertilizers.[20] The nutrient content in the full volume of fertilizer contained in a bag remains unaffected by segregation, but the uneven distribution of nutrients in that bag causes uneven distribution of nutrients in farmers' fields when fertilizers are applied manually or mechanically. Since many small-scale farmers buy fertilizers in quantities smaller than a bag, they have a high chance of receiving fertilizers that do not meet the nutrient content specified in the fertilizer label if the product that they purchase has experienced segregation. This problem can be avoided by using fertilizers of uniform granule size for the manufacture of the blend and utilizing appropriate equipment and procedures to make the blends.

The most likely explanation for nutrient content shortages in the remaining 24 percent of the fertilizer samples is insufficient input of nutrients during the blending to produce the 15:15:15 grade or to nutrient dilution along the distribution chain. At the manufacturing level, this problem can be the result of intentional insufficient nutrient input to produce the intended grade, lack of or poor control of blending procedures, or use of inadequate blending equipment.

2.2.1.2. NPK 15:15:15 Compound

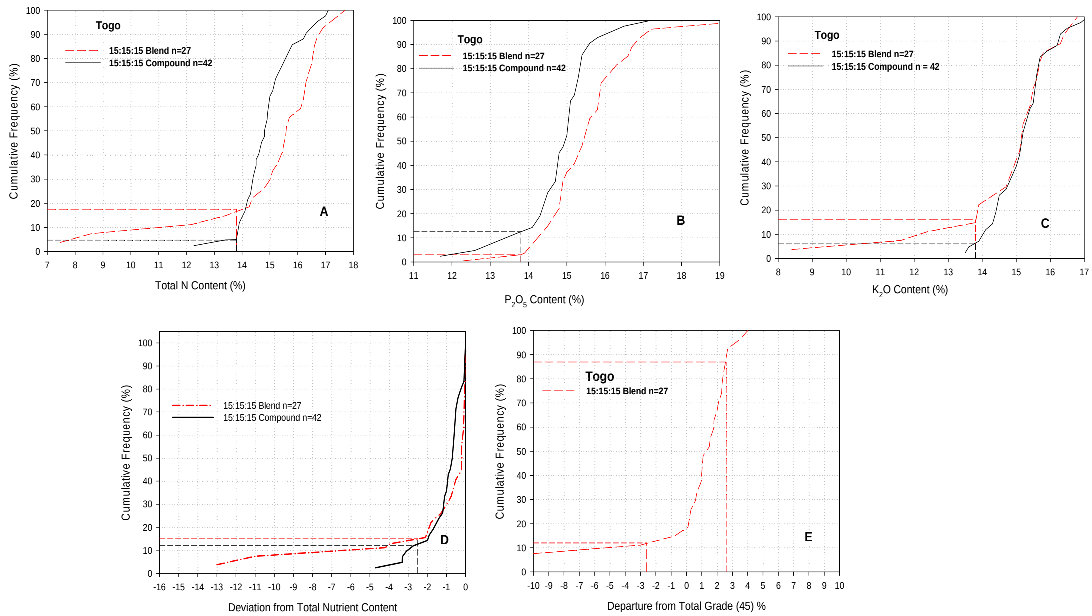
Table 1 also shows that 22 percent of the 42 samples of NPK 15:15:15 compound collected in Togo were out of compliance for at least one of the primary nutrients. However, its overall out-of-nutrient content compliance probability of 0.03 indicates that only 3 percent of the samples of this product collected were nutrient deficient both in terms of individual nutrient content and in terms of deviations from the total nutrient content as defined in the adopted ECOWAS Regulation. The 3 percent of overall nutrient deficiencies in this imported product can be explained by the combination of several factors such as importation from sources where manufacturing processes are not under complete control, intentional or unintentional nutrient dilutions that can occur along the distribution chain, or management practices that have the potential to reduce fertilizer quality (e.g., rebagging, manual manipulation of fertilizer bags and storage under inappropriate environmental conditions).

2.2.1.3. Comparison of NPK 15:15:15 Compound and Blend

Table 1 shows that, based on ECOWAS standards, overall nutrient deficiency (P_{OOC}) is much higher for the blended product than for the compound. The fertilizer analysis results indicate that there is a 6 percent chance that the NPK 15:15:15 blend sold in Togo will be out of compliance with the ECOWAS tolerance limit and a 3 percent chance for this to occur for the compound product. This result is not surprising, particularly because of the segregation problem observed in the blended product as discussed above. It suggests that further studies should be conducted to identify the origin of the quality problems of bulk-blended fertilizers and to propose appropriate solutions. However, it is important to note that, as discussed above, the nutrient deficiency is explained by factors other than segregation in 24 percent of the blended samples.

[20] By modifying the sampling method to sample the full profile in the bag, the uneven distribution of nutrients in the bags (segregation) would not be recognized.

A comparison of the probabilities of out of compliance for individual nutrients (P_N, P_P and P_K) of the two products (Table 1 and Figure 3) shows that the blend has higher percentages of samples out of compliance for total N (18 percent) and K_2O (16 percent) than the compound (4 percent and 6 percent, respectively), while the opposite is true for P_2O_5 (3 percent versus 12 percent, respectively). This result therefore indicates that the more serious individual nutrient deficiencies in the NPK 15:15:15 blend are total N and K_2O, while the most serious nutrient deficiency in the NPK 15:15:15 compound is P_2O_5. Frequent total nitrogen deficiencies in NPK blends may be explained by the use of prilled urea and its high chances of segregation from sources of P_2O_5 and K_2O due to its smaller granule size. However, it is



not easy to explain the difference in the P_2O_5 deficiency probabilities between the two types of products (blend and compound). A similar comparison conducted with data collected in Ghana shows that the blend has higher deficiencies for all three primary nutrients.

Figure 3. ECFDF of the Nutrient Content Compliance of 15:15:15 in Togo

Togo might be expected to have low variability in the importation sources and a relatively simple distribution chain due to the government control of importation and distribution. Fewer importation sources and a simple distribution chain with no intermediaries may explain the low percentage of samples out-of-nutrient compliance in Togo compared with the results obtained in the other four countries involved in this study.

2.2.2. Urea (46:0:0)

A total of 59 samples of urea were collected in Togo. Results of the analysis of their total nitrogen content (Table 1) show that these samples were good quality according to ECOWAS standards[21] because the probability of out of compliance of total nitrogen content was zero. However, given the small size of the samples of urea analyzed in this study, this result does

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[21] A supporting regulation adopted in application of the ECOWAS *Regulation C/REG.13/12/12 relating to fertilizer quality control in the ECOWAS Region* mandates that for the nutrient content of a single nutrient fertilizer with more than 20 percent nutrient content to be acceptable, any deviation of the measured value of the nutrient content from the value claimed on the label shall be an amount not exceeding 0.5 units.

not necessarily mean that the likelihood for a farmer to buy urea of poor quality in Togo is zero or extremely low. Because the nitrogen deficiency urea may have is highly unlikely of being manufacture related, a specific assessment with sampling done throughout the country when market activities are most intense is required to further verify this finding.

2.2.3. Other Fertilizers

As mentioned earlier, the sample size of some of the fertilizer products collected from the markets in Togo do not allow for inferential statistical analysis and were therefore analyzed descriptively (Table 2). The NPK 12:20:18+5S+1B blend used in cotton presented a high proportion of samples that were nutrient deficient, especially for total N (14 of 20 samples) and K_2O content (10 of 20 samples). Two of the four samples of the NPK 20:10:10 blend were out of compliance for total N, and three samples from the same fertilizer were out of compliance for K_2O. No nitrogen deficiencies were found in the four samples of Sulfan that were collected in Togo. Similar observations can be made for other products in Table 2.

Table 2. Number of Samples Out-of-Nutrient Content Compliance for Fertilizers with Few Samples

Fertilizer[22]	Manufacture Type	Number of Samples	Number of Samples Out-of-Nutrient Content Compliance		
			Total N	P_2O_5	K_2O
12:20:18 + 5S+1B	Blend	20	14	4	10
20:10:10	Blend	4	2	0	3
14:23:14+5s+1B	Blend	4	1	1	0
23:10:5+3S+2MgO+0.3Zn	Compound	5	2	0	0
Sulfan	Compound	4	0	-	-

2.3. Fertilizer Bag Weight Compliance

A total of 157 fertilizer bags were weighed in Togo. By ECOWAS standards, the assessment of bag weight compliance should be made based on a maximum allowable variation of fertilizer weight of 500 g per 50-kg bag. Unfortunately, during data collection, bag weights in this study were recorded without decimals. Consequently, the probability statements (Table 3) were constructed using 1 kg as the weight at which a bag starts to be out of compliance.

Table 3. Probability of Bag Weight Compliance for Samples Collected in the Five Countries

Country	Sample Size (n)	$P(DWL^a < -1.0) = p$ (P)
Côte d'Ivoire	18	0.28
Ghana	560	0.12
Nigeria	174	0.41
Senegal	146	0.13
Togo	157	0.06
Across countries	1,055	0.15

a. DWL = Departure from weight stated on the label.

[22] The unidentified products are not included in this analysis.

The statistical result obtained is a low 0.06 probability for a bag to fail to comply with the relaxed weight rule used, which indicates that there is approximately a 6 percent chance that a bag weight does not comply with the ECOWAS tolerance limit in Togo. The result obtained in Togo is below the probability of 0.15, which was observed when samples collected from the five countries involved in the study were aggregated (Table 2). Togo has the lowest probability of fertilizer bags out of compliance among the five countries, and this may be explained by the country's simpler distribution chain relative to the ones existing in countries such as Ghana and Nigeria.

2.4. Factors Influencing Nutrient Content

Factors considered in this analysis are fertilizer market characteristics, fertilizer dealer characteristics and physical attributes of fertilizer products.

2.4.1. Market and Dealer Characteristics

Statistical analysis for testing associations between markets and dealer characteristics and the quality of NPK 15:15:15 (blend and compound) yielded inconclusive results (Appendix E) due to the low variability in these characteristics (samples collected largely from government depots) and fertilizer quality (only 12 percent and 3 percent of samples were poor quality, respectively). However, significant associations were identified in other countries and when the data from the five countries were aggregated.

2.4.2. Physical Attributes of Fertilizers

The following physical attributes of fertilizers were assessed qualitatively in Togo: granule integrity (presence of fine particles and dust) and caking in relation with the type of bag. Due to the lack of consistency in the inspectors' judgment using the qualitative scales, results obtained showed a clear pattern for granule integrity only with the NPK 15:15:15 compound and blend. For caking, a clear pattern was found only with urea.

2.4.2.1. Granule Integrity

Granule integrity was assessed based on the levels of fine particles and dust recorded per fertilizer product and as discussed in Section 1. Figure 4 (A and B) compares granule integrity of the NPK 15:15:15 compound and NPK 15:15:15 blend in Togo.

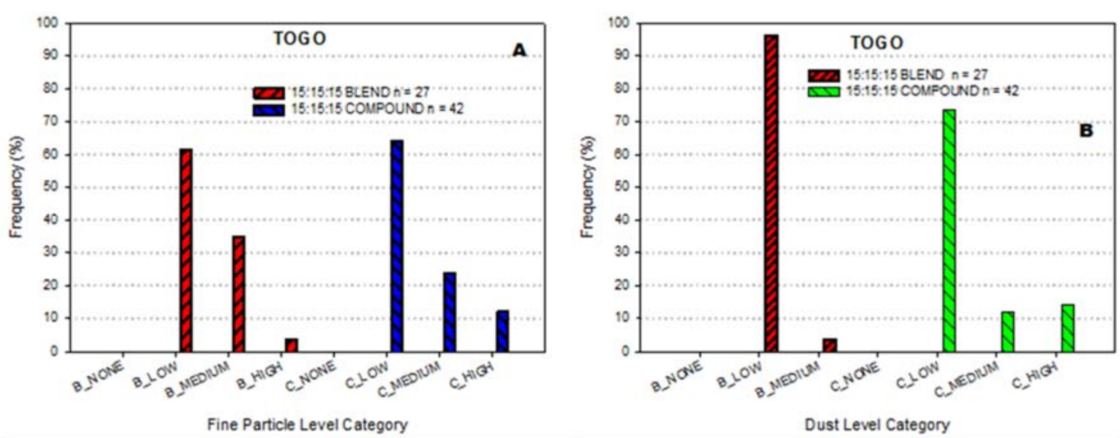
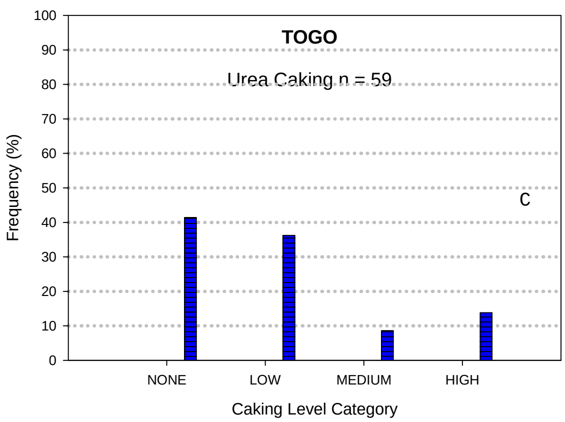


Figure 4. Frequency Distributions of Granule Integrity of 15:15:15 Blend and Compound in Togo

The percentage of samples for which the presence of fine particles (Figure 4A) or dust (Figure 4B) was considered to be high is greater in the compound 15:15:15 (12.0 percent and 14.3 percent, respectively) than in the blended 15:15:15 (3.9 percent and 0 percent, respectively). This indicates that granules from the granulated compound are more fragile than the granules from the blended components (usually urea, DAP and KCl). In the low category for granule degradation, Togo has the highest sample percentages for the compound and blended NPK 15:15:15 among the five countries involved in this study. This shows evidence that with a simple distribution chain, fertilizer bags are exposed to less handling.

2.4.2.2. Type of Fertilizer Bag and Caking

The analysis of urea caking and types of bags used in Togo shows that 78 percent of the samples collected have a zero to low degree of urea caking (Figure 5C) and all bags have plastic inner lining (Figure 5D). The relationship between the type of bag and caking of urea in Togo is strong (Figure 5C and D). The 22 percent of samples with urea caking, combining the categories medium and high, cannot be explained by inappropriate bagging because 100 percent of the bags examined in Togo were exterior woven with inner plastic lining; instead, the 22 percent of samples with caking shown in Figure 5C must be the result of the storage of urea in high stacks of bags without pallets for long periods of time. Loose bag seams and storage in warehouses with inadequate ventilation may also contribute to the 20 percent urea caking as well.



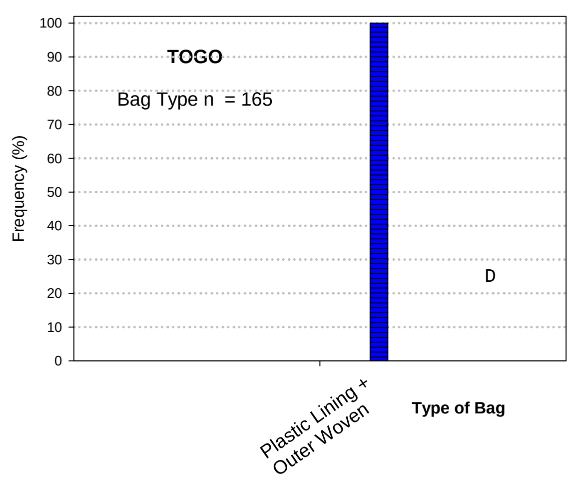


Figure 5. Urea Caking and Types of Fertilizer Bags in Togo

2.5. Adulteration of Fertilizers

There was no case of fraud completely documented in this fertilizer quality assessment in Togo. However, the sale of underweight bags, which is estimated to occur for 6 percent of the fertilizer bags traded in the country, could be considered fraudulent. Similarly, cases of nutrient deficiency (for which the most likely explanation for nutrient content shortage is insufficient use of nutrients during the blending manufacture or nutrient dilution along the distribution chain) could be considered fraudulent as well.

Conclusions and Recommendations of the Regional Report

A total of 2,037 fertilizer samples were collected from 827 distributors that included wholesalers, government depots and retailers of various sizes across all five countries involved in this assessment. The distribution of these fertilizer samples is a good representation of the relative importance of the different fertilizer products in the five countries. Urea and the NPK 15:15:15 blend are the only products common to the five countries.

The chemical analysis of the fertilizer samples focused on determination of their content of primary plant nutrients (total nitrogen, available phosphorus and soluble potassium). However, analysis of secondary nutrient content (calcium, magnesium and sulfur) was considered, but only the sulfur in the samples of Sulfan collected in Ghana was analyzed

Statistical analyses were applied to data on nutrient content, physical attributes of fertilizers, characteristics of markets and dealers and storage conditions to determine the quality of the various fertilizer products as well as to associate fertilizer quality with market and dealer characteristics. Then, the quality problems were interpreted as a result of manufacturing deficiency, mismanagement, adulteration or a combination of these three categories. To be meaningful, the nutrient content compliance was analyzed with inferential statistical methods only for the fertilizer products with at least 23 samples, and these accounted for 93 percent of all the samples collected in the study. Nutrient content compliance was assessed based on newly adopted ECOWAS standards.

The main findings of this assessment can be summarized as follows:

1. The NPK fertilizers manufactured through blending present the most frequent cases of poor quality compared with compound products. The study found, for example, that 51 percent of the 106 samples of the 15:15:15 blend were out of compliance, both with respect to the individual nutrient content and with respect to the total nutrient content, compared with only 10 percent of the 356 samples of the 15:15:15 compound product collected.
2. The main reason for nutrient deficiencies in some blends, such as Asaase Wura, Cocoa Feed and NPK 15:15:15, is the uneven distribution of nutrients in the fertilizer bags caused by granule segregation. When nutrients do not have uniform distribution in the volume of the fertilizer bag, the nutrient content of the entire bag may match the label specification, but the non-uniform distribution of nutrients in the bags will result in uneven distribution of nutrients in the crop fields. Another consequence of non-uniform distribution of nutrients in fertilizer bags is that a high percentage of subsistence farmers will not receive products with the nutrient content required by their crops because they often purchase fertilizers in quantities lower than the 50-kg bag.
3. Nutrient deficiencies in compound NPKs may be explained by problems during product granulation and/or dilution (intentional or accidental) of nutrient content through the distribution chain.
4. With a probability of out of compliance of 0.04, the total N content compliance of urea was good. Yet, there is a perception that urea is being mixed with non-fertilizer materials in the region, which the study results did not confirm. A specific assessment is required to further verify this claim.

5. Sulfan, which is a relatively new product in the market and mainly distributed in Ghana, also was good quality, with a probability of out of compliance of 0.03 for total nitrogen and 0.04 for sulfur. However, given the small size of the sample of Sulfan analyzed in this study, this result does not necessarily mean that the likelihood for a farmer to buy Sulfan of poor quality in those countries is zero or extremely low. Analysis of a larger sample is likely to yield a better representation of the quality of Sulfan traded.
6. The perception that fake or adulterated fertilizers in West African markets is a dominant quality concern is not supported by the findings of this study. Only one case of a product containing materials with no fertilizer properties was found (SSP sold in Nigeria). However, the issue merits further investigation.
7. Underweight fertilizer bags are a serious problem, with probabilities of bag weights out of compliance of 41 percent in Nigeria, 28 percent in Côte d'Ivoire, 13 percent in Senegal, 12 percent in Ghana and 7 percent in Togo.
8. Characteristics of the market, such as concentration of dealers, periodicity of the markets and type of market, impact fertilizer quality. Isolated dealers, periodic markets and urban markets showed higher frequency of samples out-of-nutrient content compliance.
9. Characteristics of the fertilizer dealer, such as type of customers, knowledge and training about fertilizers, type of distributor and possession of license to sell fertilizers, impact quality. Unlicensed retail dealers who sell mainly to small-scale farmers and have no knowledge or training about fertilizers presented a higher frequency of samples out-of-nutrient content compliance.
10. There was a clear pattern of association between the complexity of the distribution chain and fertilizer granule integrity. Large and complex distribution chains, like in Nigeria and Ghana, experience higher frequencies of granule degradation of compound NPK 15:15:15 than simpler distribution chains, like in Togo. Fertilizer bags are exposed to an accumulation of forces that cause fracture and abrasion of fertilizer granules along large distribution chains, especially when bags are handled manually and individually, like in West Africa.
11. The study found a strong association between high moisture levels and high caking levels for both the blended fertilizers and the compound fertilizers. In addition, the importance of appropriate bagging was underscored by findings in Senegal, where 41 percent of the bags were found to be outer woven without plastic inner lining, and 61 percent of the samples presented medium-to-high degrees of urea caking. Low frequency of caking in urea was closely associated with the use of laminated bags or bags with plastic lining in Ghana, Nigeria and Togo.

The results of this study indicate that the quality of fertilizers in West Africa can be enhanced through a series of actions:

1. Effectively implementing the adopted ECOWAS fertilizer regulatory system by the member countries to encourage participants across the value chain to address the quality issues, thereby ensuring that products supplied to the market meet high quality standards. The adopted ECOWAS fertilizer regulatory system calls for adequate inspection, sampling and analysis of fertilizers at importation points and along the distribution chain.
2. Conducting studies to identify the origin of the quality problems of bulk-blended fertilizers and proposing appropriate solutions.

3. Analyzing the economic impact of the high frequencies of poor quality fertilizer found in the target countries both at farmer and country levels.
4. Enhancing manufacturing knowledge and equipment for manufacturing blends, including:
   a. Sufficient use of NPK inputs for proper blend formulation.
   b. Maintenance of equipment/calibration.
   c. Implementation of technical knowledge and training.
   d. Use of high-quality and appropriately sized ingredients for blending to reduce segregation.
5. Standardization of blending plants as part of the implementation of a regulatory system.
6. Training of distributors on the following topics:
   a. Appropriate handling of fertilizer products. Fines and dust in compound fertilizers can be reduced with less manual manipulation. Use of pallets and mechanical equipment for handling bags can reduce degradation.
   b. Physical and chemical properties of fertilizers.
   c. Appropriate storage of fertilizer products.
7. Improving packaging with plastic lining to reduce caking and nutrient deficiency.

Appendix A. Procedures for Data Collection and Fertilizer Sampling and Sample Reduction

1. Data Collection

The procedure for data collection and sampling of fertilizers in each of the dealer's shops visited is described step-by-step as follows:

1. Self introduction of inspectors to the shop owner or keeper.
2. Fill out the following sections of the Questionnaire (Table A.1): General identification (Questionnaire #, Country, State), Characteristics of the Market, Identification and Characteristics of the Dealer and Characteristics of Storage. Take pictures of the storage area.
3. Find out which of the four fertilizer products selected for the state under consideration are sold in the shop.
4. Locate the fertilizers and the different lots of each fertilizer in the shop/warehouse. For this survey, the lot of a particular fertilizer product is defined as all product of that fertilizer that was ordered from a particular source at the same time and supplied to the agro-dealer on the same container or vehicle.
5. List products and lots in the first column of the section "Characteristics of Fertilizer Products" in the Questionnaire (Table A.1). A product can be listed more than once if there is more than one lot of that fertilizer or if there is one open bag of the same product for retailing in small quantities.
6. Fill out the section "Characteristics of Fertilizer Products" in the Questionnaire (Table A.1) for every product and lot listed.
7. Pick at random one bag from each product and lot listed in the questionnaire for weight verification. Take a picture of the bag label. Weigh the bag. Record in the questionnaire weight on the label and actual weight of the bag.
8. Take a sample from every product listed in the questionnaire:
   - If there are less than five bags in the product lot, take a subsample from every bag.
   - If there are between five and 20 bags in a product lot, pick at random five bags and take a subsample from each of the five bags.
   - If the product lot has more than 20 bags, pick 10 bags at random and take a subsample from each of them.
   - Take a sample from every open bag used to retail in small quantities.

2. Fertilizer Sampling

Taking a Sample from Closed Bags

Fertilizer bags must be in a horizontal position. Subsamples are taken directly from bags in the stacks. You may need a ladder to reach high bags.

- Insert the sampling probe or bag sampler (Figure 1) through a corner of the bag (Figure 2). The sampling probe must have the slots down during the insertion. When the sampling probe has reached the opposite bag corner, turn it 180° to get the slots upward. Extract the sampling probe.
- Empty the content of the sampling probe in a bucket. That is a subsample.
- Patch with tape the hole left by the sampling probe in the bag.
- Repeat this operation in each of the bags selected at random from the lot. The accumulated subsamples in the bucket make up the sample.
- Transfer the sample to a plastic bag using a funnel. Seal the bag perfectly to avoid moisture loss.
- Fill out the sample label (Table A.1).

- Fill out the form “Qualitative Assessment of Physical Attributes” (Table A.2) to evaluate physical attributes of the sample.
- Place sample and label in a second larger bag. Seal the bag perfectly to preserve moisture content in the sample.
- Wipe sampling probe, bucket and funnel with a dry rag to remove any fertilizer residue.
- Move to another lot of the same product or to a lot of different product and repeat the sampling procedure.

Taking a Sample from an Open Bag

- Scoop out three subsamples: one from the top, another from the middle and another from the bottom of the bag (Figure A.3). Place the three subsamples in a bag. Seal bag perfectly.
- Fill out the sample label, making sure to mark the “Open Bag” box on the label.
- Place label and sample in a second larger bag. Seal it perfectly.
- Take a picture of the open bag showing the product in the top (usually is moist from humidity absorbed from the air). Take another picture showing the fertilizer bag label.

9. Place all the fertilizer samples from a dealer’s shop in a cardboard box.
10. Take pictures of any condition in the shop or any practice of the dealer that you believe can affect the quality of fertilizers (i.e., spreading products on the ground to sun-dry them, blending of products, mixing of fertilizer with other materials, rebagging, etc.).
11. Record the “Time at end” at the top of the questionnaire.
12. After sampling all the dealers assigned to a sampling team:
    - Give boxes containing fertilizer samples, set of questionnaires and camera memory cards to the Coordinator. Questionnaires and memory cards must be placed in a manila envelope identified with the state name(s).
    - Submit a two-page report to the Coordinator, describing the sample collection exercise in your area. If the team had to substitute dealers in the list by other dealers, identify the original dealer and the new dealer and explain the reason for the substitution. Report conditions or practices observed during the sampling that you believe jeopardize the quality of fertilizers; be specific about dealers and products. The report must be kept confidential. Place the two-page report inside the manila envelope.

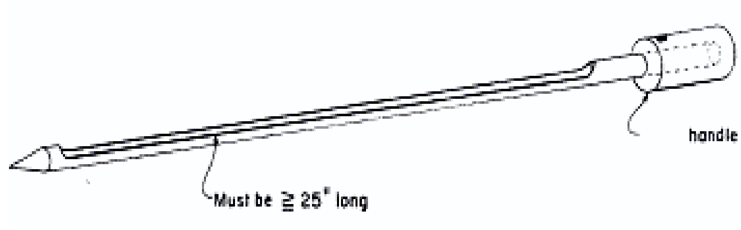


Figure A.1. Sampler for Solid Bagged Fertilizers

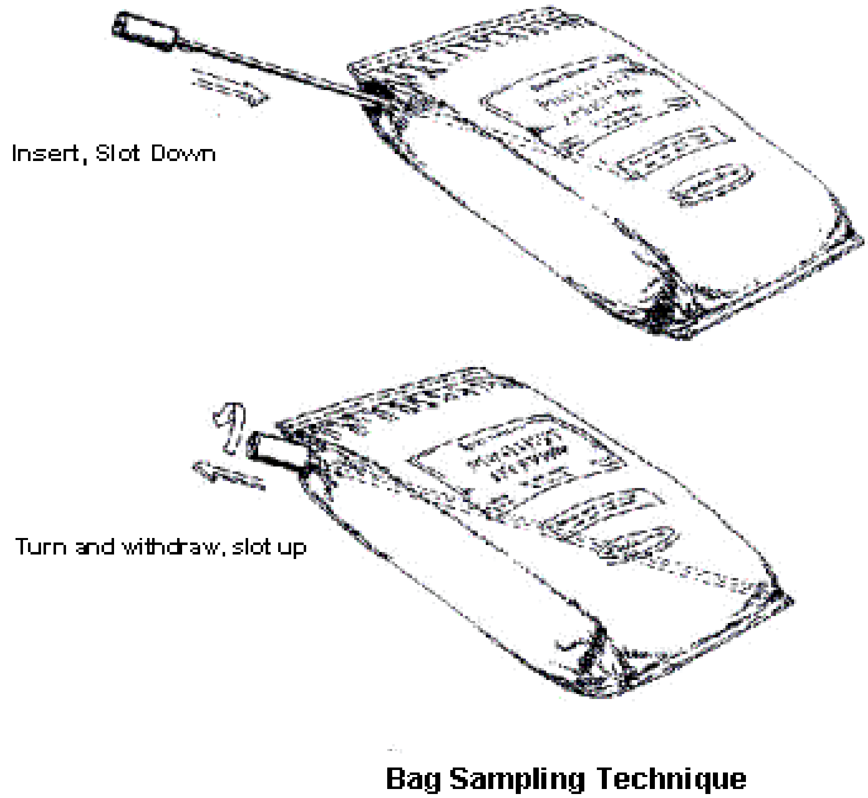


Figure A.2. Sampling Technique for Bagged Fertilizers

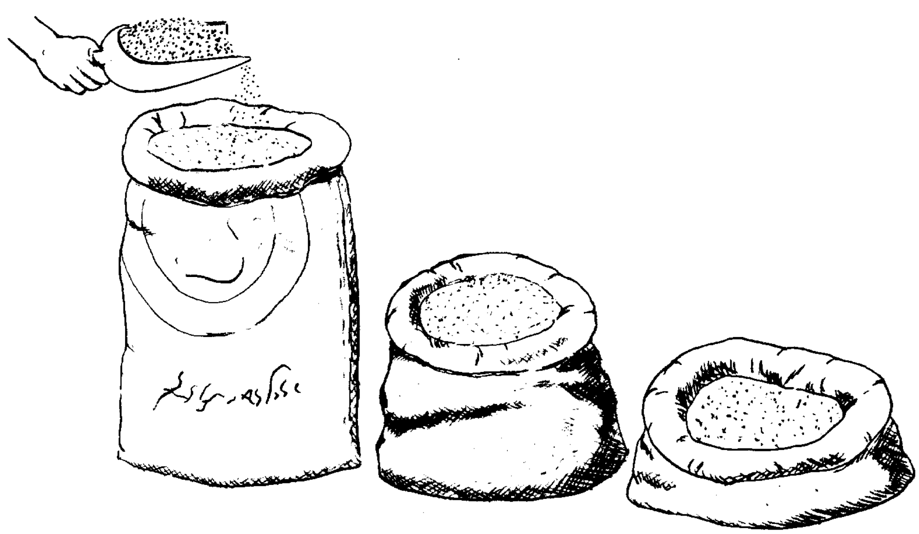


Figure A.3. Sampling Technique from an Open Bag

3. Sample Reduction

Equipment/Material

1. Riffle (Figure A.4) with two receiving pans of corrosion-resistant material.
2. Sample label for individual identification of fertilizer products sampled.
3. Sample container with a capacity of 2 kg or as required. The container must be a resistant resealable plastic bag.

Procedure

1. Make sure that all equipment/material is clean.
2. Set riffle in a level position, not tilted in any direction.
3. Place the two receiving pans in position beneath the riffle.
4. Transfer the composite sample to the hopper of the riffle.
5. Allow the entire sample to flow into the pans beneath the riffle, forming two equal portions.
6. If required, Steps 4 and 5 may be repeated by selecting alternating equal portions (pans) until the content of the collection pan is between 100 g and 200 g.
7. Transfer each final sample portion to a first resealable bag and zip it shut perfectly to avoid moisture loss.
8. Prepare sample label and place sample portion and label in a second resealable bag. Zip each of the bags shut perfectly and seal them using a pressure-sensitive tape.
9. Store the sample for analysis.
10. Clean all equipment/material before storing or reusing.

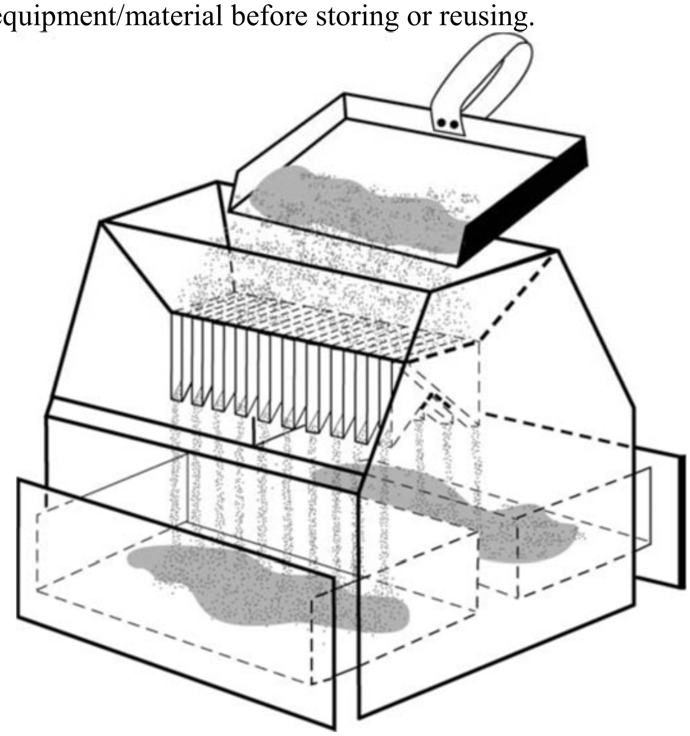


Figure A.4. A Riffle Splitter with 20 Chutes and Two Collecting Pans

Table A.1. Characteristics of Markets, Dealers, Storage and Fertilizer Products Collected During Visit to Fertilizer Dealers

Questionnaire #	Country	State	Town	Market/Community	Date	Time at Start	Time at End

Characteristics of the Market		
Type of Market	**Dealer Concentration and Number of Dealers**	**Periodicity of the Market**
Rural Urban	Low ( ) High ( ) Isolated ( )	Permanent Periodic

Identification and Characteristics of the Dealer					
Ownership: Private Government	**If Government Owns:** local government state government national /federal government				
Name of Business/Dealer:	**Licensed to sell Fertilizers?**	Yes No	**Knowledge about Fertilizers:** Good Limited None		
Attended by Owner?	Yes	No			**If yes, his/her knowledge about fertilizers:** Good Limited None
Have the owner and the attendant been trained on the knowledge of fertilizer? Owner only Attendant only Both					
Address of Store/Market and Shop #:			**Telephone:**		
Status: Importer Wholesaler Retailer	**Buyers:** Small-Scale Farmers Large-Scale Farmers Farmer's Organizations Dealers				

Characteristics of Storage		
Approximate Dimensions (m) Length:___________ Width ___________ Height _______________		
Ventilation: Satisfactory Non-Satisfactory	**Temperature:** _____**ºC** and High Low Adequate	**Relative Humidity:** ______**%** and High Low Adequate
Handling: Manual Mechanized	**If mechanized, describe equipment:**	
Neat Stacks: yes no	**Explanation:**	
Height of the stacks: Maximum number of bag layers _________ Average number of bag layers __________		
Cleanliness: yes no	**Explanation:**	
Pallets: Sufficient Insufficient None	**Condition of pallets:** Bad (%)_______ Moderate (%)________ Good (%)_______	

Characteristics of Fertilizer Products													
			Quantity In Stock					**Weight (kg)**		**Evidence of: (Yes or No) *****			
Fertilizer Type	**Category of the Supplier of the Fertilizer ***	**Is the Fertilizer a Blend?** (Yes or No)	**Quantity**	**How Long Has it Been There?**	**Average Quantity Sold in a Year # Bags/Ton**	**Bag Type ****	**Is it Rebagged?** (yes or no)	**On Label**	**Actual**	**Mismanagement**	**Manufacturing Problem**	**Adulteration**
***** Explanation:**													

***Suppliers:** Importer (I), Wholesaler (W), Retailer (R). ****Bag Types:** Inner (I), Outer Laminated (OL), Outer Woven (OW), Paper (P), Other (OT).

Table A.2. Qualitative Assessment of Fertilizer Physical Attributes

Country:										**Agro-Ecological Zone:**									
										Town/Market:									
Name of Business/Dealer:																	**Questionnaire #:**		
Product Type:													**Color(s):**						
Segregation				Filler ___%		Impurities		Granule Integrity					Caking				Moisture Content		
									High	Medium	Low	None							
No	High	Medium	Low	Yes	No	Yes	No	Fines					No	High	Medium	Low	Adequate	Medium	High
								Dust											
Comments:																			

Table A.3. Fertilizer Sample Label

SAMPLE LABEL			
Country	**State/Province**	**Town/Market**	
Name of Business or Dealer:		**Questionnaire #:**	
Sampler's Name:			
Fertilizer Type		**Close Bag**	**Open Bag**

Appendix B. Summary of Chemical Methodologies for Fertilizer Analysis

1. Total Nitrogen Analysis

Fertilizer Type	Devarda	Digestion	Distillation
Urea	-	Yes	Yes
NPK	Yes	-	Yes
Ammonium Sulfate	-	-	Yes
Sulfan	Yes	-	Yes

1.1. Total Nitrogen in Fertilizer According to Kjeldahl

Sample Preparation

A. Grind the samples by using a suitable laboratory mill or coffee grinder to a very fine texture.
B. Weigh 0.1 g of sample to an accuracy of ± 0.1 mg into 750 mL DD tubes.

Distillation

A. Dilute sample with 30 mL H_2O and add 2 g of Devarda's alloy (**Note! Do not use Devarda's alloy in powder form, but grit, to avoid the risk for contamination of the distilling unit**).
B. Add 25 mL of receiver solution to the receiver flask. Add 30 mL 40 percent NaOH to the tube. Allow reaction to settle (delay). Distill for the prescribed time (see below) and titrate distillate with standardized titrant.*

*The normality of the titrant is required to 4 decimal places. Perform a reagent blank before each batch of samples.

Calculation

$$\%\,\text{Nitrogen} = \frac{\left(V_{sample} - V_{blank}\right) \times N \times 14.007 \times 100}{m_{sample}}$$

V_{sample} = Volume titrant used for titrating the sample (mL)
V_{blank} = Volume titrant used for titrating the blank (mL)
N = Normality of titrant
m_{sample} = Weight sample (mg)

1.2 Ammonium Nitrogen in Inorganic Fertilizers According To Kjeldahl

Sample Preparation

A. Grind the samples by using a suitable laboratory mill or coffee grinder to a very fine texture.
B. Weigh 0.1 g of sample to an accuracy of ± 0.1 mg into a 250 mL digestion tube.

Distillation

A. Dilute sample with 30 mL H_2O. Add 25 mL of receiver solution to the receiver flask.
B. Add 50 mL 40 percent NaOH to the tube. Allow reaction to settle (delay).
C. Distill for the prescribed time (see below) and titrate distillate with standardized titrant.*

*The normality of the titrant is required to 4 decimal places. Perform a reagent blank before each batch of samples.

Calculation

$$\%\,\text{Nitrogen} = \frac{(T - B) \times N \times 14.007 \times 100}{\text{Weight of sample (mg)}}$$

T = Sample titration B = Blank titration N = Normality of titrant

1.3 Nitrogen in Urea According to Kjeldahl

Sample Preparation

A. Grind the samples by using a suitable laboratory mill or coffee grinder to a very fine texture.
B. Weigh 0.18 g of sample to an accuracy of ± 2 mg into a 250 mL digestion tube.

Digestion

A. Add 2 Kjeltabs Cu/3.5 (or 7 g K_2SO_4 + 0.8 g $CuSO_4$ x 5 H_2O). Add 12 mL H_2SO_4.
B. Shake gently to "wet" the sample. Position the exhaust and turn on the aspirator or scrubber.
C. Digest for 60 minutes. Remove rack with exhaust and leave to cool for at least 15 minutes.

Distillation

On some systems part or all of this is performed automatically.

A. Dilute cooled digest with 75 mL H_2O.
B. Add 25 mL of receiver solution to the receiver flask. Add 50 mL 40 percent NaOH to the tube. Allow reaction to settle (delay). Distill for the prescribed time (see below) and titrate distillate with standardized titrant.*

* The normality of the titrant is required to 4 decimal places. Perform a reagent blank before each batch of samples.

Calculation

$$\%\,\text{Nitrogen} = \frac{(T - B) \times N \times 14.007 \times 100}{\text{Weight of sample (mg)}}$$

T = Sample titration B = Blank titration N = Normality of titrant

2. Analysis of Phosphorus as P_2O_5, Potassium as K_2O, Sulfur as SO_4, Calcium and Magnesium

These nutrients were analyzed with Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES), which uses a high energy argon plasma to convert elements in a solution into a gaseous, excited state form that emits electromagnetic radiation at characteristic wavelengths. The colors of the emitted light and the light intensity can be used to identify the element and determine how much of the element is present in a sample. The ICP-OES uses an array detector so that many elements in a sample can be determined simultaneously.

2.1. Digestion of Fertilizer Sample for Analysis with ICP

A. Weigh a 1-g sample (4 decimal places), record weight on Attachment 1 worksheet and transfer to a 250-mL beaker.
B. Determine if the sample contains urea. If it does, add 5 mL HCl acid and 50 mL distilled water to the beaker, place on a hot plate and boil for 5 min. Remove beaker and cool. If the sample does not contain urea, proceed directly to Step 3.
C. Add 5 mL of HNO_3 and 10 mL of $HClO_4$ acids to the beaker. Cover beaker with a watch glass, place beaker on hot plate and digest sample. If brown HNO_3 acid fumes appear, continue adding HNO_3 acid dropwise until they no longer persist. Continue with digestion until strong white $HClO_4$ acid fumes appear.
D. Remove beaker and allow to cool. Add 100 mL of distilled water, place back on hot plate and bring to a boil for 5 minutes. (Note: This "Note" applies to K_2O analysis only. K_2O may form potassium perchlorates (indicated by white crystalline grains, "feathers" or specks) when digesting to strong $HClO_4$ fumes. These perchlorates should go into solution during the boiling procedure. If the perchlorates do go into solution, proceed to Step 5. If they do not dissolve in the boiling water, then proceed as follows: weigh (record weight to 4 decimal places on Attachment 1 worksheet) a 2.5 g sample into a 400-mL beaker. Add 50 mL of 4 percent (saturated) ammonium oxalate solution to the beaker. Add 125 mL distilled water to the beaker, place beaker on hot plate and boil for 30 minutes. This sample is for K_2O analysis only. Proceed with Step 5.
E. Remove from hot plate, allow to cool and filter through a Whatman No. 42 filter paper into a 500-mL fertilizer flask. Bring to volume with distilled water. (Filter only if needed – solution contains sand or rock particles, or is non-clear.)
F. Determine the analytes of interest (e.g., total P_2O_5, potassium and other elements). Dilution of the sample solution may be necessary. Record sample weight, sample volume, aliquot and analytical procedure to be employed for analyte of interest.

An ICP works by injecting a nebulized mist from a liquid into the center of an argon plasma. A plasma is created from a flow of gas within a high energy field. A strong alternating current of RF energy flowing in a coil just outside of the gas flow ionizes the gas and causes intense heating. When the mist of the fertilizer solution sample enters the plasma, the intense heat causes the dissociation of most chemical compounds and the energy that the component atoms absorb causes them to undergo excitation and ionization energy transitions. These transitions produce spectral emissions characteristic of the elements being excited. The spectra produced by the plasma is broken down into individual spectral lines by the ICP's spectrometer and the ICP's computer translates the spectral lines into concentrations for the nutrient elements in the fertilizer samples.

3. Quality Control

A. At least two (2) separate Magruder check standards are used to check accuracy of test per each batch of 50 samples or less.
B. At least 5 percent of samples are selected at random as replicates to check precision of test per each batch of 50 samples or less.
C. At least 5 percent method blanks are performed per each batch of 50 samples or less.

4. Reference Methodologies

A. AOAC957.02+APHA3120B – Determination by ICP-OES following AOAC Official Method 957.02, 18th Ed (2005) sample preparation for fertilizer.
B. AOAC988.05 – Total Nitrogen determination by Kjeldahl/modified Kjeldahl.

Appendix C. ECOWAS Tolerance Limits for Plant Nutrients and Bag Weight

Maximum Allowable Variation of Primary Nutrient Content

To be acceptable, any deviation of the measured values of a primary nutrient content from the values claimed on the label shall be an amount not exceeding the values in the following table:

Type of Fertilizer	Tolerance
Single nutrient fertilizers:	
With up to 20% nutrient content	Maximum 0.3 units
With more than 20% nutrient content	Maximum 0.5 units
Complex fertilizers and NPK blends	Maximum 1.1 units for individual nutrients and maximum 2.5% for all nutrients combined

The total deviation for all nutrients combined is calculated from the addition of deviations for nutrients with contents lower than the label specification; compensation from nutrients with content higher than specified to balance deficiency of another nutrient is not allowed.

Maximum Allowable Variation of Secondary Nutrient Content

To be acceptable, any deviation of the measured values of a secondary nutrient content from the values claimed on the label shall be an amount not exceeding the values calculated from the following table:

Secondary Nutrient	Tolerance
Calcium (Ca)	0.2 unit + 5% of guarantee
Sulfur (S)	0.2 unit + 5% of guarantee
Magnesium (Mg)	0.2 unit + 5% of guarantee

The maximum allowable variation when calculated in accordance with the above shall be 1 unit (1 percent).

Maximum Allowable Variation of Fertilizer Weight

The acceptable deviation of the measured bag weight from the value claimed on the label shall be 500 g per 50-kg bag.

Appendix D. Geographical Distribution of Samples Collected in Togo

REGION	FERTILIZER	COUNT
CENTRALE	12:20:18:5(S):1(B)	4
	14:23:14:5(S):1(B)	1
	15-15-15 BL	7
	15-15-15 CM	4
	UREA	10
KARA	15-15-15 BL	4
	15-15-15 CM	15
	UREA	12
MARITIME	12:20:18:5(S):1(B)	3
	15-15-15 BL	2
	15-15-15 CM	7
	UREA	10
PLATEAUX	12:20:18:5(S):1(B)	12
	15-15-15 BL	11
	15-15-15 CM	11
	20-10-10	3
	UREA	15
SAVANES	14:23:14:5(S):1(B)	2
	15-15-15 BL	4
	15-15-15 CM	9
	23:10:5:3S:2MgO+0.3Zn	4
	SULFAN	3
	UREA	15
Total		168*

* The number of samples used for chemical and statistical analysis was lower.

Appendix E. Non-Significant Results from the Statistical Analysis of Factors Influencing Nutrient Content

FACTOR	FERTILIZER	CATEGORY	Fertilizer Quality Good (%)	Fertilizer Quality Bad (%)	Chi-Sq Significance
MARKET CHARACTERISTICS					
MARKET TYPE	15-15-15 Blend	RURAL	3.7	3.7	0.3
		URBAN	81.5	11.1	
	15-15-15 Compound	RURAL	7.1	0.0	0.6
		URBAN	85.7	7.1	
PERIODOCITY	15-15-15 Blend	PERIODIC			*
		PERMANENT	84.6	15.4	
	15-15-15 Compound	PERIODIC	4.9	0.0	0.7
		PERMANENT	87.8	7.3	
DEALER CONCENTRATION	15-15-15 Blend	ISOLATED			*
		LOW			
		HIGH	85.2	14.8	
	15-15-15 Compound	ISOLATED			*
		LOW			
		HIGH	92.9	7.1	
DEALER CHARACTERISTICS					
BUYER TYPE	15-15-15 Blend	SF			*
		LF			
		SF LF	85.2	14.8	
	15-15-15 Compound	SF**			*
		LF**			
		SF LF	92.9	7.1	
FERTILIZER KNOWLEDGE	15-15-15 Blend	GOOD	84.6	7.7	*
		LIMITED	0.0	3.8	
		NONE	3.8	0.0	
	15-15-15 Compound	GOOD	85.7	7.1	0.6
		LIMITED			
		NONE	7.1	0.0	
DISTRIBUTOR TYPE	15-15-15 Blend	OTHER			0.4
		RETAILER	11.1	0.0	
		WHOSALER	74.1	14.8	
	15-15-15 Compound	OTHER			0.6
		RETAILER	9.5	0.0	
		WHOSALER	83.3	7.1	
TRAINED	15-15-15 Blend	NO	3.7	0.0	0.7
		YES	81.5	14.8	
	15-15-15 Compound	NO	4.8	0.0	0.7
		YES	88.1	7.1	

FACTOR	FERTILIZER	CATEGORY	Fertilizer Quality		Chi-Sq Significance
			Good (%)	Bad (%)	
FERTILIZER PHYSICAL ATTRIBUTES					
MOISTURE CONTENT	15-15-15 Blend	ADEQUATE	81.5	14.8	0.7
		MEDIUM			
		HIGH	3.7	0.0	
	15-15-15 Compound	ADEQUATE	71.4	4.8	0.7
		MEDIUM	21.4	2.4	
		HIGH			

* Inconclusive test due to insufficient data or insufficient variability in the data.

** SF: Small-scale Farmers,   LF: Large-scale Farmers

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