Session 4.
Fertilizer Quality Assessment

Fertilizer Quality Assessment in the Myanmar Dry Zone

J. Sanabria

Senior Scientist-Biometrician, IFDC, Muscle Shoals, AL, USA

Abstract

The Dry Zone Agro-Input and Farm Services project, which is funded by the Livelihoods and Food Security Trust Fund (LIFT) consortium and implemented by IFDC, carried out a fertilizer quality assessment in the Dry Zone of Myanmar. The four fertilizers of highest commercialization in Myanmar's Dry Zone – NPK 15:15:15, NPK 10:10:5, NPK 15:7:8, and NPK 16:16:8 – presented out-of-compliance shortages (OOCS) with frequencies of 9%, 19%, and 23% of the samples for total N, P_2O_5, and K_2O, respectively. The OOCS severities relative to the fertilizer bag label specification were -1.5%, -4.7%, and -3.2% for total N, P_2O_5, and K_2O, respectively. The rest of the fertilizers, of lower commercialization, presented OOCS with frequencies ranging between 11% and 15% and OOCS severities ranging between 2.7% and 4.1%. Based on the relatively low OOCS severities of the macronutrients in fertilizers of high and low commercialization, the nutrient content problems in the Dry Zone are not as dramatic as reported anecdotally, but they still require attention. With no evidence of adulteration found and very mild granule degradation, nutrient shortages likely originate in the manufacture of the imported products. Port inspections should be more rigorous.

Granule integrity, moisture content, and other physical properties of fertilizers were found to be good, with the exception of caking found in 12% of the samples. Storage facilities are hot and humid, but the good quality of the impermeable bags preserves the fertilizers from moisture absorption and granule degradation. The caking can be explained by bags stacked too high and the absent use of pallets. Fourteen percent of the 50-kg bags weighed presented weight shortages of more than 0.5 kg.

Fertilizer quality assessments such as this should be carried out in all Myanmar agricultural areas, including formal and informal fertilizer markets. Then, the findings of the studies should be used as a foundation for the development of a Myanmar Fertilizer Quality Regulatory Framework, which will protect farmers against fertilizers of substandard quality.

Introduction

Myanmar has an open and competitive, non-subsidized fertilizer market dependent on imports for more than 80 percent of the total market demand estimated at between 1.2 and 1.4 million product tons per annum; however, fertilizer use in Myanmar is still low by Southeast Asian standards and very low by world standards. Together with the use of improved seed, fertilizer use and adoption of modern technologies by farmers are key to raising agricultural productivity (Gregory et al., 2014).

The Myanmar government and the country's private sector envision Myanmar becoming an agriculture-based economy larger than Vietnam and rivaling Thailand by upscaling production of rice and other crops, such as pulses and beans, sesame, groundnuts, rubber, maize, cotton, oil palm, and other perennial and annual crops. One of the essential conditions for these projections to become reality is the establishment of a culture of good fertilizer quality in the country through the development of a fertilizer regulatory framework and its implementation.

This fertilizer quality assessment was conducted by the Dry Zone Agro-Input and Farm Services project, funded by the LIFT Fund consortium and implemented by IFDC. The objective of the assessment was to make a diagnostic of the Dry Zone fertilizer quality condition and to identify the critical factors, such as characteristics of the distribution chain and characteristics of the fertilizer products themselves, that play important roles in fertilizer quality in Dry Zone markets. The study was conducted using a scientifically based methodology that has been tested and improved across 12 developing countries in West and East Africa (Sanabria et al., 2013).

Information generated by this type of study conducted in all agricultural areas of the country would be indispensable to support the development of a Myanmar Fertilizer Quality Regulatory System.

Methodology for Data and Sample Collection

The fertilizer quality assessment was restricted to six townships (Pakokku and Yesagyo in Magway region and Maghlaing, Myingyan, Nahtogyi, and Taungtha in Mandalay region) located inside the Myanmar Dry Zone. Before conducting the field survey to collect samples and data from fertilizer markets, six IFDC staff members and six Department of Agriculture (DOA) staff members were trained for two days in theoretical and practical components of the scientifically based methodology designed to inspect fertilizer quality in fertilizer markets. In teams of three people, the 12 trained IFDC and DOA staff members took turns conducting the fertilizer quality inspection in markets of each township. It was very important that each inspection team working in the townships included a DOA member; as government representatives, the DOA staff members confer authority to the inspection team to collect data and fertilizer samples from the fertilizer dealerships.

The methodology consisted of two sampling steps: the first was the random selection of a sample of fertilizer dealers, and the second was the random selection of fertilizer samples and data collection in each dealer shop selected in the first step.

Sampling of Fertilizer Dealers

A list of 144 fertilizer dealers provided by the DOA was the basis to define a conceptual population of fertilizer dealers in the Dry Zone. The fertilizer dealer sample size was determined based on the sampling capability of one inspection team depending on the net number of sampling days – discounting travel time – and the number of dealers that the sampling team was able to visit in a day. The random process for selecting the sample of dealers was weighted by the number of dealers in each township and the number of shops in each dealer category: retailer and wholesaler. This means that the subsample of dealers from a township had a size proportional to the total number of dealers in the township, and the representation of wholesalers and retailers was proportional to their presence in the townships.

The random sample of dealers included 33 fertilizer dealers, equivalent to 22.9% of the population. A list of the dealers in the sample was prepared for each of the six townships; a number of additional dealers selected at random were added to make substitutions when a dealer in the sample list was not found or when the dealer did not have any fertilizers.

The inspection teams collected fertilizer samples and collected data about characteristics of markets, dealers, storage conditions, and fertilizer products following procedures specified by international standards. Data collected about these characteristics were used to explain fertilizer quality problems (Sanabria et al., 2013).

Chemical Analysis of Fertilizers

Two DOA laboratories, one in Yangon and the other in Mandalay, that provide soil, plant tissue, and fertilizer analysis services were evaluated about their capabilities to analyze fertilizers. After satisfactory analysis of macro- and micronutrients in blind samples given to the labs, the Yangon laboratory received 30 duplicate samples from the 82 samples collected in the Dry Zone. All 82 samples were analyzed at the IFDC laboratory in the USA.

Nutrients determined were total nitrogen (N), available phosphorus (P_2O_5), and soluble potassium (K_2O). Samples included fertilizers that contain sulfur (SO_4^{-2}), calcium (CaO), magnesium (MgO), iron (Fe), and zinc (Zn). Analysis of cadmium (Cd) was performed in a group of fertilizers containing P_2O_5, based on concerns about the natural content of Cd in phosphate deposits and the potential of this heavy metal accumulation in soils as fertilizers are applied season after season.

Physical Analysis of Fertilizers

The physical properties evaluated in the samples collected were: granule integrity through quantification of fine particles and dust, granule segregation, color, moisture content, critical relative humidity, caking, presence of fillers, and presence of impurities. The definition of physical properties was developed by Rutland (1993), and the assessment methodologies used in fertilizer markets was explained by Sanabria (2016).

Data Analysis and Interpretation

Nutrient Content Compliance

The 82 samples collected in the Dry Zone were classified as fertilizers of high commercialization and fertilizers of lower commercialization. The group of lower commercialization was also classified as granulated, liquid, and powder fertilizers. Fertilizers in the high commercialization group and fertilizers inside each subgroup of the lower commercialization group were pooled to assess shortages of total N, P_2O_5, and K_2O.

Due to the absence of a Myanmar Fertilizer Quality Regulatory System, the macronutrient shortage tolerance limit (TL) of 1.1% from the European Union (EU) was used (European Parliament, 2003). This TL was developed accounting for all the random variability involved in the process of adding nutrients to fertilizers in the manufacture of fertilizers and the random variability involved in the determination of nutrient content in the chemical analysis of fertilizers. A nutrient shortage is defined as follows:

$$\text{Shortage}_{(nutrient)} = \text{Nutrient Content}_{(laboratory)} - \text{Nutrient Content}_{(label)}$$

A nutrient shortage is out of compliance when the $\text{Shortage}_{(nutrient)} < TL_{(nutrient)}$.

The macronutrient European OOCS TL of -1.1% will be used for determination and interpretation of nutrient shortages in this study.

The magnitude of an OOCS is expressed by combining the frequency and the severity of the OOCS. The frequency is obtained from the cumulative frequency associated with the shortage values out of compliance in the cumulative frequency distribution function (CFDF), and the severity is calculated as the mean of the nutrient shortage values out of compliance ± one deviation standard. For example, the frequency of OOCS for total N in Figure 2A is 9%, and the OOCS severity for total N is -1.5±0.29%.

The CFDF was used with quantitative continuous variables, such as the nutrient content of fertilizers and the fertilizer bag weight shortage (BWS). In addition, the frequency distribution function (FDF) is used in categorical variables, such as the ones associated with the market and dealer characteristics as well as with the fertilizer physical properties.

Bag Weight Verification

Prior to sampling each fertilizer product in a shop or warehouse, a bag was randomly selected to be weighed to verify the weight declared on the fertilizer label. The weight reported on the label and the weight obtained from the scale were recorded in two separate columns on the survey questionnaire, and the difference between the two values was used for the development of the weight CFDF. The CFDF graphs show the BWS in the abscissa and the cumulative frequency (percent) in the ordinate. The BWS is out of compliance when it is lower than 1% of the weight declared on the fertilizer label. The dominant bag weight found in the Myanmar Dry Zone is 50 kg; therefore, in most cases, the BWS tolerance limit is -0.5 kg.

Evaluation of Fertilizer Physical Properties, Characterization of Markets and Dealers, and Qualitative Storage and Packing Conditions

Given the categorical nature of some of the fertilizer physical property variables, such as caking or moisture content, as well as the characteristics of markets, dealers, and some of the storage and packing characteristics, the frequencies associated with the different categories of these discrete variables were obtained directly from the FDF.

Factors Influencing Fertilizer Quality

The factors that have the potential to affect the chemical and physical properties of fertilizers can be classified as internal and external factors. Some of the internal factors are themselves fertilizer characteristics, such as physical properties that are expected to influence the fertilizers' nutrient content compliance, or factors related to the environment (storage) where fertilizers are located. External factors, such as characteristics of markets and dealers, have an indirect effect on fertilizer quality; the potential effect of these types of factors on fertilizer quality is associated with behaviors of dealers and consumers based on their knowledge about fertilizers and the location of the markets and shops. Internal factors have a high likelihood of influencing the physical and chemical properties of fertilizers, while external factors have a potential effect on fertilizer quality; a potential effect means that such impact may or may not occur.

Relationships tested were the effects of physical properties, storage conditions, and market and dealer characteristics on nutrient content compliance. The effects of storage and bag conditions on fertilizer physical properties were also tested. All these relationships were evaluated with logistic regression models (Stokes et al., 2009).

Results

Distribution of Fertilizer Samples

Eighty-two fertilizer samples were collected from six townships in the Myanmar Dry Zone. Figure 1 depicts the relative importance of various fertilizers in the fertilizer markets of the Myanmar Dry Zone; the likelihood of finding the first four products listed in the figure in every store visited was high, while the likelihood of finding the rest of the fertilizers in every shop was low. Urea is underrepresented in the figure because its sampling was purposely reduced to a minimum due to the very rare nitrogen content shortages of this fertilizer. Only one sample was collected from each of 23 additional fertilizers not shown in Figure 1A. The NPK 15:15:15 product in various forms, some of them containing secondary and/or micronutrients, is the fertilizer of highest commercialization in the area, followed by NPK 10:10:5, NPK 15:7:8, NPK 16:16:8, NPK 0:21:0, and NPK 13:13:21. Eighty-two percent of the fertilizer samples were from granulated fertilizers, 10% from powder fertilizers, and 8% from liquid fertilizers (Figure 1B). The following bulk blends were found in markets of the Dry Zone: NPK 11:20:20, NPK 16:16:8, NPK 20:10:10, NPK 20:10:5, and NPK 20:12:12.

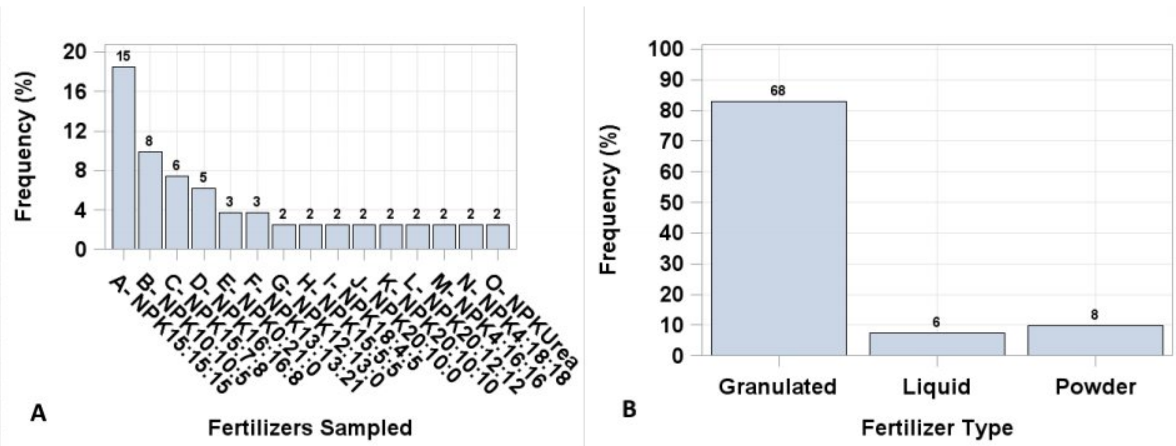

Figure 1. Frequency distribution of fertilizer samples collected (A), and frequency distribution of fertilizer types sampled (B) in the Myanmar Dry Zone.

Nutrient Content Compliance of Fertilizer

Granulated Products of High Commercialization

The granulated fertilizers of highest commercialization in the Myanmar Dry Zone were NPK 15:15:15, NPK 10:10:5, NPK 15:7:8, and NPK 16:16:8 (Figure 1A). Results from chemical analysis of these four products were pooled for the analysis of frequency used for the assessment of nutrient content compliance. Since Myanmar does not have a Fertilizer Quality Regulatory System, the EU TLs are used here as a reference for establishing the OOCS of each macronutrient content. The EU TLs for total N, P_2O_5, and K_2O content in solid granulated fertilizers is -1.1%.

Two samples, or 9% of the samples (Figure 2A), present OOCS for total N content. The total N OOCS severity is -1.5±0.29%. P_2O_5 OOCS takes place with a frequency of 19% and an OOCS severity of -4.7±3.3%. (Figure 2B). K_2O OOCS occurs with a frequency of 13% and an OOCS severity of -3.2±3.7% (Figure 2C). The total N shortages are very mild, while the P_2O_5 and K_2O shortages are more serious.

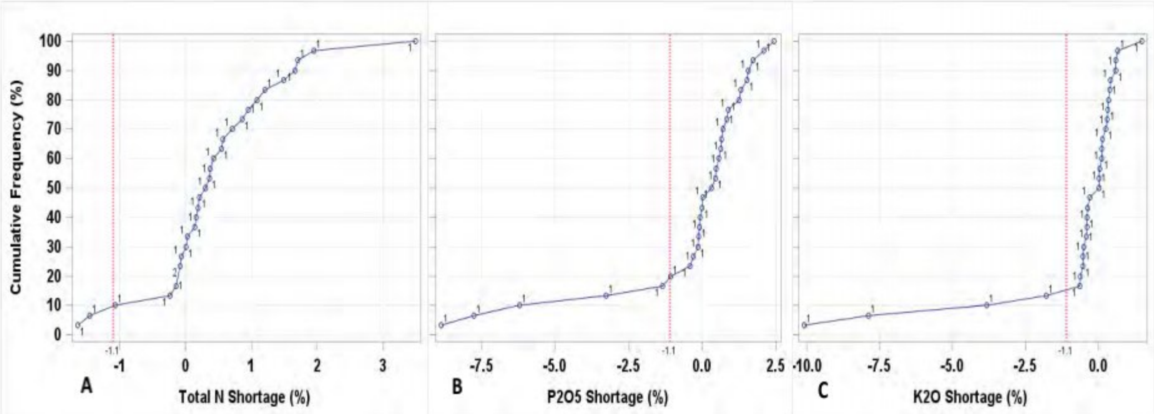

Figure 2. Cumulative frequency distribution function of total N (A), P_2O_5 (B), and K_2O (C) content shortages found for the fertilizers of highest commercialization in fertilizer markets of the Myanmar Dry Zone using the Indian and European Union tolerance limits.

Fertilizer products with three or fewer samples were classified as granulated, liquid, or powder and pooled within these three classes to conduct the analysis of frequency for nutrient content compliance. Interpretation of the nutrient content OOC will continue using only the EU TL.

Among the granulated fertilizers, the total N OOCS happened in 12% of the samples with an OOCS severity of 4.13±3.8% (Figure 3A), the P_2O_5 OOCS occurs in 15% of the samples with an OOCS severity of 3.13±4.1% (Figure 3B), and the K_2O OOCS takes place in 11% of the samples with a severity of 2.7±3.9% (Figure 3C). Among the liquid fertilizers, none is in OOCS for total N content (Figure 3A), two of the five samples present OOCS for P_2O content (Figure 3B), and one of the five samples shows OOCS for K_2O content (Figure 3C). Among the powder fertilizers, one of the seven samples presents OOCS for total N (Figure 3A), one sample presents OOCS for P_2O (Figure 3B), and none of the samples present OOCS for K_2O content (Figure 3C).

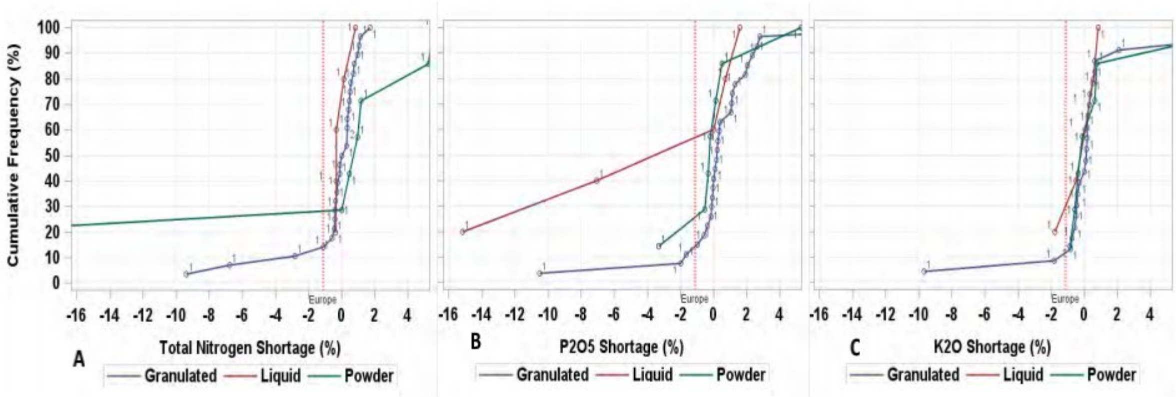

Figure 3. Cumulative frequency distribution functions for the nutrient content shortages of the three physical presentations of fertilizers of lower commercialization in the Dry Zone.

There were enough samples from fertilizers containing sulfur to develop the CFDF. From the 18 fertilizers that claim sulfur content in the form of sulfate (SO_4^{2-}), nine of them, or 50% of the samples, had sulfur shortages below the 0.36% EU TL.

Bag Weight Verification

Most of the international regulations suggest 1% as the TL for weight shortage, meaning that in the predominant 50-kg bags used in Myanmar, the maximum weight shortage is 0.5 kg. Eighteen percent of 50-kg bags sampled in Myanmar presented weight shortages higher than 0.5 kg.

Underweight bags result from lack of control in filling and weighing the bags during manufacture or rebagging. In some cases, it is possible that the underweight bags are the result of a deliberate act. The random error committed during the filling of the bags can be estimated from the weighted mean of frequencies associated with overweight 50-kg bags. The random error calculated this way is 4.0%. After subtracting the random error, it is estimated that 14% of the bags sampled are intentionally underweight.

Effect of Country of Origin on Nutrient Content of Fertilizers

The fertilizers' country of origin does not have a major effect on the nutrient content compliance of fertilizers (Figure 4). All of the countries of origin for the products sampled have the majority of the sample points at the right of the TL line for the three macronutrients. At the left of the TL line, there are just a few OOCS points for each macronutrient from China, Thailand, Vietnam, and Russia. China and Thailand have a few points more than the other countries in the "out-of-compliance area" across the three macronutrients. This is not evidence of lower fertilizer quality associated with these countries but is due mainly to the fact that these two countries have the largest sample size; by far, the largest proportion of samples from China and Thailand are in the compliance area.

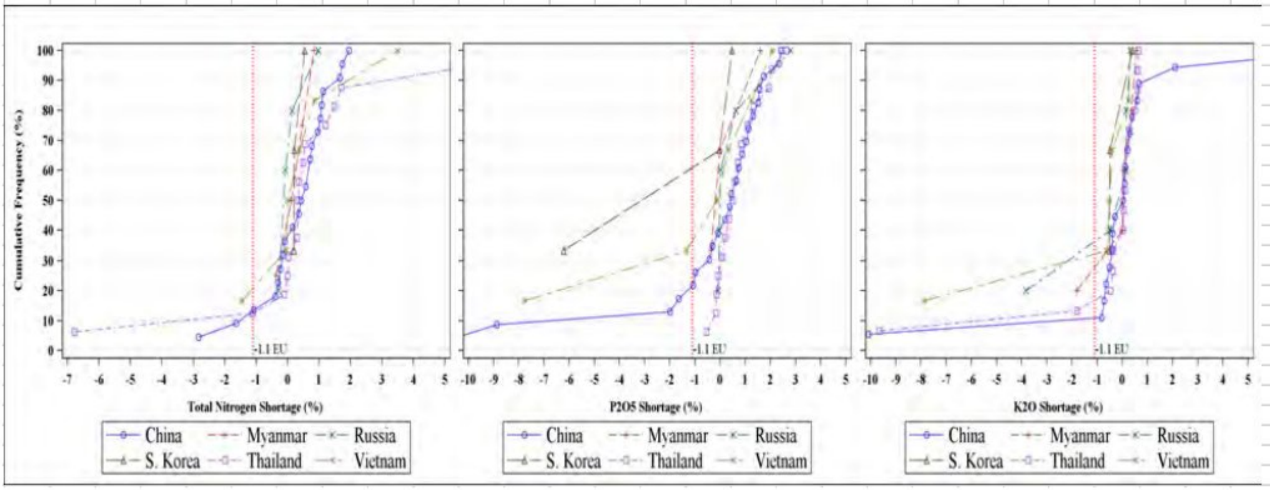

Figure 4. Cumulative frequency distribution function of nutrient shortages from samples of fertilizers imported from five countries or manufactured in Myanmar.

Cadmium Content in Phosphate Fertilizers

Cd is considered a toxic heavy metal and occurs naturally in soils and in the phosphate rock deposits used to manufacture fertilizers. Its accumulation in soil and uptake by crops have raised concerns and prompted considerable research and legislation to understand the problem and magnitude of the risks and to protect the public against the potential health problems associated with exposure to this heavy metal (Roberts, 2014). Forty-three of the fertilizers containing phosphorus that were collected in the Dry Zone were analyzed for cadmium. Sixteen of the samples contain Cd at levels lower than the analytical method detection limit; the rest of the fertilizers have Cd contents ranging between 0.011 and 0.83 mg Cd/kg P_2O_5. Even the maximum Cd content found in fertilizers of the Dry Zone is far below the 20 mg/kg P_2O_5 TL suggested by the EU (Roberts, 2014).

Storage and Packing Conditions

Physical properties of fertilizers in terms of moisture content, caking susceptibility, and integrity of the granules are highly affected by the temperature and relative humidity (RH) of the storage areas. In general, high temperature and high RH during the storage period are detrimental to the fertilizers' physical properties. Temperature in appropriate storage facilities should not exceed 30°C, and the relative humidity must be low enough to protect fertilizers from absorbing moisture from the environment. Absorption of moisture from the environment by fertilizers depends on the particular critical relative humidity (CRH) of each fertilizer. The CRH of any particular fertilizer depends on the hygroscopic characteristics of the constituent materials of the fertilizer. Figure 5, which has been constructed with RHs measured at temperatures between 28° and 32°C, shows that the CRH for NPK 15:15:15 is 43% and CRH for urea is 73%. This means that the NPK 15:15:15 and urea fertilizers at a storage temperature of 30°C start absorbing moisture from the air when the room RH is 43% and 73%, respectively. Other common NPK fertilizers in the Myanmar Dry Zone, such as NPK 10:10:5, NPK 15:7:8, and NPK 16:16:8, are expected to have a CRH similar to the NPK 15:15:15.

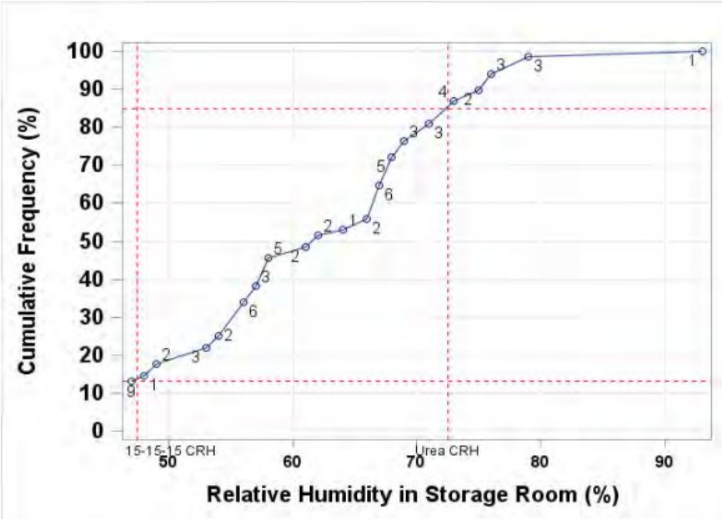

Figure 5. Cumulative frequency distribution function of the relative humidity in storage rooms and identification of critical relative humidity for 15:15:15 and urea in the fertilizer markets of the Myanmar Dry Zone.

The average temperature in the storage facilities inspected in the Myanmar Dry Zone is 32°C, and 80% of them are expected to reach temperatures of 30°C or higher during the afternoon. Fifty percent of the storage facilities are able to reduce the temperature inside only by 2°C with respect to the temperature outside; reductions of 4°C take place in just 32% of the storage rooms visited. The average RH in the storage rooms inspected was 58%, significantly higher than the CRH for NPK 15:15:15 and similar NPK fertilizers. Only 28% of the storage facilities inspected are able to reduce the inside RH by 2% with respect to the RH outside. Higher inside RH reductions, such as reductions of 4%, occur only in 12% of the storage facilities in the Myanmar Dry Zone.

The high temperatures and RH common in the fertilizer markets of the Myanmar Dry Zone are the result of inadequate ventilation and poor air circulation in the storage areas. Fifty-five percent of the storage rooms inspected had no ventilation or deficient ventilation, and the majority of them had poor air circulation. The poor ventilation and circulation are due to the absent use of pallets in 88% of storage rooms and none of the rooms having at least half a meter of free space between the walls or roof and the bag stacks as well as free space between stacks of different fertilizer lots.

Physical Properties of Fertilizers

Adequate moisture content was found in 98% of the fertilizer samples observed. The highly frequent cases of low or adequate moisture of the fertilizers commercialized in the Myanmar Dry Zone can be attributed mainly to the good bagging conditions, despite the very frequent storage conditions with high RH and the very limited capability of the storage facilities to reduce the RH with respect to the outdoors. Twelve percent of the bags inspected showed some caking, ranging from low-degree caking to high-degree caking. This degree and frequency of caking can be explained by a combination of factors that contribute to the fusion of fertilizer particles that end in caking. Pressure is exerted on bags located at the bottom of medium to high bag stacks, which are prevalent in 82% of the storage rooms. This, in conjunction with the low use of pallets and moisture reaching fertilizer granules in the few cases of torn bags and loose seams, can lead to caking. Another factor that may have contributed to the 12% caking may be thin inner layers of bags that allow penetration of water vapor inside the fertilizer bags. The dominant adequate moisture content, identified through the high flowability of dry granulated fertilizers, is mainly the result of the good quality bags used in the Myanmar Dry Zone.

The particle size distribution in the five most commercialized fertilizers in the Myanmar Dry Zone is dominated by the regular granule size (2-4 mm); the average presence of fines (1.9 mm-1 mm) is 2%, 1%, 0.5%, and 0.5% in NPK 10:10:5, NPK 15:7:8, NPK 15:15:15, and NPK 16:16:8, respectively, and negligible in NPK 13:13:21. Dust particles (< 1 mm) were present, with an average of 0.5% in NPK 10:10:5 and 4% in NPK 15:7:8. Three of the five fertilizers have close to zero granular degradation, and the other two fertilizers have granular degradation at non-concerning levels. Such a low level of granule degradation must be explained mainly by the manufacture of the products with an adequate granule hardiness that withstands the impact, crushing, and abrasion forces that act together and accumulate during the dominant manual handling of individual fertilizer bags practiced in the Myanmar Dry Zone. Another contributing factor to the low granule degradation in the Dry Zone is the good quality of the bags, which minimizes contact of fertilizer granules with environmental moisture.

The bulk blend fertilizers found in the area of this study were NPK 11:20:20, NPK 16:16:8, NPK 20:10:10, NPK 20:10:5, and NPK 20:12:12. No particle segregation was present in NPK 20:10:10, NPK 20:10:5, or NPK 20:12:12; in these three fertilizers, the granules of the three main constituents were symmetrically distributed in the three left columns of the sieve box, and the proportion of three types of granules was about the same in the three columns. This distribution of the granules indicates that the three components of the fertilizers have about equal proportion of granule sizes that range between 4 mm and 1.4 mm. The NPK 11:20:20 and NPK 16:16:8 fertilizers showed mild granule segregation, with urea (2.6-4.0 mm) showing a slightly higher proportion of particles than the other two components of the blend. The granule segregation analyzed by the particle distribution of the different components of the blend with the sieve boxes is usually corroborated by the chemical analysis; the blend components with higher proportion of particular size ranges are expected to show larger nutrient content than specified in the label, while the nutrients contained in particle sizes of low proportion show nutrient shortages. None of the samples collected from the five bulk blends found in the Dry Zone markets had OOCS for any of the three macronutrients.

Adulteration of Fertilizers

The presence of fillers or foreign materials that can be used to dilute the nutrient content of granulated fertilizers were not found in fertilizers packed in original bags or in rebagged fertilizers. Impurities that could indicate tampering of fertilizer bags were not found either. Fertilizer quality inspectors were asked to record any evidence of adulteration found in each of the fertilizer bags inspected. There was not one record related to adulteration of granular fertilizers.

Effect of External Factors and Fertilizer Physical Properties on Fertilizer Quality

From all the external factors tested for possible effect on nutrient content compliance, only the type of buyer showed evidence of having a significant effect on the nitrogen shortages of granulated fertilizers (Table 1). The probability from the chisquare distribution (Pr>ChiSq) equal to 0.058 indicates a significant effect of the type of fertilizer buyer on the nitrogen content shortages. The odds ratio for the type of buyer indicates that the occurrence of OOCS of total N in a fertilizer shop has 4.831 times higher odds when the shop buyers are small-scale farmers only than when the shop buyers are a combination of small-scale farmers, commercial farmers, and fertilizer retailers. This estimated odds ratio is significant because the 0.95 confidence interval (0.95 CI) does not contain zero.

Other relationships, such as the effect of physical properties on the shortage of macronutrient content and the effect of storage conditions and bag characteristics on fertilizer physical properties, were tested, but none of them helped to identify additional significant factors affecting fertilizer quality. Low variability of the physical properties (most of the samples were found within good physical categories that help to preserve good fertilizer quality) led to non-significant relationships in the logistic models.

Table 1. Significance test and odds ratio estimation from a logistic model predicting the effect of fertilizer dealer characteristics on nitrogen content shortages in the Myanmar Dry Zone.

Effect	DF	Wald Chi-Sq	PR > ChiSq	Odds Ratio Label	Odds Ratio Estimate	0.95 CI	
Owner Training	1	0.064	0.801				
Business Status	2	1.588	0.452				
Type of Buyer	1	3.604	0.058	Buyers: SS Frm only vs SS Frm+Com Frm/Ret	4.831	0.95	24.564
Owner Knowledge	1	2.513	0.113				

Evaluation of Laboratories for Chemical Analysis of Fertilizers

The staff working at the two DOA laboratories evaluated in Yangon and Mandalay demonstrated the scientific knowledge, experience, and administrative capability to perform fertilizer chemical analysis. The two laboratories performed well in the analysis of the blind samples, but the Mandalay lab has no capability to analyze micronutrients.

The equipment available in the two laboratories is antiquated and allows very limited automation; for this reason, the two labs have a turnaround of no more than 10 to 20 fertilizer samples a day. For the two labs to be capable of analyzing a large number of samples within the implementation of a Myanmar Fertilizer Quality Regulatory System, their equipment must be updated.

Conclusions

- The four fertilizers of highest commercialization in the Dry Zone – NPK 15:15:15, NPK 10:10:5, NPK 15:7:8, and NPK 16:16:8 – presented very mild OOCS for total N, but the OOCS for P_2O_5 and K_2O occurred in 19% and 23% of the samples, respectively, with -4.7% and -3.2% average shortage of P_2O_5 and K_2O, respectively.
- Among the fertilizers of lower commercialization in the Dry Zone, the macronutrient OOCS had a frequency ranging between 11% and 15%, and the severity of the shortages ranged between -2.7% and -4.1%.
- Based on the relative low OOCS severities of the macronutrients, the nutrient content problems in the Dry Zone are not as dramatic as reported anecdotally but

still require attention. Without evidence of adulteration and very mild granule degradation, the shortages likely originate in the manufacture of the imported products. Port inspections should be more rigorous.

- Macronutrient shortages do not show a difference among countries of origin. The majority of samples from different countries show nutrient contents in compliance. China and Thailand have some nutrient shortages out of compliance, but this is not enough evidence to indicate that products from these two countries are lower quality than those imported from other countries.
- The five bulk blends, each with only one or two samples, did not show nutrient shortages or granule segregation. These characteristics of the blends manufactured in recently established blending plants in Myanmar suggest the use of input fertilizers with uniform granule size and appropriate technology/equipment to manufacture this type of fertilizer.
- Fourteen percent of the bags showed weight shortages greater than 0.5 kg.
- Cadmium content in the fertilizers traded in Myanmar is not a concern; the maximum Cd concentration found in phosphoric fertilizers is well below the tolerance limit contained in international standards.
- High bag stacks and absent use of pallets produced caking in 12% of the samples. The good quality of the bags protects fertilizers from moisture absorption, granule degradation, and higher caking despite the hot and humid storage conditions.
- Appropriate granule hardness of imported products is a factor to explain minimum granule degradation despite manual and individual handling of the fertilizer bags.
- Of all the external factors evaluated, the only factor that had a significant relationship with nutrient shortages out of compliance was the type of buyer. When dealers sell fertilizers only to small-scale farmers, the odds of N shortages out of compliance are 4.8 times higher than when the dealer sells to a combination of small-scale farmers, commercial farmers, and fertilizer retailers.

Recommendations

- Updating the country regulatory framework, coupled with regional harmonization of regulations and standards, could contribute to making it more difficult for poor-quality fertilizer to be traded in Myanmar.
- Dealing with quality problems linked to the manufacturing process will require more stringent inspection arrangements at the points of entrance to the country. Regular training of inspectors to update their skills and knowledge should be emphasized in quality assurance plans. Laboratories located in the port inspection points able to provide nutrient content results quickly are required.
- There is a chance that informal markets or informal fertilizer dealers distribute fertilizers with quality characteristics lower than the ones found in the formal markets sampled in this study. Such informal distribution points must be identified and included in future sampling for assessment of fertilizer quality in the Dry Zone.

References

European Parliament and the Council of 13 October 2003 relating to fertilisers. Regulation (EC) No 2003/2003. Annex II.

Gregory, D.I., U.T. Maung Shwe, and N. Oo. 2014. "Myanmar Fertilizer Policy Evaluation," IFDC.

Roberts, T.L. 2014. "Cadmium and Phosphorus Fertilizers: The Issues and the Science," *Procedia Engineering*, 83(2014):52-59.

Rutland, D. 1993. *Manual for Determining Physical Properties of Fertilizers*, 2nd Edition, IFDC.

Sanabria, J., G. Dimithe, and E. Alognikou. 2013. "The Quality of Fertilizers Traded in West Africa: Evidence for Stronger Control," IFDC.

Sanabria, J., J. Ariga, and D. Mose. 2017. "Fertilizer Quality Assessment in Markets of Kenya," IFDC.

Stokes, E.M., C.S. Davis, and G.G. Koch. 2009. *Categorical Data Analysis Using the SAS System,* second edition, SAS Institute, Cary, NC.