



FERTILIZER RESEARCH & RESPONSIBLE IMPLEMENTATION

IDENTIFYING FACTORS THAT DRIVE YIELD RESPONSE OF MAIZE TO NPK FERTILIZATION

The yield response of maize to fertilizer application differs greatly from place to place in Ghana. FERARI conducted a study¹ using two different advanced modeling and statistical methods to understand these responses. Almost 1,700 points of yield response data from on-farm and on-station trials were used in our analysis. The overall increase in fertilizer use during the past decades has led to only modest increases in maize yields.

In a previous FERARI study and related policy brief, Buah et al. (2020)^{2,3} collected 1,684 data

points from on-station and on-farm trials during the past decades and found that maize yield responses to fertilizer applications were highly variable across the agroecological zones of Ghana. Some locations showed significant grain yield responses of up to 8 metric tons per hectare (mt/ ha) to fertilizers, while other areas had responses of only 0.5 mt/ha. This variability in maize yield responses to fertilizer use diminishes farmers' incentive to purchase fertilizers in subsequent seasons.

A key question, therefore, is why does the response of maize yield vary so greatly. Given that the rate of NPK applied per hectare in Ghana is growing rapidly, from an average of 8 kg/ha in 2016 to 21.5 kg/ha in 2020 (MoFA, 2020⁴; AfrcaFertilizer.org, 2021⁵), it is essential to understand this variability. Modeling approaches called Quantitative Evaluation of Fertility of Tropical Soil (QUEFTS) and Akaike Information Criterion in Multiple Linear Regression (AIC-MLR) framework statistical analysis were used to identify the factors that determine these significantly different yield responses.

- 1 K.K.A. Kouame, P.S. Bindraban, I.N. Kissiedu, K. El Mejahed, W.K. Atakora, 2021. Evaluating and geospatial analysis of variability in maize yield response to fertilizer (NPK) using modeling in Ghana. IFDC FERARI Research Report No 7.
- ² Bua, S., K. El Mejahed, D. MacCarthy, D.S. Adogoba, I.N. Kissiedu, W.K. Atakora, M. Fosu, and P.S. Bindraban. 2020. Yield Responses of Maize to Fertilizers in Ghana. IFDC FERARI Research Report No. 2.
- ³ Bua, et al., 2020. Yield responses of maize to fertilizers in Ghana. IFDC FERARI Policy Brief No. 2.
- ⁴ AfrcaFertilizer.org. 2021. www.AfricaFertilizer.org/ghana.
- ⁵ MoFA. 2020. "Meet the Press," Presentation by the Minister of Food and Agriculture. Minist. Food Agric. Stat. Res. Inf. Dir. MoFA, Accra, Ghana.



FERARI maize test plot.

Authors:

K.K.A. Kouame^{1,2}, P.S. Bindraban^{2*}, I.N. Kissiedu², K. El Mejahed¹, W.K. Atakora^{2*}

- ¹ Mohammed VI Polytechnic University (UM6P), Ben Guerir, Morocco
- ² International Fertilizer Development Center (IFDC), USA
- * Correspondence: pbindraban@ifdc.org watakora@ifdc.org

Contributing partner:



August 2021

Visit the FERARI project online at:

https://www.ifdc.org/projects/ fertilizer-research-and-responsibleimplementation-ferari/

QUANTITATIVE EVALUATION OF FERTILITY OF TROPICAL SOIL

QUEFTS is a simulation model that estimates yield based on soil fertility characteristics, including soil organic carbon, total nitrogen, total phosphorus, exchangeable potassium, Olsen phosphorus and acidity (pH), and applied amounts of chemical and/or organic fertilizers. The model explained only 24.6% of the yield variability for on-farm trials and 12% for on-station trials (Figure 1).

AKAIKE INFORMATION CRITERION IN MULTIPLE LINEAR REGRESSION

Analysis with AIC-MLR was conducted to consider factors other than chemical soil fertility, including soil physical characteristics, such as root zone depth (Rzd) and water-holding capacity, and climatic factors, such as rainfall and temperature (T). The AIC-MLR methodology was run many times for various combinations of factors that could determine the yield responses. The best MLR combination included minimum and maximum temperature (Tmin and Tmax, respectively), root zone depth, water-holding capacity, pH, sand, silt, and nitrogen and phosphorus fertilizers. This combination of factors explained 50% of the yield variability. Soil physical factors explained about 25% of the variability, environmental factors about 10%, and chemical soil fertility characteristics about 33% for on-station trials. For on-farm trials, environmental factors explained more variability in yield response than physical and soil chemical factors. Furthermore, high temperature and high rainfall combined with shallow rooting depth (<50 cm) reduced the effectiveness of fertilizer application. The yield tended to decrease as the Tmin and Tmax increased, irrespective of the application of fertilizers. Since agriculture in Ghana is rainfed, the scarcity of rainfall harms the crop, but Figure 2 highlights that soils are generally shallow (less than 100 cm) where rainfall is high. The shallow depth might increase runoff of rainwater, which is then unavailable for the maize crop. Runoff may also cause loss of fertilizer and soil nutrients, deteriorating the fertility of soils.

Interestingly, fertilizer application tended to increase both yield and yield stability. As shown in Figure 3, the yield variation (Coefficient of Variation, or CV) was very high in the control plots, ranging from 71% on-station to 83% on-farm. The variation decreases with increasing fertilizer application to an average of 43% on-farm and 36% on-station.

Figure 1. Comparison of grain yield predicted by QUEFTS model with observed yield.



Figure 2. Scatter plot of observed yield and AIC–MLR–predicted yield as a function of Tmax (A), Tmin (B), rainfall (C), and Root zone depth (Rzd) (D) of on–farm trials.







Application rates of N (first letter), P (middle letter), and K (last letter) grouped as H=high (above 90 kg ha⁻¹ for N; ave 89 kg ha⁻¹ for P₂O₅ & K_2 O), M=medium (60–90 kg ha⁻¹ for N; 46–89 kg ha⁻¹ for P₂O₅ & K_2 O), and L=low (below 60 kg ha⁻¹ for N; below 48 kg ha⁻¹ for P₂O₅ & K_2 O).



CONCLUSION AND RECOMMENDATIONS

In this study, different scientific methods were used to identify the factors that determine the yield response of maize to fertilization in Ghana. The QUEFTS method revealed that soil fertility alone was insufficient to explain yield responses in on-station and on-farm trials, suggesting that other factors are also important . The AIC-MLR method (advanced statistical regression analysis) identified rootable soil depth, water-holding capacity, rainfall, temperature, sand, and silt to be as important as soil nutrients and fertilizer application.

All of these factors together explained over 50% of the yield responses found in both on-station and on-farm trials. These findings suggest that researchers who study the impact of fertilizers on crop yield should consider not only soil fertility but also these other factors. The importance of rainfall, temperature, and soil water-holding capacity suggest that climate change could heavily impact maize yield.

