# *Field Trial Protocols: Enhancing Fertilizer Recommendations and Cropping Systems in the Guinea Savannah Agroecological Zone*

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Field Trial Protocols

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## 1. Background

The decline in soil fertility, a fundamental biophysical constraint, makes maize farming in Ghana challenging. Ghana's Guinea and Sudan savannah zones typically have infertile soils due to poor agricultural practices such as continuous cropping without sufficient fertilizer input, bush burning, and removal of crop residues after harvest (Adu et al., 2018). Despite the crucial role of fertilizers in boosting maize yields, their utilization in sub-Saharan Africa (SSA) remains low, with an average application rate of 14 kg ha−1 according to Nziguheba et al., (2021). This highlights the urgent need to address the issue of low fertilizer use to sustain maize production in Ghana and other parts of SSA.

To address the issue of low fertilizer usage, the Ministry of Food and Agriculture and other agricultural organizations have advocated for blanket fertilizer application nationwide. However, this approach poses challenges as not all sites respond favorably to the recommended application rates due to variations in soil properties and environmental conditions. Furthermore, suboptimal yields can also result from the choice of seed and adherence to Good Agricultural Practices (GAP). Over the years, different development partners in collaboration with the government research organization worked towards the development of fertilizer recommendations tailored to different agroecological zones across the country.

In light of this context, it is crucial to conduct validation trials in real field conditions, incorporating various recommended fertilizer rates established in prior projects within the country. This encompasses evaluating the blanket recommendation rate, a recent initiative introduced by the International Fertilizer Development Center (IFDC). Notably, the interaction of different fertilizer rate with different maize varieties has yet to be examined and tested. These trials aim to yield data on maize productivity, providing a comprehensive assessment of the efficacy of recommended fertilizer rates and the compatibility of maize seed varieties in the Guinea Savannah zone. The results of these trials can subsequently be showcased to farmers, expediting adoption and improving agricultural practices.

## 2. Objectives

- To determine the optimal fertilizer rates for maize cultivation in the Guinea savannah zone, based on plant growth, yield, and other parameters.
- To compare the performance of OPV and Hybrid maize seed under different fertilizer treatments and identify the varieties that are best suited to local growing conditions.
- To provide stakeholders and policymakers with evidence-based recommendations for selecting maize varieties and applying fertilizers to maximize crop productivity and profitability.

## 3. Experimental Design

The experimental design was a split-plot design with three Varieties and seven fertilizer /management regimes. The experiment was replicated three times per site. Maize varieties were the main-plot factor while fertilizer/management regimes were the sub-plot factor.

**Varieties**: Three improved maize varieties – two OPVs and a Hybrid, were evaluated under the fertilizer rates. The maize varieties selected for this study are well-suited to the Guinea savannah zone. The OPVs were locally made breads, this is to ensure availability and sustainability which could the very critical for scaling purposes in the future.

Table 1: Characteristics of the maize varieties to be evaluated.

| Name of Variety | Origin/Source | Characteristics | Preferred Ecology | Pedigree Line | Year of Release | Year of Registry |
|---|---|---|---|---|---|---|
| CSIR-Sanzalsima | CSIR-SARI/IITA | Days to physiological maturity:110 days (medium).<br>Potential yield: 5.4 t/ha.<br>Drought tolerant.<br>Tolerant to lodging. | Guinea savannah, Sudan savannah, Forest savannah transition and Forest | OPV DT SYN 1 W | 2015 | 2015 |
| SeedCo SC719 | SeedCo WECA<br><br>(Imported Variety) | A late maturing white maize hybrid.<br>High yield potential of up to 16.8 tonnes per hectare (Mbawa Malawi). | N/A | | | |
| CSIR-Wang-Basig | CSIR-SARI/IITA | Potential yield: 4.7 t/ha<br>Days to physiological maturity: 90 (early)<br>Striga and drought tolerant; tolerant to lodging, tolerant to rust, blight, streak and curvularia. | Guinea and Sudan savannah, and Forestsavannah transition | OPV | 2012 | 2015 |

**Treatments**: The fertilizer rates were based on recommendation rate rates by CSIR – Soil Research Institute, IFDC, and a commonly adopted fertilizer rate used by maize farmers and input credit companies. Table 2 highlights the treatment description for this experiment.

Table 2: Treatment Description

| Treatments | Description | Source |
|---|---|---|
| T1 | Geographic area recommendation (Guinea Savannah): 100-40-40 N $P_2O_5$ $K_20$ | Tetteh et al., (2019) |
| T2 | Recommendation from IFDC 100-60-60 N $P_2O_5$ $K_2O$ | IFDC |
| T3 | 83.75-25-12.5 $NP_2O_5K_2O$ + 37.5S+5Mg+0.75Zn (2bags of Yara Activa + 1 Bag of SA per acre) | Degas' fertilizer rate/ common fertilizer and rate used by most farmers: Variating in N $P_2O_5$ $K_2O$ |

| | | |
|---|---|---|
| T4 | T3 + Zinc | |
| T5 | T2 + Maize cowpea intercrop | |
| T6 | T2 + Tied ridges | |
| T7 | ISFM (1/2 T2 + ½ Manure + intercrop) | |

Fertilizer requirement per plot is available at: https://cgiar-my.sharepoint.com/:x:/g/personal/a_jizorkuwie_cgiar_org/EUkw6LWCXR9ChhZq2l3pb1EBlpcJZb0gJOJ1_hIKLxmvZA?e=gFYuNd

**Field preparation**: the boundaries of the selected field used for the experiment were marked and ploughed with a tractor to a depth of at least 20 – 30 cm. A harrow was used to break up clumps of soil and create smooth and even seedbeds.

**Layout and replication**: the plots were quadrilateral, measuring 4.5m by 5m with 1m alleys between plots and 2m meter alleys between blocks, requiring about 55m X 37.5 m (2,062.5 m2) per site. Figure 1 below shows the layout of the experimental field under one fertilizer application rate. The experiment was replicated three times for each site, resulting in about 63 plots per site.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rep1 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | SC 719 |
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | Sanzalsima |
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | Wang-Basig |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rep2 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | SC 719 |
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | Sanzalsima |
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | Wang-Basig |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rep3 | T1 | T2 | T3 | T4 | T5 | T6 | T7 | SC 719 |
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | Sanzalsima |
| | T1 | T2 | T3 | T4 | T5 | T6 | T7 | Wang-Basig |

Figure 1: Experimental field layout for one block/replicate

**Experimental sites**: the experiments were established in Northern and Upper West regions during the growing season under rainfed conditions (June – November 2023). Six trials were established per region (Table 3)

Table 3: Trial sites

| Name of community | Region | District | Latitude | Longitude |
|---|---|---|---|---|
| | | | | |
| Jakpahi Kukuo | Northern | Kumbungu | 9.4522202 | -1.04195 |
| Limo | Northern | Gushegu | 9.495501 | 0.960763 |
| Tampion | Northern | Nanton | 9.579116 | 0.675783 |
| Nyamalgu Yapala | Northern | North-East Gonja | 9.273892 | -0.671851 |
| Daasuyili | Northern | Tolon | 9.377633 | -1.01317 |
| Duko | Northern | Savelugu | 9.565973 | -0.82258 |

| | | | | |
|---|---|---|---|---|
| Dangi | Upper West | Sissala East | 10.7049 | -1.7539 |
| Bullu | Upper West | Sissala West | 10.826 | -2.10689 |
| Bussie | Upper West | Daffiama – Bussie – Issa | 10.48123 | -2.49869 |
| Kulpong | Upper West | Wa East | 9.9293 | -1.8685 |
| Welembele | Upper West | Sissala East | 10.03942 | -2.50666 |
| Dariyira | Upper West | Wa West | 9.8986 | -2.6833 |

**Plot Labeling**: Sub-plots were labeled immediately after plot layout for easy identification of treatment plots. The labels were made from durable materials to be able to withstand weather conditions. The labels were printed and laminated. Each label contained information on site, Block number, Variety, Fertilizer/Treatment and Planting Date (Figure 2).

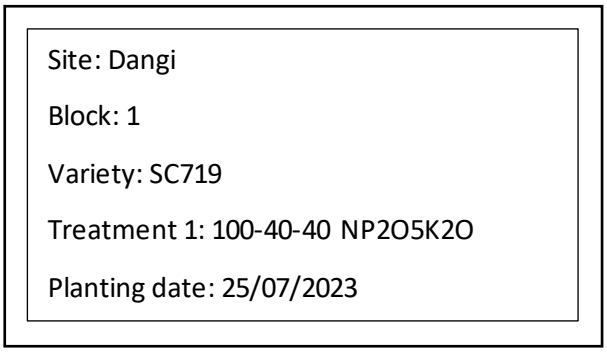


Figure 2: Plot labeling

**Randomization**: The treatments were randomly allocated for each replicate but sequentially numbered to reduce the errors associated with position. A sketch was drawn per trial.
**Planting**: The Spacing was 0.75 m and 0.40 m spacing between rows and plants respectively. In each trial, three maize seeds were initially planted per hill, and later thinned to two plants per hill two weeks after emergence. This resulted in a final population density of 83,000 plants per hectare. Refilling was done when necessary. For intercropping, cowpea was planted between the rows of maize four weeks after planting with a spacing of 20 cm between the cowpea seeds.

**Fertilizer application**: Fertilization for each treatment were applied at planting, applying fertilizer at planting ensures that essential nutrients are readily available to the crops during their early growth stages, promoting healthy root development, efficient nutrient uptake, and overall crop establishment. The fertilizer was deposited in a hole about 5 cm away from the plant stand and covered with soil. Nitrogen application will be split, first nitrogen was applied with NPK fertilizer (meeting the total requirement of P and K but some percentage of required N). The remaining N was applied using Urea or Sulfate of Ammonia depending on the treatment at 6 WAP after rains.

**Weed control**: Pre-planting weed control was done by clearing the land of all weeds and debris before planting using a tractor. A pre-emergent herbicide was applied after planting to reduce the

growth of weeds. After the maize germinated, the hand weeding method was used to remove any weeds that had managed to grow.

**Materials required for demarcation**:

- Site characterization forms
- GPS device
- Field book for additional notes
- Tape measure
- Wooden pegs
- Strings/lines/ropes

## 4. Data Collection Procedures used for Evaluating Treatment Impacts on Maize Trials

This section outlines the methodologies employed in the collection of data from agronomic multisite trials. It details the systematic process of soil sampling using a diagonal pattern and the measurement of various maize plant growth parameters and yield components such as plant height, chlorophyll content, and leaf area. Additionally, it delineates the collection of maize plants for stover, cob, and grain yield determination. Each stage highlights the systematic approach adopted to ensure the comprehensive capture of essential data points.

**Data collection**:

*i.* *Soil sampling*: Soil physicochemical properties are analyzed before and after an experiment to understand the initial and final state of soil before treatment and after treatment application. The information on the state of the soil might help explain the observations that are made for the treatments.

Procedure:

- Variability of initial soil condition over a field before experiment is assumed to be low. For this reason, the entire field is divided based on uniform soil characteristics and not per plot basis (e.g., texture, color, slope).
- A soil auger is used to collect soil samples at a consistent depth of 0-20 cm and 20-50cm depths within each rep using diagonal sampling pattern (figure 3).

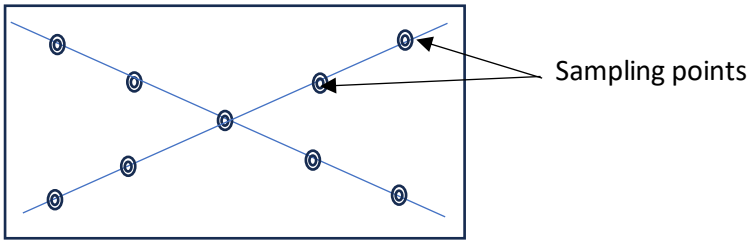


Figure 3: Diagonal Method

- Multiple soil cores per sampling unit are collected to obtain a representative sample.

- The soil samples from each sampling unit are combined into a clean bucket or container and mixed thoroughly, air-dried and sent to the laboratory for analysis.
- The soils from 0 to 20cm and 20 to 50cm are taken and analyzed separately.

*ii.* *Plant height*: The height of maize plants is recorded for each treatment at various stages of growth to assess plant growth rate and development.

- Six plants are tagged per plot and their heights are measured with ruler starting from the base to the point of intersection of the upper most leaves for younger plants.
- For older plants with tassels, the measurement is from the base to the point of attachment of the last leaf on the on the stalk (Figure 6).

Figure 4: Established field trial

Figure 5: Agronomic Data collection

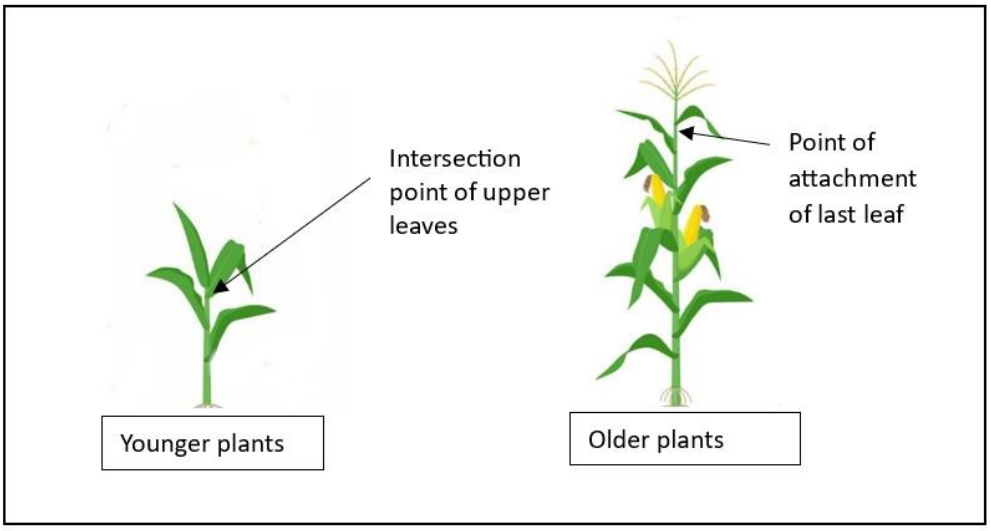


Figure 6: Points of consideration for plant height.

*iii.* *Chlorophyll content*: chlorophyll content is taken for six plants per plot, specifically the same plants on which the plant heights were measured.

- The SPAD meter is used in taking the chlorophyll content on the fifth and sixth leaf from the base of the plant.
- Three spots are taken for each leaf (fifth and sixth leaf) and the average is recorded for each leaf per plant.

*iv.* *Leaf Area*: Leaf area is used in estimating the photosynthetic capacity of the maize crop, which is crucial for understanding its ability to convert sunlight into energy.

- The leaf area for each crop is taken from the third leaf from the top.
- The length and breadth of the third leaf is measured and recorded. The middle portion of the leaf (mostly the largest part) is where the breadth of the leaf is focused on.

*v.* *Stover yield*: subplots are marked in each plot for the harvesting of maize plants for the determination of biomass/stover yield.

- The middle rows of the plots are considered for the harvesting, for example, in plot sizes of 5 by 4.5m (22.5m) and with planting space of 0.7m by 0.4m, seven rows will be achieved, in this way, the three middle rows are harvested – discarding the two outer rows on each side of the plots.
- 1m of the edges of each row to be harvested is also discarded. In this case the harvested area is about 3m by 1.5m as illustrated in figure 7.
- The maize plant is cut from the base, the cobs are removed from the plants in a way that the husks remain attached to plants.
- The sample plants from the harvested plots are tied and weighed with a hanging scale and recorded as fresh biomass weights.
- A subsample is taken (five plants from the total harvested plants) cut into pieces and mixed uniformly. The plant mixture is then divided into 4 and a quarter of the division is kept in an envelope and weighed as fresh biomass of sampled biomass.
- They are well labeled and later dried in oven at 65 ℃ degree Celsius for 48 hours and reweighed for the weight of dried biomass. This can help determine the moisture contents of the weights of biomass at the time of harvest.

*vi.* *Cob and grain yield:* The detached cobs of maize from each sampling plot are considered for the determination of total cob number and weight.

- Also, five cobs are randomly selected from the total cobs and weighed.
- The cobs from the five sampled cobs are shelled and the grains are weighed also, and moisture content is determined with seed moisture meter.
- The weight of grains sampled per plot is converted into kg/ha.

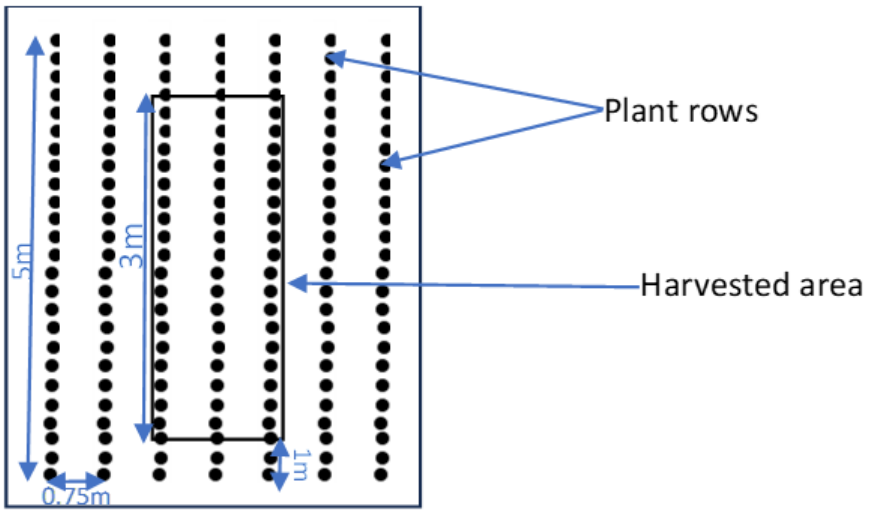


Figure 7: Harvested area

Figure 8: weighing of maize biomass

Figure 9: weighing of maize cobs

## 5. Acknowledgments

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## 6. References


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## Appendix

**Data collection sheet**

| | |
|---|---|
| **Treatment** | |
| **CROP MANAGEMENT INFORMATION** | |
| Date of land preparation | |
| Method of land preparation | |
| Type of seedbed (flat, ridges or mounds) | |
| **Plot level data** | |
| Planting date | |
| Date of refilling/thinning/transplanting | |
| Row spacing - Distance between rows (cm) | |
| Distance between plants in a row (cm) | |
| Plot size (plot length x plot width) | |
| Plant population per ha | |
| **Fertilizer application** | |
| Date of 1st fertilizer application | |
| Type (Grade) of fertilizer applied (e.g. 15-15-15, Urea, TSP, etc.) | |
| Fertilizer placement method | |
| Fertilizer rate | |
| Date of 2nd fertilizer application | |
| Type (Grade) of fertilizer applied | |
| Fertilizer placement method | |
| Fertilizer Rate | |
| **Weed control** | |
| Weed control method after planting (e.g. hoe weeding, herbicide, etc.) | |
| Number of weeding | |
| weeding dates (1st, 2nd, 3rd) | |
| **Cropping history** | |
| Major crops cultivated on this land | |
| Type of fertilizer applied to the plot last cropping season | |
| was crop residue left on the field? | |
| Was there bush fire/burning on this field | |
| **Soil sampling (0-20cm depth)** | |
| Soil sampling date | |

**Data collection sheet for growth parameters**

| **Site** | | | **GPS:** | | | | **Date** | |
|---|---|---|---|---|---|---|---|---|
| **Trts** | Plt Ht/cm | Stem Girth | Leaf Chlorophyll Content | | No. of leaves | Leaf length | Leaf Width | No. of leaves |
| **Rep: Variety: Treatment:** | | | 5th Leaf | 6th Leaf | | | | |
| Plant no. 1 | | | | | | | | |
| Plant no. 2 | | | | | | | | |
| Plant no. 3 | | | | | | | | |
| Plant no. 4 | | | | | | | | |
| Plant no. 5 | | | | | | | | |
| Plant no. 6 | | | | | | | | |

**Data collection sheet for yield parameters**

| **Site:** | | | | | **GPS:** | | | | | | **Date:** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Lodge @ Harvest** | **Area Harvested (No. of rows)** | **No. of Plants** | **No. of Missing Plants** | **No. of Cobs** | **Cobs Weight (Kg)** | **Biomass Weight (Kg)** | **Fresh Biomass Weight (5sampled) (g)** | **Fresh Cob Weight (5sampled) (g)** | **Grain Weight (g)** | **1000 seed weight** | **Moisture Content** |
| **Rep: Variety:** | | | | | | | | | | | | |
| T1 | | | | | | | | | | | | |
| T2 | | | | | | | | | | | | |
| T3 | | | | | | | | | | | | |
| T4 | | | | | | | | | | | | |
| T5 | | | | | | | | | | | | |
| T6 | | | | | | | | | | | | |
| T7 | | | | | | | | | | | | |