ATTACHMENT 4: PROCEDURE FOR SOIL FERTILITY EXPERIMENT ON MICRO-DOSING

DETERMINING OPTIMAL MIXTURE OF ORGANIC AND INORGANIC FERTILIZERS FOR SOIL FERTILITY AND PLANT RESPONSE

BACKGROUND

Context:

In south-central Uganda, as in much of the developing world, smallholder farmers are facing severe natural resource constraints that threaten their ability to sustain either subsistence or commercial livelihoods. As population pressure reduces the amount of land available to fallow, continual mining of soil nutrients is resulting in steadily declining soil fertility. There is an urgent need for farmers to introduce more intensive techniques to replenish soil nutrients while reducing the land needed to produce the same crop yield. This issue is especially pertinent to commercializing farmers who aim to venture into high value crops, such as vegetables and specialty (non-staple) horticulture since these tend to be heavy feeders on soil nutrients. Despite these trends, smallholders find it difficult or undesirable to invest in additional fertilizers. This can be attributed to a number of reasons, such as the high price of both organic and inorganic fertilizers, poor understanding of the reasons and impact of fertilizing, lack of technical knowledge on correct application, and perceptions that certain types of fertilizers have undesirable effects on the soil (such as depleting the soil or carrying disease).

Rationale:

Many smallholders depend on livestock for a significant contribution to their livelihoods, both for animal protein and fertilizer. Because this source of fertilizer is readily available and part of traditional farming systems, the common practice is to use only the fertilizers collected on-farm to supplement the nutrients lost through cropping. However, this is often insufficient to compensate for nutrient depletion, let alone fertility improvement. Furthermore, insufficient knowledge of application considerations may lead to inefficient soil fertility management across the entire farm. Even farmer willing to invest in supplemental fertilizers simply cannot afford more than a limited amount of fertilizer at a time. If a farmer is in position to purchase fertilizers, inorganic forms pose many advantages such as ease of transport and storage ability. Further, the different qualities of inorganic forms of fertilizer (such as immediate nutrient availability to the crop) versus organic forms may fill an important role in increasing crop yields. Thus, there is some mixture of inorganic and organic fertilizer that will serve to optimize both crop response (short term economic/nutritional benefits) and soil fertility improvements (long term asset/natural resource benefits).

Approach:

Our approach to this issue is to conduct research to determine this optimal ratio. Moreover, to ensure relevance, this research will attempt to operate according to local norms while controlling for as many key variables as possible in on-farm trials. This research will be conducted on eight farms in the area and represent various soil conditions found in the area.

The key local norms adhered to by this research relate to various management issues. First, application rates of inorganic fertilizers are limited to micro-doses that are within a reasonable economic threshold faced by small farmers in the region. Second, since some monetary investment is needed to supplement with inorganic fertilizer, crop choice was determined farmers' perception of good cash crop that is mutually amenable for household consumption (in this case cabbage). Third, timing of the experiment coincides with traditional planting seasons of cabbage in the area. Finally, since the 8 host farms will experience different weather conditions, water management will be carried out and recorded by host farmers. Chemical pest and disease management will be used to ensure a sufficient population survives to harvest, and that crop characteristics are responses indicative of fertilization.

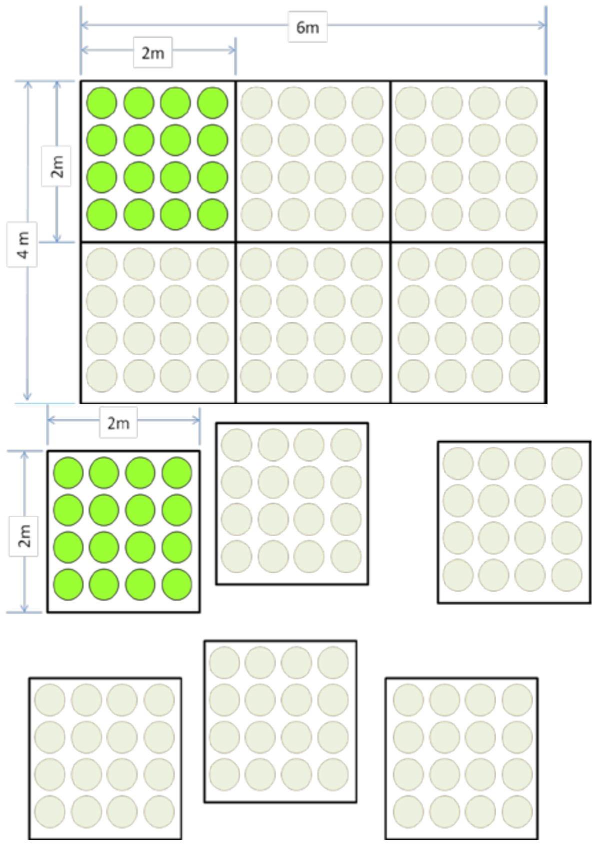
Desired Results:

The outcome of this research will be to discover the most suitable fertilization ratio to maximize plant response and improved soil fertility based on criteria of economic return on investment and effects on soil fertility enhancement. The recommendations from this research will serve to provide small farmers with the knowledge of how to supplement inorganic fertilizers to traditional organic methods to improve both their short term economic/nutritional gain while maintaining or building the fertility of their soil within an attainable investment.

METHODOLOGY

Plot Layout and Randomization:

The study will be implemented on farms in and around the town of Nkokonjeru. Six plots (2 m x 2 m) will be demarcated (Fig. 1a & b) on each of 7-8 replicate farms. On each farm, plots should be as close together as possible (preferably adjacent to one another as in Fig. 1a) and be as similar as possible with respect to shade cover, slope and soil type. Plots may be separated somewhat if there are obstructions in the designated reseach area (Fig. 1b).



1a **1b**

Figure 1a&b: Example layouts for six plots on a replicate farm where a) all plots are adjacent to each other; or b) the plots are close together, but not sharing borders.

Within these each replicate farm, the 6 demarcated plots will be allocated to the following 6 fertility treatments:

100F - 100% mineral fertilizer
75F25M - 75% fertilizer + 25% manure
50F50M - 50% fertilizer + 50% manure
25F75M - 25% fertilizer + 75% manure
100M - 100% manure
C - Control (no fertilizer or manure)

These treatments should be randomly allocated to each of the plots on the 7-8 farms according to Fig. 2 and Table 1.

1	2	3
4	5	6

Figure 2: Plot positions for use in treatment randomization

Table 1: Randomization of Treatments to Plot Positions

Position	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8
1	75F25 M	25F75 M	100F	25F75 M	100F	25M75 M	C	100F
2	50F50 M	100F	C	100F	100M	75F25 M	25F75 M	75F25 M
3	25F75 M	100M	75F25M	C	C	50F50 M	50F50 M	C
4	100M	C	25F75M	50F50 M	25F75 M	100M	100M	100M
5	C	50F50 M	100M	75F25 M	75F25 M	C	75F25 M	50F50 M
6	100F	75F25 M	50F50M	100M	50F50 M	100F	100F	25F75 M

Treatment Details:

Fertilizer will be added as urea (46% N) and NPK (15% N), while manure will be obtained from local cattle owners and applied as is. Treatments with manure on all farms in the study should receive manure additions as close to each other as possible (in time) to avoid differences in manure chemistry between farms (manure can lose N rapidly over the course of several days, especially if it is fresh and wet, and if it is mixed with cattle urine).

Nutrient additions for each plot are based on equivalent monetary inputs, except for the control which has no fertility input costs. Inputs equivalent to 500 UGX per 2 x 2 m plot were used to provide a reasonable minimum N input (roughly 210 kg N ha^{-1} for the 100F plot) while representing only a small portion of the estimated gross income potential for a commercial cabbage plot (50,000 UGX for a 20 x 20 m plot). The following price assumptions were used to calculation input amounts for the 6 different fertility treatments:

- 1 truckload of cattle manure = 50,000 UGX
- 50 kg urea = 90,000 UGX
- 50 NPK (15-15-15) fertilizer = 90,000 UGX

Although fertilizer applications can be easily be calculated based on weight, the exact quantity of manure in a truckload is unknown and extensive partitioning must be done to obtain applicable portions.

Manure will be divided up into units worth 125 UGX each (only 10,000 UGX or 1/5 truckload will be need for the entire experiment). To do this the truckload of manure must first be divided into 5 equal piles. One of these piles needs to be selected and thoroughly mixed/homogenized for use in the study. After mixing, the 10,000 UGX pile will be divided into 8 equal parts. Then each part will be divided into 10 equal units worth 125 UGX each. Thus, the 2 x 2 m treatment plots on each replicate farm will receive the following amounts of manure and/or fertilizer:

100F – 138.9 g urea + 138.9 g NPK fertilizer + 0 units of manure
75F25M – 104.2 g urea + 104.2 g NPK fertilizer + 1 unit of manure
50F50M – 69.4 g urea + 69.4 g NPK fertilize + 2 units of manure
25F75M – 34.7 g urea + 34.7 g NPK fertilizer + 3 units of manure
100M – no fertilizer + 4 units of manure
C – no fertilizer or manure

Nursery planning:

Nurseries for cabbage seedlings can be established individually on each replicate farm or all seedlings can be grown at a central nursery to provide cabbage starts for all replicate farms. The same variety of cabbage should be planted on all of the replicate farms and treatment plots. Each farm will require a minimum of 96 healthy cabbage seedlings for transplanting, so at least 150-200 seeds should be planted for each replicate farm. Seeds should be sown in fertile soil with adequate spacing (1-2 cm) to allow for separation of cabbage starts. Both manure and/or fertilizer should be used in the nurseries in order to obtain healthy seedlings for transplanting. Seedlings for all replicate farms should be treated as similarly as possible at all stages of the study.

Baseline Soil Fertility Sampling:

Ideally, additional funding will be obtained and allow us to continue these same treatments on these same plots for multiple years, so that we can understand what happens to both yields and soils after many years of manure and/or fertilizer applications. Thus, after demarcation of plots and prior to treatment implementation (nutrient additions), soils (0-15 cm) should be sampled from each plot to provide baseline nutrient information for each replicate farm and plot. In the absence of a soil corer (we hope to send one later), soil can be sampled by carefully using a shovel or hoe. I small pit will be dug to 20 cm in depth and needs to have at least on vertical wall. Then a knife and ruler can be used to cut away wedge of soil down to a 15cm depth, ensuring that an equal volume of soil is removed from each depth. Two sub-samples should be removed from each 2 x 2 m plot and combined in a plastic bag with the farm name and treatment written on it. Upon return to RASD (local resource center and implementing partner), the soils should broken apart by hand (into clods < 1cm in diameter) and air-dried for several days by leaving the bags open on a table indoors - stirring the contents occasionally. If the weather is very wet, it may be necessary to arrange the use of an oven (hopefully this is possible) and place the soils at low temperatures (<50 °C) for 1-2 days. A fan may also be used to help increase airflow and speed up the drying process. Once dry, the soils should be sealed up in plastic bags and preferably stored in a dark dry place. It may be possible to send a portion of this soil directly (before drying) to the NARO lab in Kwanda for analysis. Regardless, we will save a sample baseline air-dried soils for future/additional analyses at UC Davis or in Uganda

Planting and Fertility Application:

Seedlings will be ready for transplanting 3-4 weeks after planting. Manure should be applied 5-7 days before transplanting by spreading out the designated number of units in each plot and incorporating it into the soil evenly (roughly 15 cm deep) with a shovel or hoe. All plots on a replicate farm can be tilled at this time to ensure loose soils for planting and equivalent disturbance across all treatments. Seedlings will be planted in a grid with 50 cm spacing between each row and 50 cm spacing between each plant within a row, resulting in a total to 16 cabbage plants per plot (Fig. 3).

Fertilizer will be applied in two separate doses. The NPK should be applied 5-7 days following planting while the urea can be applied approximately 3 weeks after planting. Given that there will be 16 cabbage plants per plot, 1/16 of the allotted fertilizer amount for a plot should be applied to each plant by spreading the fertilizer evenly around the diameter of the plant's leaves and covered by a light layer of soil.

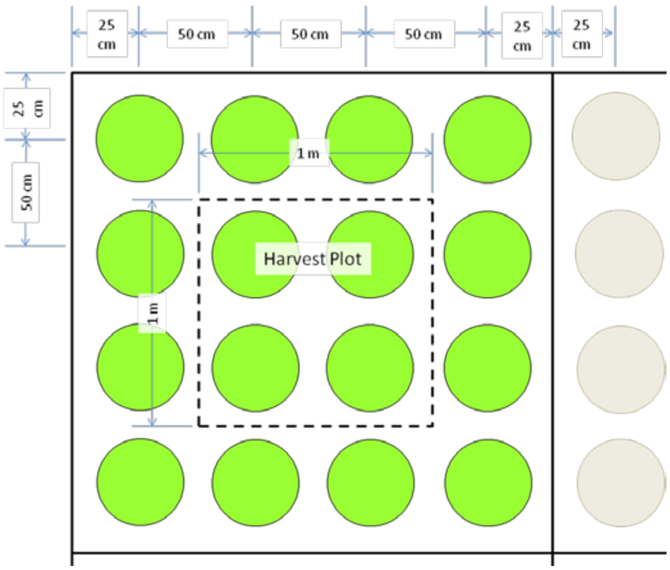


Figure 3: Layout for individual 2 x 2 m plot with 16 cabbage plants per plot and 1 x 1 m harvest/sampling area in the center.

Maintenance:

To ensure uniform management across all replicate farms, plot maintenance (pest control, weeding…) will be conducted (or at least overseen) by a single person or crew over the entire course of the experiment. Weed and pest control should be conducted by standard practices, using technologies available to the farmers (pesticides, hoeing,…).

Harvest – Soil and Plant Sampling:

When cabbages are ready to harvest, researchers should remove the 4 cabbages from the harvest plot - the participating farmers can perhaps harvest border areas, but only after all of the soil and plant samples have been extracted from harvest plot. The four cabbage plants should be weighed whole to determine total fresh wt biomass, and then the sellable portion can also be weighed for a more relevant determination of yield. Cabbages may have to be cut in two if they are too big for the scale. Perhaps someone familiar with the cabbage market could be present to provide an approximate market value for each cabbage removed from the harvest plot, as it seems that cabbage in the local market isn't sold by weight, buy by size and appearance. A subsample of each cabbage should be taken by slicing a section out of the middle of the cabbage. A slice (wedge) from the 4 cabbages should then be combined to get one number for each plot. We will want to measure total N and P in the cabbage and perhaps some micronutrients (Fe, Zn,…) if we can afford it.

The NARO lab in Kwanda will be consulted to see how they want the soil and plant samples to be prepared (fresh vs. dried…). Soil can be sampled by the same method used for the baseline samples, or hopefully a soil corer will be available to make this task easier. Multiple (3-4) subsamples should be taken from within the harvest plot and combined to make on composite sample.