FtF Volunteer Supplementary Report. Soil test evaluation for Bukowa Area Cooperative Enterprise, Iganga Uganda.

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We collected six soil profile samples from a farm located near Bunya Road, LATITUDE 0.574778, LONGITUDE 33.541454 on July 19, 2017. The profile sample provides analytical data for a small farm that is considered “typical” by members of the Bukowa Area Cooperative Enterprise board. Three points in one farmer’s field were selected. Soil samples were collected at a 5 cm increment to a depth of 30 cm at each sample point (producing six composite samples). Soil samples were submitted for nutrient testing on July 20, 2017 (refer to appendix page 27 for soil test report). Soil analysis shows that oilseed crops, legumes and maize plus numerous horticultural crops would be well suited for this soil, if select fertilizers and nutrient-enriched or fortified compost are applied to off-set nutrient deficiencies.

This summary provides a description for one location. Upon close inspection of other farms, we will find that not all suggestions identified for this location will accurately apply to every farm. Because of this, it would be highly beneficial and very appropriate to develop and implement a plan to sample and evaluate more farms – to develop site-specific guidelines – to better serve the entire farm community.

SUMMARY OF CHALLENGES AND OPPORTUNITIES

Overall, the main nutrient management issues appear to be 1) phosphorus placement; 2) nitrogen application timing; 3) deficiencies of base-cations potassium, magnesium and calcium; and 4) soil acidification. Soil pH is becoming excessively low at depths below five centimeters. This condition reduces the efficiency of DAP applications. This problem can be remediated over time with aggressive applications of mature well decomposed nutrient-fortified compost. Refer to Table 1 for area conversions for rates in kg/A to g/sq. meter, etc.

1) **Phosphorus Placement.** Apply DAP at a depth of 25 to 30 cm at planting. Apply all 20 to 30 granules (12 to 13 grams of DAP per sq. meter) as a nugget or tight cluster in a hole close to each maize seed. Avoid turning or disturbing the soil when stabbing holes to apply DAP.
2) **Nitrogen Application Timing.** Split-apply UREA at a rate of 50 to 100 kg/acre (12 to 25 grams per sq. meter) so that 1/3 is applied at V8, 1/3 at early silk stage, and 1/3 at early grain fill. Avoid surface applications of UREA.
3) **Potassium Deficiency.** This is a minor to moderate problem. It should not be considered a severe problem for a low-yield environment.

   Option: Apply 25 to 50 kg/acre of potash (0-0-60) at planting (6 to 12 grams per square meter, or 5 to 10 grams per square yard). Deep application would be appropriate. Potash is soluble in water but it also binds very quickly to soil particles and not move to deeper positions in the root zone.

   - ✓ Apply POTASH in the same manner as deep-placement DAP fertilizer.
   - ✓ Alternatively, compost all crop residues and green plant material moistened with nutrient-rich slurry that includes potash. This would produce compost that is very rich in potassium.

NOTE that nutrient rich compost acts like chemical fertilizer in that it can burn seeds and roots of young plant seedlings – so, always deep-place apply nutrient-fortified compost at a distance of at least 5 cm from the planted seed.

4) **Magnesium Deficiency.** This is a minor to moderately severe problem. It should not be considered a severe problem for a low-yield environment.

   Find alternate sources of magnesium. Epsom salts could be a suitable candidate. Epsom salts contains only 9.1 percent magnesium.

   - ✓ If one were to apply Epsom salts to fulfill the theoretical target rate of 33 kg/acre of magnesium, one must apply about 360 kg/acre of Epsom salts (33 ÷ 0.091 = 363). This application rate could be considered cost prohibitive for most systems and could also introduce excessively high levels of sulfur to the root zone.
   - ✓ Alternative option: apply one half the theoretical optimum rate of Epsom salts each season to provide a good and safe source of sulfur while building levels of magnesium over time.

     Set up at least three test plot areas, as described for calcium (see next section).

     Surface-apply 45 grams of Epsom salts per square meter or 37 grams of Epsom salts per square yard. Cover it with crop residues. Rainwater will rinse this material into the root zone where it is needed.

5) **Calcium deficiency.** This is a long-term challenge. This is a moderately severe to very severe problem. It should be considered a significant problem.

   Consider at least three materials and methods to remediate this deficiency

   - *Calcium carbonate (AgLime)*

     This is a suitable material to use for amending the surface 15 to 20 cm of soil. Apply three to five metric tons of AgLime per acre (0.74 to 1.23 kg/sq. meter) and thoroughly incorporate by vigorously mixing the AgLime into the soil to a depth of 15 to 20 cm.

   - *Lime stabilized biosolids*

     Human waste biosolids can be remediated (process to reduce pathogen load) with hydrated lime to control pathogens and subsequently applied to farmland would serve as an additional source of calcium. This material is referred to as lime stabilized biosolids and can be either directly land-applied, or included as a feedstock for compost. The added benefit of using lime stabilized biosolids is its content of a full suite of micronutrients, plus nitrogen, phosphorus and sulfur.

   - *Gypsum*

     Gypsum may be a logical material of choice for remediating this problem. Gypsum is calcium sulfate. It contains 21% calcium (Ca) and 16% sulfur (S). The application rate of this product is calculated by dividing the decimal percentage of gypsum's calcium content (0.21) into the desired calcium rate (Table 2, MT/acre). This translates into gypsum application rates from 22.8 metric tons per acre to 26.7 metric tons per acre.

Fulfilling the calcium requirement using gypsum could easily overload the soil with sulfur. Sulfur is a required plant nutrient, but a safe application rate should not exceed 50 kg/A.

- *Set up test plots* to evaluate the effects of applying AgLime or gypsum at a rate of 0.74 to 1.23 kg/sq. meter (Table 2). This is a process that requires good planning and complete documentation (consider this one of the most important steps in developing and maintaining soil health for cooperative members):
  - ✓ Establish about three small areas in the field to set up test plots. Each test area should be an area of six to nine square meters.
  - ✓ Clearly mark the areas for future reference so that you can easily identify each area document crop yields.
  - ✓ Uniformly broadcast apply the material over the soil surface to cover a test area.
  - ✓ Cover the applied area with plant residues.
  - ✓ Irrigate in or allow rainfall to leach the material into the soil.
  - ✓ Over time, the calcium not removed by a crop will migrate deeper into the soil. The benefits or problems should become noticeable within one growing season. Full benefits may not be noticeable for more than one year.

6) **Soil Acidification.** Soil acidification is a natural process and will continue unless properly managed. Agricultural lime applications may not be practical, because the depth of acidification imposes a challenge of practicality. A soil depth of 20 to 30 cm is too great and technically difficult to properly remediate with lime. Aggressive use of mature fully decomposed compost will produce organic substances that will help buffer the soil and chelate or tie up aluminum, iron and manganese (this is needed) – and make phosphorus more available to plant roots.

   Identify and plant a cover crop with good tap roots (e.g., clovers and radish, etc.). Compost the crop residues and terminate your cover crops just before flowering. Strive to develop a thick soil cover.

   - ✓ Terminating when the cover crop plants are succulent and sugar-filled will dramatically increase microbial activity in the soil and the formation of beneficial organic substances needed to build and protect a healthy soil.
   - ✓ A thick soil cover will promote microbial activity which is needed to build soil humus – the conversion of organic matter into humus.

7) **Lessons from a tree.** Remember that when you are confused or can't remember all of the details of how to best manage your soil, consider the life of a tree – a tree cares for its soil – in return, the soil cares for the tree.

Table 1. Application rate conversions.

1 metric ton/acre	x	0.247	=	0.247 kilograms per sq. meter
1 metric ton/acre	x	247	=	247 grams per sq. meter
50 kilograms/acre	x	0.247	=	12.4 grams per sq. meter
10 kilograms/acre	x	0.124	=	1.2 grams per ½ sq. meter

SOIL TEXTURE

Soil textural analysis of the soil profile shows us that sand dominates the upper 15 cm (sandy loam) with clay content increasing from 10% to 30% at a depth of 20 cm to 30 cm (sandy clay loam). Refer to Figure 1. Sandy surface soils tend to have a relatively low water-holding capacity, despite the presence of higher organic matter content (see Figure 2). When this soil is exposed to the energy of the sun, soil water will quickly evaporate from the sandy soil. This analysis provides evidence that maintaining a year-round thick soil cover will benefit the farmer by shading and cooling the soil and therefore decreasing water loss through evaporation. Ample soil cover will also help to maintain soil organic matter and promote humus formation near the soil surface. A soil with ample humus is better able to absorb and retain moisture. A good soil cover is needed to protect humus from exposure to the energy of the sun.

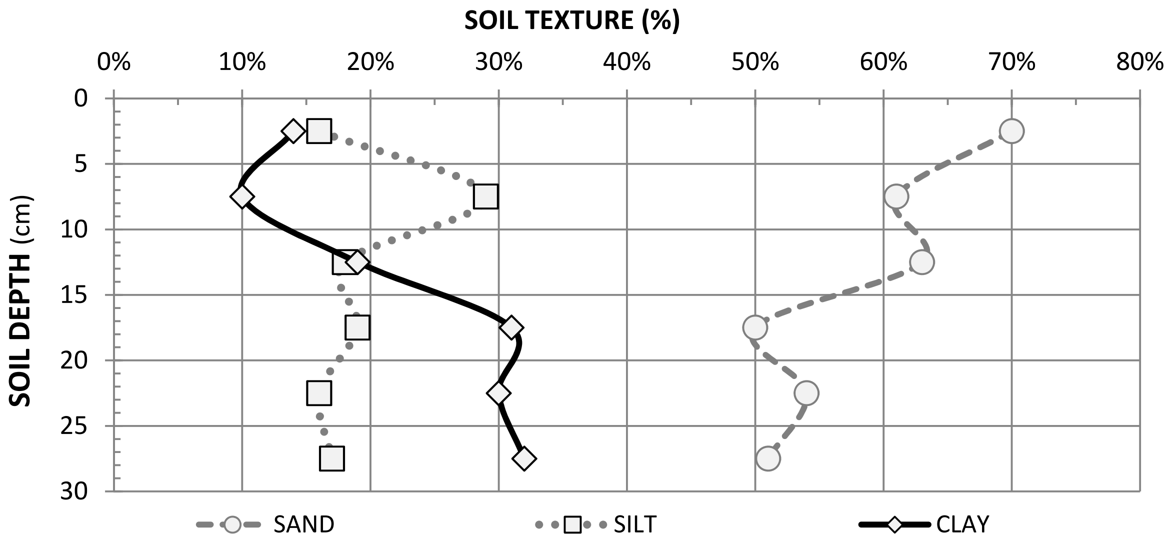

FIGURE 1. Soil Texture. Percent sand, silt and clay is shown for each 5-cm increment to a depth of 30 cm.

SOIL pH, Cation Exchange Capacity (CEC) and Soil Organic Matter (SOM)

Soil pH at the soil surface (5 cm) is ideal for plant growth, but becomes increasingly acidic with depth. As a soil acidifies, base-forming cations (Calcium-Ca, Magnesium-Mg, Potassium-K, and Sodium-Na) become more soluble and attach to sulfates, nitrates and chloride ions. In this form, these base cations can readily leach or migrate to deep positions in the soil, sometimes out of reach of most plant roots. When a soil pH falls below 5.2, aluminum converts into a form that is toxic to most plant roots. Iron and manganese are also affected by pH and become much more soluble and available for plant uptake under acid conditions. Aluminum, manganese and iron are known to fix phosphorus under acid soil conditions, rendering most of the soil phosphorus unavailable for plant uptake. Additions of compost can, over time, lessen the severity of the negative effects associated with soil acidification.

A probable cause for the high pH (6.7) in the 0-5 cm sample may be associated with either (1) annual crop residue burning or (2) agricultural lime (AgLime) application(s).

1. Crop residue burning releases most of the organic nutrients (carbon, nitrogen, and sulfur) as smoke while the base-forming minerals (e.g., potassium, calcium, magnesium, sodium and zinc) are retained in ash and tend to accumulate near the soil surface or to the depth where the ash is incorporated into the soil. The extent of movement of base-forming minerals and other metals such as aluminum, manganese and iron is controlled by the pH and cation exchange capacity (CEC) of the soil. For these reasons, ash that accumulates near the soil surface can cause a slight increase in soil pH. Note that potassium unlike calcium, magnesium and zinc, is very soluble in this form and can quite easily migrate with water deeper into the soil.
2. AgLime is typically applied at very high application rates (3 to 5 MT/acre) relative to fertilizers (50 to 150 kg/acre). AgLime is applied to raise the soil pH. AgLime must be thoroughly blended and well mixed into an acid soil. This is because the active ingredient of Ag Lime (calcium carbonate, $CaCO3$) does not dissolve in water nor migrate with water through the soil. It generally remains in the position where applied and incorporated or mixed into the soil. Soil particles that come into contact with AgLime particles undergo a chemical change that causes the soil pH and soil solution pH to rise. When the soil pH rises above 5.2 to 6.5, nitrogen, phosphorus, and potassium use by the plant system becomes much more efficient.

Cation exchange capacity **(CEC)** is a measure of a soil's ability to hold cations (e.g., calcium, potassium, magnesium, sodium, zinc) in a state that is accessible to plant roots. Variation in cation exchange capacity by soil depth for this location is illustrated in Figure 2.

Soil organic matter **(SOM)** and clays have a potential to hold large numbers of cations. So it follows that as the content of soil organic matter and/or clay content increases, so does the soil's cation exchange capacity. Note that soil organic matter content of the surface sample (0-5 cm) is high and the clay content is low, resulting in a relatively high cation exchange capacity.

Note that the soil organic matter of the surface soil sample (0-5 cm) is very likely dominated by charred plant residues, a product of annual crop residue burning. This form of organic matter is somewhat resistant to microbial degradation and is also less able to absorb and hold water. The Walkley-Black method used to determine soil organic matter content (oxidizable carbon) is an excellent protocol, but unfortunately does not differentiate forms of organic matter.

In our example, the CEC at the soil surface is represented by soil organic matter (3.8%), while clay content is very low (14%, Figure 1). CEC drops to a low of 14 cmoles/kg in the 5-10 cm depth and then gradually increases to a high of 29 cmoles/kg at the 25-30 cm depth. In this example, organic matter decreases with depth (Figure 2) while clay content generally increases with depth (Figure 1).

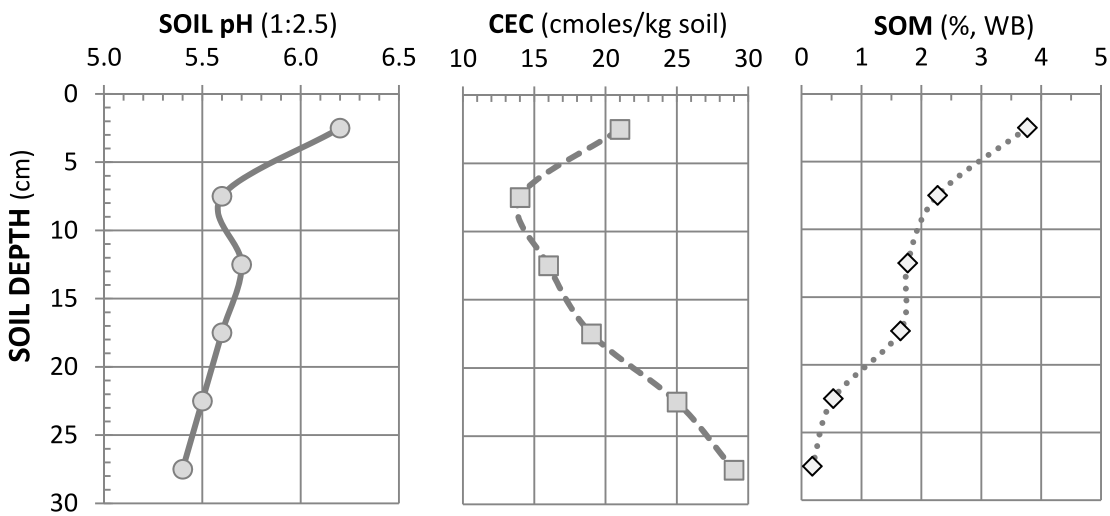

Figure 2. Soil pH (1 part soil to 2.5 parts water), Cation Exchange Capacity (CEC) by ammonium displacement, and soil organic matter (SOM) by Walkley-Black method. Ammonium displacement measures may overestimate CEC in acid soils.

BASE SATURATION

Base saturation is a measurement that provides insight into the relative availability of the essential plant nutrients calcium, magnesium and potassium. It is the ratio of the sum of base-forming cations relative to the soil cation exchange capacity (CEC). As mentioned above, the cation exchange capacity of a soil is a measure of the relative ability of a soil to provide minerals (cations) to plant roots. Base saturation takes the measurement one step further by indicating more specifically the relative availability of base forming cations for removal and use by plant roots. Variation by depth of individual base-forming cations plus their sum (base saturation) are illustrated in Figure 3.

Optimal base saturation for moderate to high yield environments is often considered to be 80% to 95% of the cation exchange capacity or exchangeable nutrient complex of a soil. Individually, the optimal saturation for potassium is two to five percent, magnesium is 12 to 18 percent, and calcium saturation is 65 to 75 percent. Our data shows very clearly that all three of the base-forming cations are among the major factors limiting crop yields. Calcium is severely deficient at all depths (10% to 30% saturation, much lower than the optimal of 75%). Magnesium is also deficient , only 6% to 13% rather than the optimal of 18%. Potassium is deficient, but should be much more practical and affordable to remediate with moderate application rates of deep-placed potash or potash fortified compost.

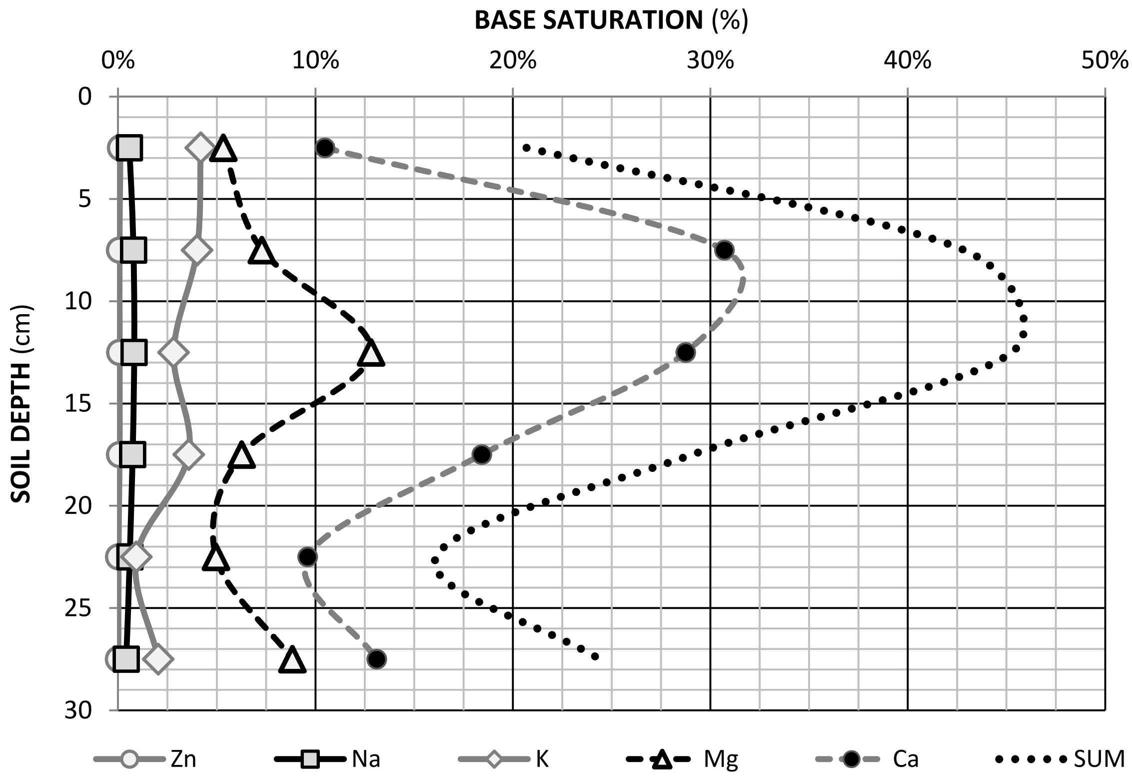

Figure 3. Base Saturation. Extractable base-forming cations relative to the cation exchange capacity of the soil. SUM represents the total base saturation at each of six depth increments, from 5 cm to 30 cm.

We can use this information to approximate nutrient needs for crop production. By transforming the nutrient saturation data into a theoretical nutrient optimum we calcuate that calcium is a seriously limiting nutrient. Magnesium and potassium are also limiting, although at a much lower state than calcium (Table 2). Potassium levels can be elevated with relatively minor applications of mineral fertilizers, e.g., POTASH (0-0-50, K or 0-0-60, K_2O). Magensium levels can be elevated with more significant applications of a sulfur-based mineral fertilizer, e.g., epsom salts (0-0-0-9.1Mg -14S). This may not the case for calcium, where exceptionally high rates of a sulfur-based mineral fertilizer, e.g., GYPSUM (0-0-0- would be needed to sustain moderate to high grain yields. Examples of fertilizers and application rates for base cations are provided in Table 2.

Table 2. Calcium, Potassium and Magnesium supplements, theoretical needs. The range of nutrient additions for moderate to high yield environments are based on theoretical optimums relative to base saturation of the soil cation exchange complex (CEC). The corresponding fertilizer application rates are presented as metric tons per acre (MT/A) or kilograms per acre (kg/A).

THEORETICAL NEEDS	CALCIUM (kg/acre)	GYPSUM ($CaSO_4$)	POTASSIUM (kg/acre)	POTASH (0-0-60)	MAGNESIUM (kg/acre)	EPSOM SALT ($MgSO_4$)
MINIMUM	4816	22.8 MT/A	16	27 kg/A	33	362 kg/A
MAXIMUM	5564	26.7 MT/A	165	275 kg/A	186	2.0 MT/A

SULFUR (S)

Sulfur is a plant essential nutrient that is used by the plant to form proteins, oils and various amino acids. Both grain and oil seed crops benefit by applications of sulfur fertilizer. It has been shown that for each kilogram of sulfur applied to an oilseed crop, the edible oil content will increase by 3.0 to 3.5 kilograms. When sulfur is not readily available in soil, all crops benefit from applications of sulfur-based fertilizers. The typical range of sulfur application rates is 8 to 16 or 20 kg of sulfur per acre (refer to Table 3).

Sulfur-based fertilizers can also include plant essential nutrients such as calcium (gysum), magnesium (Epsom salts), potassium, and various micronutrients such as zinc and copper. We should consider these nutrient as well as sulfur when making our fertilizer selection decision. Examples of nutrient application rates are presented in Table 3.

Table 3. Sulfur-based fertilizer application rates with amounts of additional nutrients provided (kg/acre).

SULFUR (kg/A)	GYPSUM ($CaSO_4$)	CALCIUM (kg/acre)	EPSOM SALT ($MgSO_4$)	MAGNESIUM (kg/acre)
10	58.8 kg/A	12.9	71.4 kg/A	6.5
15	88.2 kg/A	19.4	107 kg/A	9.8
20	117 kg/A	25.9	143 kg/A	13.0
25	147 kg/A	32.4	179 kg/A	16.3

If we were to follow the theoretical guidelines proposed in Table 2, sulfur application rates would become excessively high. Rates of sulfur applications resulting from the suggested theoretical rates in Table 2 are presented in Table 4. As we can see, the sulfur application rates become excessively high, and could potentially damage the crop and cause additional environmental damage.

Based on these observations, it follows that one could effectively apply one half the theoretical minimum rate of Epsom salts for each growing season without exceeding a reasonable rate for sulfur. This means that one could apply 180 kg/A Epsom Salts (25 kg sulfur per acre) per growing season to achieve the nutrient needs for both sulfur and over of period of three to four growing seasons, magnesium as well. This solution does not address the serious issue of calcium deficiency.

Table 4. Effect of theoretical rates presented in Table 2 on sulfur application rates.

THEORETICAL NEEDS	GYPSUM ($CaSO_4$)	SULFUR (MT/A)	EPSOM SALT ($MgSO_4$)	SULFUR (kg/A)
MINIMUM	22.8 MT/A	3.73	362 kg/A	50.8
MAXIMUM	26.7 MT/A	4.30	2.0 MT/A	286

CALCIUM (Ca)

Calcium is required in relatively large quantities by crops. Calcium is severely limiting at this location. During my travels and visits to various farms in and around Iganga, I noticed what appeared to be calcium deficiencies – in crops, fruit trees, and even poultry. Our soil analysis data confirms this to be a real issue. In Figure 4 I show calcium needs by 5-cm soil increment, from 0 to 30 cm. Calcium needs vary with depth, with the lowest needs at a depth of 5 to 10 cm, and highest at a depth of 25 to 30 cm. Total calcium amendment needs for this site range from 4.8 metric tons per acre to 5.6 metric tons per acre. Clearly, this is a daunting problem that imposes a significant limitation on production, which ultimately filters throughout the community by delivering calcium deficient grain to the consumers.

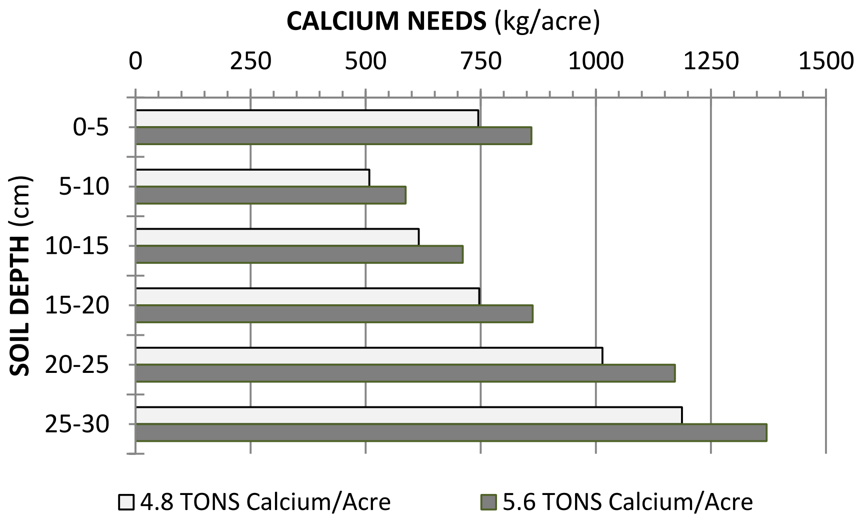

Figure 4. Calcium needs for each 5-cm increment to 30 cm depth – based on calculations an assuming optimal calcium base saturation range of 65% (light colored bars) to 75% (dark colored bars) of soil CEC.

We showed in Table 4 that GYPSUM may not be an appropriate product to use for amending serious calcium deficiencies. We also know that calcium carbonate (agricultural lime) requires thorough incorporation into a soil because it is not water-soluble and is quickly bound to soil particles. GYPSUM is water soluble and does not readily bind with soil particles. Use of this material allows both sulfur and calcium to migrate deep into the root zone.

The deficient calcium status of Iganga soils is a daunting challenge that farmers alone may not be able to rectify. Because of the numerous and obvious implications of a severe deficiency of calcium, focus should be directed to further evaluation of soil conditions across this region and others across Uganda. This effort should be coupled with a thorough examination of alternative calcium deficiency remediation techniques and options. Government and NGO-assisted intervention would be very appropriate and necessary for developing a distribution network for remediation products, e.g., gypsum and lime stabilized biosolids, plus a system of subsidies to defray costs for farmers and human waste treatment facilities.

POTASSIUM (K) AND MAGNESIUM (Mg)

Magnesium and potassium levels as indicated by soil testing for this location will sustain low to moderate grain yields. Over time when soil health improves and grain yields rise to match those of a high yield environment, both magnesium and potassium levels will need to be amended using mineral fertilizers or potassium fortified compost. In Figures 5 and 6, we illustrate theoretical potassium and magnesium needs by 5-cm depth increment to 30 cm.

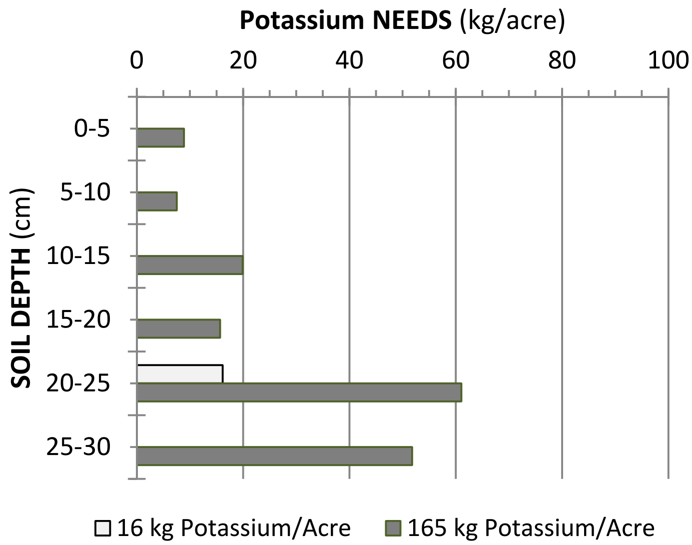

Figure 5. Potassium needs (kg/Acre) for a moderate (open bars) and high (filled bars) yield environment.

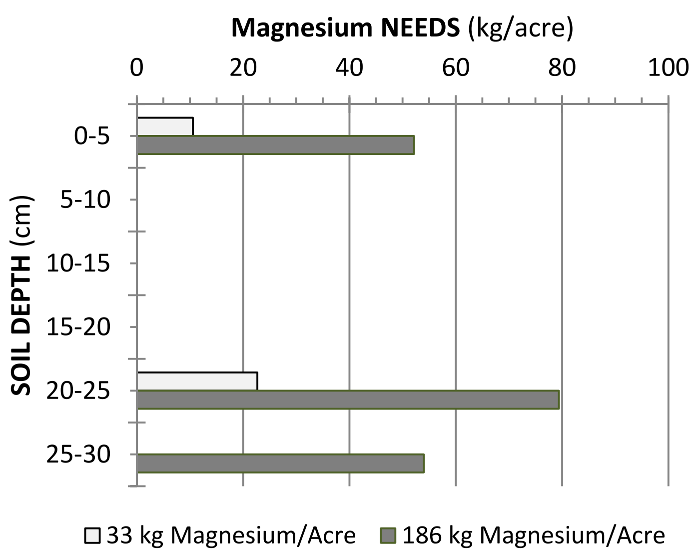

Figure 6. Magnesium needs (kg/Acre) for a moderate (open bars) and high (filled bars) yield environment.

PHOSPHORUS (P)

Soil test results for phosphorus are illustrated in Figure 7. Plant available phosphorus (BRAY P1) levels are above the typical minimum threshold of 20 ppm to a depth of 15 cm. For climate conditions that provide timely rainfall or irrigation from planting through grain fill, no phosphorus fertilizer need be added to the soil.

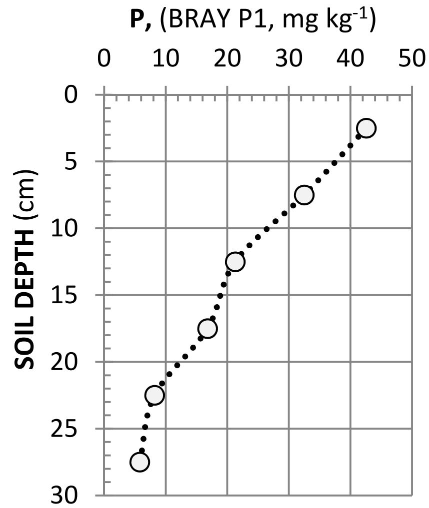

Figure 7. Soil test phosphorus, BRAY

Plant available phosphorus below 15 cm is lower than the typical minimum threshold of 20 ppm. Our profile nutrient analysis confirms that farmers may benefit by altering the practice of applying phosphorus (DAP) at a depth of 15 cm. Due to recent changes in the reliability of precipitation patterns, farmers should increase placement depth of DAP from 15 cm to 25 cm or 30 cm. Also, because of the acid soil conditions, DAP should be applied as a nugget or tight cluster of fertilizer granules. Blending DAP into an acid soil will severely decrease the application efficiency of DAP and other phosphorus fertilizers.

LOGIC. At this site, high phosphorous will promote aggressive root proliferation in a relatively shallow zone from the soil surface to about 15 cm. The combined effect of vigorous root proliferation (biomass accumulation) and a sandy soil texture with low water-holding capacity will cause the upper 15 to 20 cm of soil to dry out very quickly. Without timely rainfall or irrigation, nutrients in the upper 15 cm will not be available for plant uptake during pollination. When the soil is dry, roots are unable to extract nutrient.

Because phosphorus levels are very low (< 10 ppm) at the depth of 25 to 30 cm, deep-placement of DAP as a nugget or tight cluster of fertilizer pellets will effectively promote deeper root proliferation. The added benefit of deep placement DAP is the increased probability that roots of a pollinating crop will retain access to soil moisture reserves that can reside deeper in the soil.

Recall that clay soil can hold more water than sandy soil, and that the cation exchange capacity of a clay soil is much higher than that of a sandy soil low in organic matter. Clay soil at this depth is more closely associated with subsurface clays and stored soil water. Typically, clays dominate soils in deeper profile positions. Water that is held deeper in the soil will wick or migrate up into a clay soil. This is referred to as capillary motion. Conversely, water is not able to wick freely from a soil layer with ample clay to up into soil layer high in sand. This problem may be effectively eliminated or minimized when a sandy soil layer is amended with a very mature compost. Compost will provide humus. Humus and decomposing organic matter can effectively wick water from a clay soil below.

Always maintain a thick soil cover to minimize loss of soil water through evaporation. Soil cover will shade the soil. Soil cover will help to cool the soil. A cooler soil loses less water through evaporation. This means that more soil water will remain available for the plant. More soil water for the plant translates into more sugar production in the leaves. More sugar production in the leaves, especially during and after pollination will result in higher grain yields, higher oil yields and higher crop quality.

MICRONUTRIENTS (Zn, Cu, Fe, and Mn)

Zinc and copper levels are adequate to sustain moderate crop yields. Iron and manganese levels are very high to excessively high. High levels of manganese and iron are known to bind with phosphorus rendering it unavailable to the roots of most crops (Figure 8).

High concentrations of iron have been implicated in a condition that promotes cementing of clay particles. Apparently, clay particles that are surrounded by iron ions under moist soil conditions will form a concrete-like structure upon drying. In some soils, this hardened material becomes hydrophobic – resists absorption of water. One proven method for remediating this condition is the generous use of highly decomposed compost. Humic substances will flow into the clay soil and chelate or form a bond with iron (also aluminum and manganese) and thereby minimize the formation of a concrete-like layer.

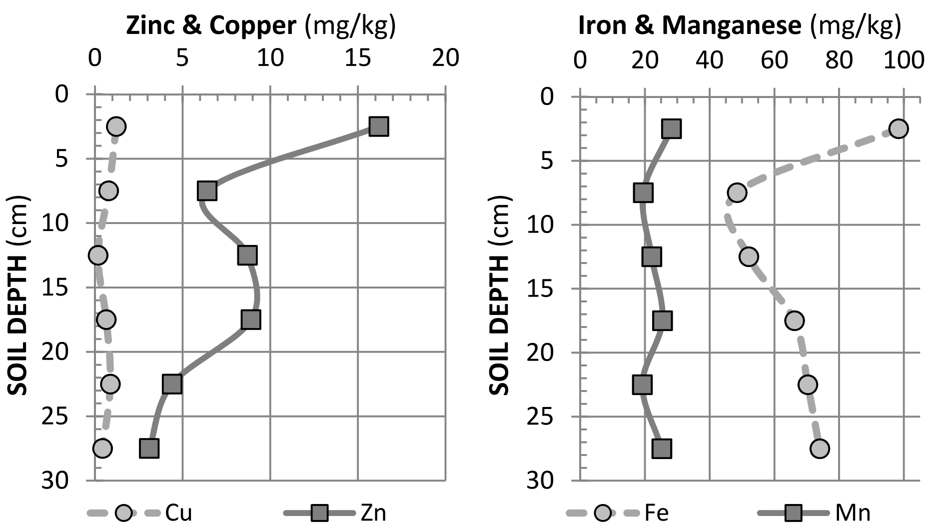

Figure 8. Micronutrient status.

MINERAL NITROGEN (NO3-N, NH4-N)

This test results is typical for a dry soil condition (Figure 9). With the onset of rains, the nitrate forms (associated with higher soil organic matter, Figure 2) will flow with water, attaching to exchangeable bases (Ca, K, Mg) and leach to lower soil layers. Nitrate-N will migrate down to the sandy clay loam soil at 15 to 30 cm or deeper if a significant inundation of rain precedes active plant development. Conversion of ammonium-N to nitrate-N will further acidify this soil. The soil high in sand will acidify more rapidly than a soil higher in clay. In our example, we can assume that the effect of the conversion from NH4 to NO3 will have a larger impact on soil pH in the upper 15 cm than below. It is worth noting that long-term effects of applying UREA fertilizers will cause similar effects, especially when a full rate of UREA (50 to 100 kg/acre) is not split applied, but applied as a single application. If a single application of UREA is consistently applied from season to season, the probability of losing nitrate-nitrogen through leaching will remain high. This translates into 1) loss or migration of base cations (Ca, Mg and K) to lower soil profile positions, 2) more soil acidification, especially the upper 15-cm, sandier phases of soil, and 3) loss of crop yields and money.

SOIL ORGANIC MATTER AND ORGANIC NUTRIENTS: N, P and S

The content of organic matter as oxidizable carbon provides a measure of carbon that reacts or exchanges minerals and other plant nutrients. This form of carbon may be readily available to bacteria, fungi and other decomposers in the soil.

Soil organic matter forms as above-ground plant parts and roots decompose. Over time, while soil moisture and temperature conditions favor microbial activity, microbes and soil fauna feed on plant residues. As microbes feed on plant residues, the plant materials are converted into various forms of organic matter and humus. As microbes and other larger soil fauna complete their life cycle, they too decompose and become part of the soil organic matter complex.

With conventional farming systems, soil organic matter and the associated organic nutrients tend to accumulate near the soil surface. In Figure 10 we see that soil organic matter and associated nutrients are most abundant near the soil surface, but quickly decrease with increasing soil depth. Recall that soil organic matter improves a soil's ability to absorb and hold water – and improves a soil's ability to retain nutrients in a form that is generally available to plant roots. Our soil test results provided data for phosphorus and nitrogen, but not for sulfur. Sulfur concentrations also closely follow soil organic matter concentrations. This is because proteins in plant tissues are made of molecules that contain large amounts of carbon, nitrogen, phosphorus and "sulfur".

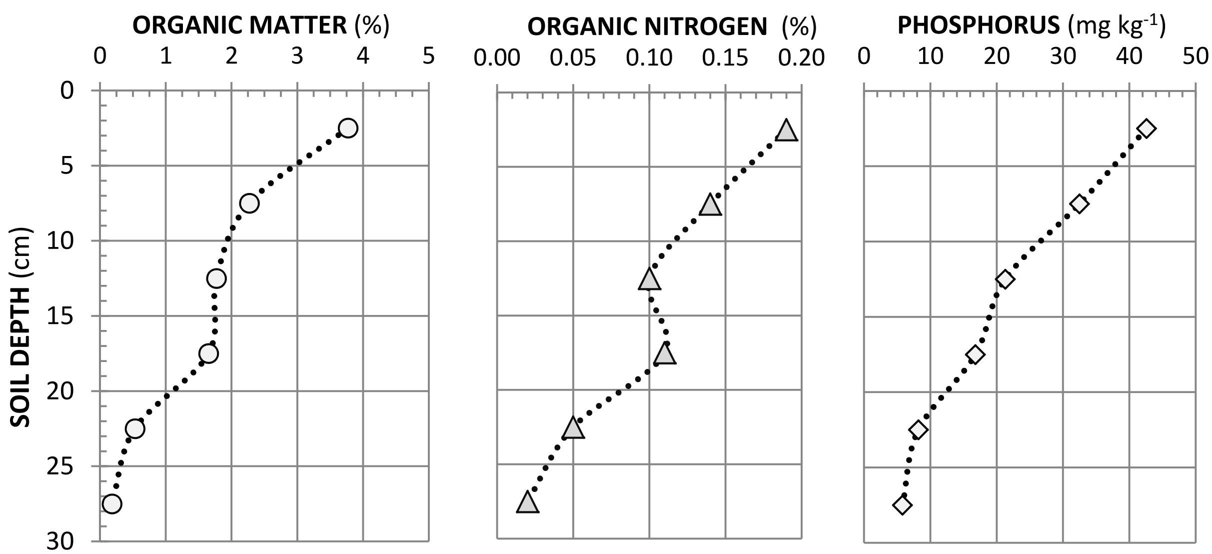

Figure 10. Soil Organic Matter (SOM), Organic Nitrogen (ON) and Phosphorus (P) by soil depth (0 to 30 cm).

What can we do to improve the soil organic matter status of soil at depths below ten centimeters?

1) Deep placement of DAP will promote prolific root development deeper in the soil. As these roots decompose, organic matter will form deeper in the soil.
2) Apply compost deeper in the soil. Poke or jab holes into the soil to a depth of 25 to 30 centimeters. Fill the holes with compost and cover with soil and plant residues.
3) Maintain a thick soil cover to protect organic matter. Energy from the sun will oxidize humus and organic matter, releasing it to the air by returning it to its original form … carbon dioxide and water.

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Department of Agricultural Production

SOIL ANALYSIS RESULTS

6 Soil Samples From Catholic Relief Services
c/o Wayne Thompson

Laboratory Analysis

The air-dried soil sample was pounded, sieved through 2 mm to remove any debris then subjected to physical and chemical analysis following standard methods described by Okalebo et al. (1993). Soil pH was measured in a soil water solution ratio of 1:2.5; Organic matter by potassium dichromate wet acid oxidation method; total N determined by Kjeldhal digestion; Extractable P by Bray P1 method; exchangeable bases from an ammonium acetate extract by flame photometry (K^+, Na^+) and atomic absorption spectrophotometer (Ca^{2+}, Mg^{2+}); and particle size distribution (texture) using the Bouyoucos (hydrometer) method.

Routine Analysis

Sample Ref:	pH	OM	N	P	K	Na	Ca	Mg	%Sand	%Clay	%Silt
		%age		ppm	cmoles/kg				Texture		
BU0005	6.2	3.77	0.19	43	0.88	0.12	2.2	1.1	70	14	16
BU0510	5.6	2.27	0.14	33	0.56	0.11	4.3	1	61	10	29
BU1015	5.7	1.77	0.1	21	0.45	0.13	4.6	2.1	63	19	18
BU1520	5.6	1.65	0.11	17	0.68	0.14	3.5	1.2	50	31	19
BU2025	5.5	0.53	0.05	8.2	0.23	0.15	2.4	1.2	54	30	16
BU2530	5.4	0.18	0.02	5.8	0.59	0.12	3.8	2.6	51	32	17

Sample Ref:	NH_4-N	NO_3^--N	Cu	Zn	Fe	Mn	CEC	Al
	mg/kg						cmoles/kg	
BU0005	5.3	19.2	1.22	16	98.4	28.2	21	
BU0510	3.2	11.1	0.78	6.4	48.5	19.5	14	
BU1015	2.2	14.1	0.18	8.7	52.1	22.1	16	
BU1520	1.2	2.2	0.65	8.9	66.2	25.4	19	
BU2025	1.1	4.1	0.88	4.4	70.3	19.2	25	
BU2530	1	3.1	0.44	3.1	74	25.2	29	

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