Production and harvest/post harvest operations of the banana industry

Under Chemonics' contract agreement with the U.S. Agency for International Development (USAID) to Haiti for the provision of plantain technical assistance and related services.

Sponsoring USAID/HAITI Office: Haiti

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I. Introduction

Plantain is an important staple food in Haiti. Per capita consumption is about 22 kg per year, and in rural production zones consumption exceeds that with up to 60 kg per person per year. With annual production of 270,000 tons, Haiti is one of the main countries producing plantains in the Latin America-Caribbean region. The French plantain (musquée) grown in Haiti is a special casebecause cultivation is concentrated mainly in the alluvial coastal plains. The Arcahaie plain is the main production zone. Port-au-Prince (population 2,100,000) is the main consumption center. (Lescot and N'Guyen 1998).

The fruit is an important source of carbohydrates, vitamins, proteins, potassium, iron, calcium, carotenes and ascorbic acid and also contains moderate amounts of thiamine, riboflavin, nicotinic and folic acid (Rasheed 2003). Plantains therefore play a key role in the economy and food security of Haitians.

In Haiti, Arcahaie is a region known for its production of bananas. This supplies nearly 25% of domestic production and over 60% of consumption in Port-au-Prince. The Arcahaie region is a coastal plain at the foot of the Matheux chain in the far north-west, crossing the country from east to west and leading to the plain of the Cul-de-sac. Near the capital (less than 40 Km), the soils are deep with good water holding capacity. Irrigation systems allow agriculture within the limitations of a semi-arid tropical climate.. This region specializes in banana: over 70% of the cultivated area is devoted to this crop, alone or in combination. An important part of this production is sold in local markets and then transported to Port-au-Prince (Fréguin 2005).

Field losses of plantain have been relatively large, especially for the second growing cycle. These losses are due primarily to weather conditions (wind and drought), but also to water shortages (especially in the dry season), strong soil pests (mainly nematodes), Black Sigatoka, and poor nitrogen availability. These factors have resulted in the reduction of the bunch weight and main periods of culture for the plants from that are four to five years old and two years old.

Plantains require high amounts of nutrients for optimum growth and fruit production, but these nutrients are often supplied in part by the soil (Lahav 1995). Since the soil in Haiti lacks the necessary nutrients, the difference has to be supplied from external sources.

External inputs of nutrients could either be organic materials (such as animal waste, which is mostly in the form of feces, compost manure and farmyard manure) or inorganic fertilizers. Animal manure is a source of nutrients and organic matter, which could improve soil bio-physical conditions (Munoz *et al*. 2004) for sustainable food production. Poultry manure increases soil pH, organic matter content, available phosphorus, exchangeable cations and micronutrients, as well as reduces soil salinity and extractable ions (Jinadasa *et al*. 1997).

USAID/HAITI is helping farmers improve their techniques in order to intensify plantain production, and is helping to increase the capacity of the Haitian agricultural sector through theoretical and practical training on combating Sigatoka, fertilization techniques, harvesting techniques and planting. At the same time, the WINNER project's use of demonstration plots and testing improve the production system through increased yield and protection of the environment.

II. Tasks

The consultant completed the following tasks:

2.1. Theoretical training on combating Sigatoka, fertilization techniques and planting

According to the list of participants, 54 people attended two days of theoretical training (May 14 and 15) on combating Sigatoka, fertilization techniques, and planting.

2.1.1. Theoretical training on combating Sigatoka

Participants were shown the how to combat black Sigatoka. They could observe the damage of the fungus that causes the disease, the fungus life cycle, factors that favor its development, the evolution of symptoms, and some management practices to reduce the severity of the damage to plants.

Black Sigatoka is caused by an airborne fungus called *Mycosphaerella fijiensis* Morelet. The life cycle of *M. fijiensis* (anamorph *paracercospora fijiensis*) is characterized by two phases: one perfect phase and another imperfect. Both play an important role in host infection. The life cycle of M. fijiensis consists of two phases which are the asexual and sexual phase, in which the fungus reproductive structures are implicated in the spread and infection or interaction with the host plant. The epidemiology of black Sigatoka is influenced by climatic factors (Pérez *et al*. 2006), among others. The patterns of temperature and humidity (the number of hours the leaf surface remains wet) determine its severity. Mourichon and Zapater (1990), suggest that the disease has a seasonal dynamic determined by variations in temperature and rainfall throughout the year.

Arcahaie is located on the northwest edge of the plain of cul-de-sac in the Gulf of Gonave. It has a climate characterized by rainfall between 600 and 1000 mm/year, concentrated between April and October, and high evaporation (2000-2500 mm per year) almost always more than twice of the rain. There are two seasons: a dry season from late November to mid-April, and a rainy season, from April to November (80% of rainfall). The average annual temperature is 24.7°C and altitude varies between zero and 50 meters above sea level, depending on the coastal and alluvial plains.

Arcahaie, Cabaret and Montrouis have a dry subtropical climate with a precipitation rate less than or equal to 60 mm between the months of November to March. One might expect that in these weather conditions (a reduction in rainfall) the severity of black Sigatoka attack would decrease from November to March. However, as there is no type of pest management, there are high rates of infection occurring in this period; we expect a gradual increase in severity of illness onset, from the beginning of the rains in April. Temperature does not limit the development of disease throughout the year.

In general, management of black Sigatoka depends on the pressure exerted by the fungus. It must be approached through the development of technological packages, which are a recommended set of agricultural practices that describe all stages of production, e.g. soil preparation, crop planting, pest and disease management, soil fertilization, and harvesting and packing methods.

The WINNER project has a group of technicians that knows how to conduct the phytosanitary survey with the Stover method modified by Gauhl (Figure 1), and thus let the producers know phytosanitary status of the plantation. This activity can motivate the producer to use techniques to control black Sigatoka control through leaf pruning and surgeries each eight to ten days to reduce the sporulation of the fungus.

Figure 1. Haitian technicians put into practice the phytosanitary survey with the Stover method modified by Gauhl.

The most important practice in reducing the infection source of black Sigatoka is removal of affected leaves or portions thereof. Early pruning of the tips of young leaves (before submitting spore injury) and rapid clearance of harvested plants can reduce the inoculations (Orozco *et al*. 2008). Strategies to control black Sigatoka disease can, according to the country and the scale of production, include not only chemical and cultural practices, but also the use of mixed crops or resistant clones. Some natural substances derived from plants and microorganisms antagonistic to fungi have also been reported as effective in reducing the development of *M. fijiensis*.

In Haiti there is a small array of chemical or acceptable products for the control of Sigatoka. A mixture of two pounds of calcium plus one pound of sulfur, diluted in 20 liters of water (this is enough to apply to one hectare) can be used as an alternative. Extract of *Melaleuca alternifolia* (trade name Timorex) to 0.5 liters/ha of the commercial product can also be used.

2.1.2. Fertilization techniques

According to Fréguin (2005), the flood plain is about 60% of the area of Archaie and extends between 10 and 50 meters. It is formed on river alluvium, which has resulted in relatively deep brown soils. Though the texture of these soils can be rocky (medium to fine), their water holding capacity is more or less good. The soil is constantly rejuvenated by new inputs (siltation, runoff, irrigation). The organic matter content is moderate. It is decreasing due to cultivation with insufficient returns of organic matter in relation to exports.

Soil which is supplied with organic fertilizer has more than enough nutrients in the form of nitrogen, phosphorus and potassium, which are essential for plant growth (Khaliq *et al*. 2005). The improvement of fertility and quality of soil, especially under low input agricultural systems, requires the input of organic materials. Besides that, the effect of organic nutrients on crop yields is long term and not immediate. Thus farmers are reluctant to use organic fertilizer in their cropping system (Arshad *et al*. 1992).

The area in Archaie has been converted into irrigated land. It is the preferred area for growing. The biggest crop in the area is plantain (70 to 80% of the cultivated area). Farmers combine multi-year plantain plantations (plantation period of 2-3 years) in rotation with food crops (cassava, maize, beans, peas) or gardening (tomato, eggplant). The plots are fitted with racks holding irrigation water.

***2.1.2.1 Farms* selected for plantain fertilization recommendations**

The farms selected from the WINNER database were those that have banana as a principal crop. The principal culture was defined as the primary crop by dollar value grown on the farm (Hylkema 2011). From the soil-analysis database of farm sites within the Archaie/Cabaret area, 256 farms were identified. The relations between Calcium (Ca), Magnesium (Mg) and Potassium (K) were calculated from the Laboratory analysis report. The relations were Ca/K, Ca/Mg, Mg/K and Ca+Mg/K.

In interpreting the results of soil analysis it is important not only take into account the absolute elements contents, but it is also necessary to observe the equilibrium relationships between them. If the plant contents of any one of these nutrients is high in comparison to the other, this condition causes problems in bananas growth (López and Espinosa 1995).

Geographic Information Systems (GIS) map layers were developed from the soil fertility analysis results by GIS specialists affiliated with the WINNER project. In general the results for NPK and pH were as follows for plantain recommendations:

2.2.1.2 Nitrogen (N)

Nitrogen was the limiting nutrient for most soils in Archaie, Cabaret and Montrouis zones. Figure 2 illustrates soil N content ranging from low (<10 ppm), medium (10-20 ppm), high (20-30 ppm) to excessive (>30 ppm). The amount of N in soil, available for plantain, is relatively small. For this reason, this nutrient should be supplemented by the regular fertilization programs.

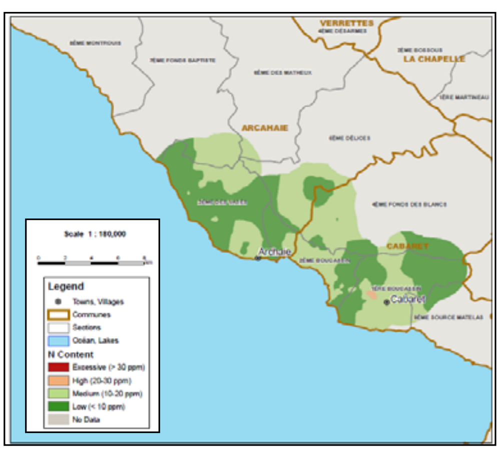

Figure 2. Soil N content in the Archaie, Cabaret and Montrouis zones.

2.1.2.3 Phosphorus (P)

For the regions, approximately 35% of soils (89 of 256) had sufficient M-3 P concentrations (> 20 ppm) while 65% of samples (167 of 256) had M-3 P that were below (< 20ppm) method detection limits (Figure 3). Phosphorus fertilizer applications would be recommended for approximately 65% of the soil sampled. In the map this is shown by the zones with dark green color. Plantain requirements to P element are very low (10 to 40 ppm), and extraction by low mobility of the element in the ground, but is very important within the plant (Simmonds 1973). When checking for the availability of P, one must take into account that high calcium and pH around 7 are conditions for calcium insolubility (Barrera *et al*. 2008). The Phophorus and the calcium content are high for all samples.

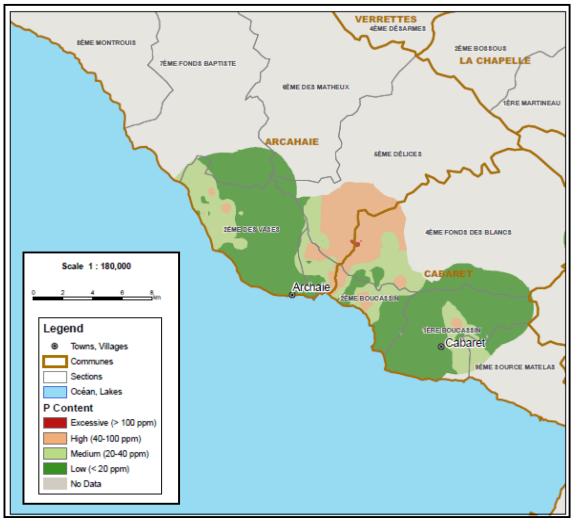

Figure 3. Soil P content in the Archaie, Cabaret and Montrouis zones.

2.1.2.4 Potassium (K)

According to M-3 soil-test results, 100% of soil samples (256) were sufficient in K (Figure 4). The lower K concentrations were 148.95 ppm, and signify excessive levels for plantain. This finding can be attributed to centuries of fertilization creating K build-up in soils (Hylkema 2011). These findings imply that the response of banana to K fertilization is unlikely. Consequently, the recommendation would be to apply moderate amounts of potassium to maintain these levels in soil.

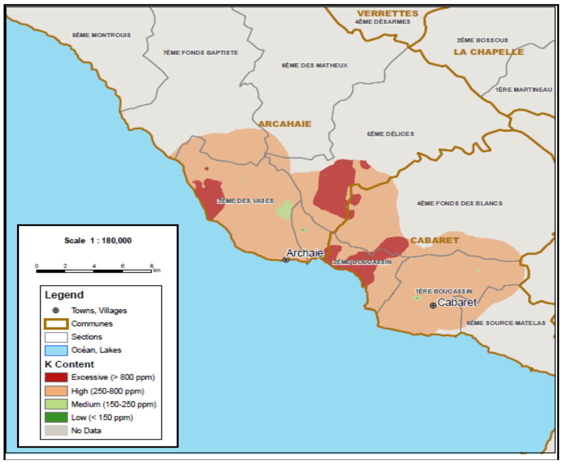

Figure 4. Soil K content in the Archaie, Cabaret and Montrouis zones.

2.1.2.5 Soil reaction (pH)

Soil pH (1:2 soil to deionized water ratio) was determined. According to this, 100% of soil samples (256) are above the range of pH (5.5 - 6.5) which is optimal for the development of plantain. The minimum value is 6.70 and the maximum 7.98 (Figure 5). Soil pH is an important property from the point of view of the application of fertilizer. If the pH is acidic, losses are large, while, if the pH is neutral, losses can be null. One important property of fertilizers and principles of fertilizer application which users should become familiar with is water solubility (Valarini *et al*. 2002). Water solubility indicates how much of the fertilizer will dissolve in water. Most nutrients are taken up from the soil solution by the plant; therefore, if a fertilizer will not dissolve in the soil solution, it will probably not be an effective fertilizer (Westfall and Gangloff 2004).

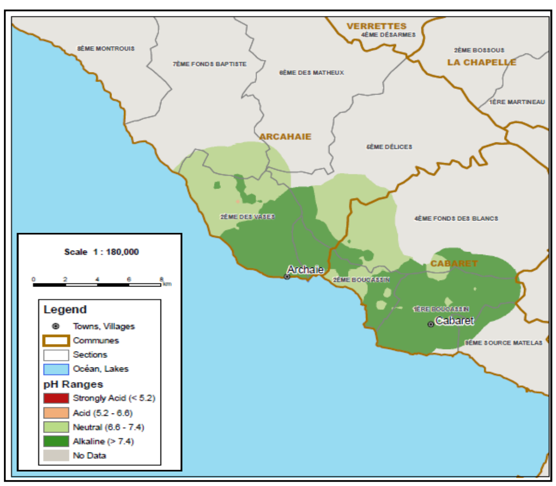

Figure 5. Soil pH in Archaie, Cabaret and Montrouis zones.

2.1.2.6 Generalities on fertilization

Nutritional imbalances can be reduced with the addition of chemical fertilizers. However, fertilizers are now costly inputs for low-income producers and they are not available in many regions (López and Espinosa 1995). Efficient and rational use of the fertilizers is imperative not only for obtaining more yields per unit area on a sustainable basis, but also to ensure safe food and to conserve the environment.

Sustainability is the most important aspect in all the proposed systems for alternative soil management. According to Hansen and Jones (1996), sustainable agriculture is “the ability of farming systems to continue into the future”. Sustainable agriculture has multiple-dimensional characteristics that include economic, environmental and social aspects (Pretty and Hine 2001). In sustainable agriculture, organic farming is being promoted due to the positive environmental, social and economic impacts (Legg and Viatte 2001). Bananas and plantains, when grown in perennial production systems, maintain soil cover throughout the year. If their biomass is used for mulch, soil fertility and organic matter remain stable (Frison and Sharrock1998).

Cayón *et al*. (1992), determined that the plantain requires a minimum of 7 to 10 functional leaves in order to grow and develop fruits. Fertilization is one of the factors that takes part in the good growing and development of these leaves, and is essential in ensure good yields (Bhamgo and Karon 1962).

Based on results of soil analysis, the application of fertilizer is generally recommended. This is a restricted diagnostic tool because the nutrients concentration in vegetables could be 10 and 1,000 times higher than the concentration of the external environment medium (Salisbury and Ross 1994). In many cases, the use of fertilizer is evident as there are visual symptoms that show its deficiency on plants. The use of conventional doses is inefficient, wastes fertilizer, and does not take into account the real requirements of extraction of nutriments and the growing stages of the crop. Each leaf and the parts of one plant represent the investment of resources in the physiological processes. For the plantain crop, its growth depends on the development of its foliar area (Gutiérrez 1997).

2.1.2.6.1 Nutrient losses

Top Soil, indigenous, and fertilizer nutrients that are not taken up by the plantain crop or absorbed into soil particles are dissolved and lost through surface runoff, volatilization, denitrification, or leaching. Absorbed nutrients may also be lost in eroded soil and sediments.

Losses are more pronounced at particular phases in the life of a plantain plantation. The potential for nutrient losses is probably greatest immediately after land-clearing when the soil surface is exposed to erosion and uncontrolled surface runoff losses before legume cover plants (LCP) have been established. Losses can be great when large amounts of nutrients such as potassium (K) are released when the standing biomass (e.g. fronds, trunks) is burned during plantation development.

The other period when the risk of nutrient losses is high occurs when ground vegetation is sparse due to poor light penetration through the closed plantain canopy. At canopy closure, the LCP dies off and a large amount of nitrogen (N) is released from the decomposing LCP biomass. Unless plant growth is vigorous, losses of mineralized N due to leaching are likely to be large.

Nutrient losses are more pronounced in areas of the plantation where steep topography and inadequate soil conservation measures result in erosion and uncontrolled surface wash.

Clearly, a proper assessment must account for these temporal and spatial aspects of the potential for nutrient losses.

Leaching losses are more prevalent in coarse-textured soils in high rainfall or excessive irrigation water application areas where large fertilizer application rates are required but fertilizer recovery efficiency is poor. Nitrogen may be lost to the atmosphere due to volatilization but, as we shall see, N fertilizers differ in their susceptibility to volatilization losses, which are also affected by the field conditions when the fertilizers are applied.

The deterioration of the banana root system and its effect on production is due to climatic, edaphic (physical and chemical) and biological factors. There are two kinds of root deterioration processes: 1) a fast one with accelerated collapse of the root system (days to months) due to site specific characteristics (limited effective depth of soil, very high sand, gravel or clay content, high water table, and high soluble salt and sodium content); and 2) a slow and gradual collapse due to the degradation of soil physical and chemical conditions, deterioration of soil biological activity, inefficient drainage (design, construction, management and maintenance) and poor crop management practices (disease control, nematodes, insects and weeds).

2.1.2.7 Plant analysis as a diagnostic tool for banana nutrition management

Plant analysis has been considered a very practical approach for diagnosing nutritional disorders and formulating fertilizer recommendations (Self 2012). Plant analysis, in conjunction with soil testing, becomes a highly useful tool, not only in diagnosing the nutritional status, but also an aid in management decisions for improving crop nutrition. Plant analysis is the quantitative analysis of the total nutrient content in a plant tissue, based on the principle that the amount of a nutrient in diagnostic plant parts indicates the soil's ability to supply that nutrient and is directly related to the available nutrient status in the soil (Rashid 2005).

For plant analysis, a specific plant part at a particular growth stage should be sampled because comparison of an assay result with established critical or standard values or sufficiency ranges is used to interpret analytical results (Rashid 2005). Samples are taken from three leaf parts at different positions on the plant (Figure 6), are taken either just before or following floral emergence, and when all parts are visible. Besides the stage of sampling, it is important to obtain a sample that will represent the plantation. In an average crop, a representative sample can usually be obtained from 20 plants at a given stage of growth.

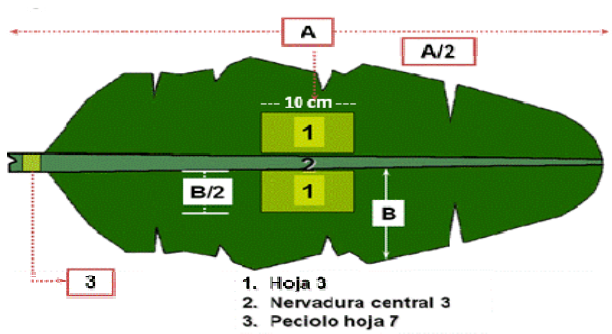

Figure 6. Tissue to be sampled in plantain.

The sampling method includes three parts of different leaf position in the plant.The laminar structure of the leaf is sampled by extracting a strip of tissue 10 cm wide (A), on both sides of the central vein (1), and discarding everything but the tissue that extends from the central vein to the center. Sampling the midrib (2) also takes a section of 10 cm in length towards the center of the leaf. The sample of the leaf petiole 7 (3) is taken from near the base part of the leaf so as not to obtain too much sample (Lopez and Espinosa 1995).

Estimation methods and doses of amendments

The conceptual model to estimate the fertilization rates in crops, whose bases are in the balance between the nutrient demand of the crop (DOC) and supplying within the soil (SOS), so that if the demand is greater than the supply will produce a nutrient deficit, which requires supplement with fertilization. When demand is lower than supply, apply a maintenance dose to maintain soil fertility and crop yields, based on agronomic criteria and experience local, regional or national. In these terms, the fertilization rate (FR) is defined by this demand and supply, and the efficiency of use of fertilizer by the crop (EF), as only part of the nutrient applied is taken, finally has a model for calculate the fertilization rate, as summarized in the following equation:

FR = (DOC-SOS)/EF

2.1.3. Theoretical plantain planting

The soils used to plant bananas should be predominantly dark colors, and may determine a high content of organic matter. Soil texture should be average, between sandy loam and sandy clay loam. Loam soils (clays between 7 and 27% and silt 28 to 50%) have a more balanced texture to the smooth conduct of the crop, because they retain water and also allow the diffusion of gases. These are appropriate conditions for the physiological functions of the plant. Textured soils that are suitable include loam, silt loam, silty clay loam, fine sandy loam with good moisture retention (capillary porosity and optimum). Moderate soils have thin textures (less than 60% clay). Unsuitable soils range in texture from very fine to moderately thick.

Plantain is a plant with a rapid growth rate, high consumption of water, shallow and spreading root distribution, roots with weak penetration strength in the soil, poor ability to draw water from drying soil, low resistance to drought, and rapid physiological response to soil water deficit. These factors indicate that banana is sensitive to even slight variations in soil water content, and that irrigation scheduling is critical. The water holding capacity of the soil, effective rooting depth of the plant, and the depletion percentage of total available water allowed before irrigation determine the amount of water to apply. Meanwhile the crop coefficient, together with the evapotranspiration data, determines the irrigation interval.

Once the planting area and planting system are defined, one can proceed to the stroke, which is marked with stakes or lime. The sites will be planted with corms or plants. The recommended system is the triangle or three rolls because there is a better use of land and airspace. It also allows for better adaptation to all types of terrain, and supports more plants per hectare. The planting distance depends on the chosen system. At a distance of 4 m between double rows, one meter between rows, and 1.67 m between single plants, dual stroke in rows, one can obtain a density of 2.395 plants/ha. Another spatial arrangement that allows a high density planting is a double row of 3 x 1 x 2 meters giving a density of 2,500 plants per hectare.

When making the hole for planting banana, physical preparation is essential to the hole, because the roots are very weak and loose soil is needed for proper development. Adding 1 kg of compost mixed with topsoil facilitates the permeability, aeration and root penetration. If possible, waste plant weeds should be placed around those newly planted, in order to increase water infiltration, retain moisture, temperature, and prevent rainwater from splashing.

2.2. Practical training on harvesting techniques

According to the list of participants, 53 people attended two days (May 16 and 17) of training on combating Sigatoka, fertilization techniques, and planting.

Haitian producers and technicians were taught the post-harvest handling practices and forms of transport to preserve quality. Additionally, training addressed how to select quality fruits packed in plastic crates in order to get better prices in a distinct market.

The post-harvest technologies don't create the quality, but instead maintain it. Any investment made by the farmer in the development stage of the crop may be lost to a great extent by mishandling the product during and after harvest. Therefore, it is important to know the product well in order manageit appropriately to maintain quality. Postharvest is concerned with maintaining crop quality until the crop reaches the consumer. This is particularly important for perishable crops which deteriorate rapidly, such as plantain.

The most important physiological processes in harvested plantain fruits are transpiration and respiration. Postharvest improvements aim to slow down these physiological processes. A reduction in the rate of transpiration or respiration extends market life and improves overall fruit quality. Factors affecting plantain ripening can be physiological, physical or biotic. Physiological factors relate to fruit maturity or environmental factors, which affect the metabolism of plantain. Physical factors include mechanical damage, or relate to dimensions of the fruit. Biotic factors include attack from pests and diseases.

Bunches or fruit qualities of plantains are judged by important criteria at all stages in the market chain irrespective of the cultivators (N'da Adopo 1993). Different standards are applied by individuals in the distribution network to assess plantain quality: (1) bunches with well filled fingers and sufficiently round fruits at the time of harvest, (2) fresh fruits without cracks, (3) length of fingers, (4) caliber of the fingers, (5) level of maturity (peel color of the fruits), (6) number of fingers per pack, (7) packaged fruit weight (8) fruits without mechanical damage, (9) well defined orange rose pulp, and (10) fruits without pest or fungal attacks. The fragile and perishable nature of the plantain demand careful handling and transporting to preserve the original fruit quality.

Improved handling and storage methods can be used on farms (as presented in this guide), at loading sites (changing whole bunches by dehanding them), during transport (packing fruits in plastic cages), and at the market. Improved storage maintains fruit quality from farmers' fields to consumers. A major problem for plantain is that the fruits are highly perishable. At ambient tropical temperatures, plantains have an average market life of 1-10 days, compared with several weeks for yam, for example.

The marketing system in Haiti usually involves several retailers. Buying and selling takes time and leads to increased crop damage. Transport is often delayed, and can fail altogether, because of poor conditions of vehicles, and bad conditions of marketplaces and roads. The environment within the market is also not suited to long-term storage. A combination of high perishability, high ambient temperatures, slow marketing systems, and poor market conditions lead to losses in fruit quality, and ultimately, to postharvest losses.

Improved handling and storage methods can be used on farms as shown in Figure 7, at loading sites (changing whole bunches by dehanding them), during transport (packing fruits in plastic cages), and at the market. Improved storage maintains fruit quality from farmers' fields to consumers.

Today there is a supermarket that orders bananas packed in plastic boxes. This system is expected to continue to grow to become a major source of employment and income in the area.

Figure 7. Changing whole bunches by dehanding ones and packing fruits in plastic cages.

2.3. Planting

Most smallholders in many parts of the world to plant bananas still manually perform soil preparation through using hoes. Larger farms use plows and harrows pulled by tractors, which results in the complete inversion of the top 20 to 30 cm of the soil. Hence, ridging is very common all over Latin America, whereas tied ridging is primarily conducted in the semi-arid zones to conserve both soil and water in individual basins.

Erosion has been identified as a critical constraint to agricultural productivity in Haiti (Sánchez and Cochrane 1980, Scherr and Yadav 1997). Soil loss can be prevented or reduced by appropriate crop management, which includes cover cropping, multiple cropping, and high density planting. Covering the soil surface also suppresses weeds. Minimum tillage describes a practice where soil preparation is reduced to the minimum necessary for crop production and where 15% to 25% of residues remain on the soil surface (Morgan 1995).

Cover crops such as the legumes *P. phaseoloides*, *M. pruriens*, *Centrosema pubescens*, *Stylosanthes guianensis*, and *Phaseolus aconitifolius,* or the grasses *Pennisetum purpureum*, *Brachiaria ruziziensis*, and *Paspalum notatum,* are plants that grow rapidly and close (Lal 1995).

Multiple cropping involves different kinds of systems depending on the temporal and spatial arrangement of different crops on the same field (Morgan 1995). Banana planting in double rows (Figure 8) allows another crop in the space between the double rows planted with bananas. However, whatever the crop, it must be managed with its own technical production package.

The seed to establish a plantain plantation may come from different sources: seedlings produced in nurseries, plantlets in vitro produced by tissue culture, planting material from corms (sword or maiden suckers) and corms of harvested plants. The selection of the seed must be made from plants that are vigorous, healthy and with high productivity, taking into account the optimal characteristics of the cultivar.

Figure 8. Plantain planted in double rows.

Producers were encouraged to plant small corms in plastic bags (Figure 9) and have a small nursery of about 100 to 150 plants in case replanting is necessary. These plants can be kept in bags and under shade for up to two months. Using pest and disease free planting material reduces the spread of plant parasitic nematodes and banana weevils. Removal of roots and infested corms prior to planting is effective in reducing the initial levels of nematode and weevil infestation in plantain.

Figure 9. Small corms planted in plastic bags and moistened.

III. Recommendations

Consider, if possible, the Haiti winner Work Plan: October 2011 - September 2012. Section vii. Project level Activities. A. Project Level Activities by Key Results. A1. Increase

Agricultural Productivity. Promote market-driven access to agricultural inputs and seeds. 1.1.6 Provide technical assistance for the development of organic fertilizer.

Description: Given the widespread availability of organic materials (e.g., farm waste, organic solid waste, agro-forestry byproducts), Haiti has potential for the development of the production of quality organic fertilizer. WINNER will work with the assistance of US companies to introduce new techniques for the production of organic fertilizer, including conducting trials with micro-organisms that increase the speed of the composting process. Given the high cost and difficulties of transport of compost, we will facilitate the establishment of composting units near areas of agricultural production. We will also implement demonstration sites of best practices for the production of organic fertilizer at our CRDDs.

Zone:	All regions
Timing:	December 2011 – September 2012
Partners:	Private sector
Responsible staff:	Livelihoods Component Leader
WIF cost:	$50,000

Increasing organic matter content improves the biophysical characteristics of the soil, and makes it more sustainably productive. Thus, manure or compost application may increase soil nutrients and organic matter, with long lasting residual effects on crop yield and soil properties (Eghball *et al*. 2004).

Effective microorganisms (EM) commercial solution is a mixed group of microorganisms such as lactic acid bacteria, photosynthetic bacteria, actinomycetes and yeast, which help to enhance the concentration of nutrients by accelerating organic matter decomposition and increase the availability of nutrients for crop utilization (Higa and Wididana, 1991). Composting time takes 21 to 28 days when using EM.

The Haiti WINNER project must initiate the introduction of legumes and other plants for use as hedges and green manures (Figure 10). It should increase the content of organic matter to improve soil properties.

Cornell University (Lathwell 1990) reported that the Canavalia ensiformis contributes up to 231 kg N / ha. This same study shows that the amount of nitrogen fixed by the legume is greater than that of a species such as Mucuna (152kg/ha), pigeon pea (229kg/ha) and Pueraria (116kg/ha).

Figure 10. Using canavalia in plantain planted with the double row.

Tithonia diversifolia (Figure 11) is an herbaceous plant of the family Asteraceae, native to Central America. It has a wide range of adaptation, tolerates acidic conditions and low soil fertility. Drechsel and Reck (1998), reported that biannual pruning of tithonia hedges in Rwanda produced about 8 kg of fresh biomass per m of hedge in a year. This corresponds to about 1 kg dry matter m^{-1} yr^{-1}.

Figure 11. *Tithonia diversifolia.*

WINNER's staff supervises storage of 20-20-00 fertilizer formula in Cabaret on the route to the collection center. This fertilizer is prepared by Fersan in the Dominican Republic and in the case of plantain, can be used.

Diammonium phosphate (DAP) solid fertilizer, applied directly to ground with the highest concentration 18-46-00 primary nutrients (nitrogen and phosphorus respectively), is considered a good source of fertilizer.

The WINNER project should consider other options with less phosphorus content. However, calibrations should be made taking into account the average weight of bunches and foliar analysis of those farms using fertilizer.

Urea fertilizer between solids is a nitrogen source of higher concentration (46%). This has economic advantages because it can be mixed with other sources and is easy to use for highly demanding crops of nitrogen (N) like plantain.

Sidenote

Regarding the demonstration plots to show the system double row planting: growing plants showed good development and had uniform growth. This was a result of a good ranking in the size of corms that were planted. Winner technicians demonstrated that they had applied the technique very well, implementing the lessons learned.

The corms were planted properly aligned so it was a good distribution of plants.

For desuckering, one should always take into account the orientation of the rows of plants north or south. This is to keep the double rows and ensure that the alley that separates them remains free. If the planting orientation is east-west, desuckering should also be done.

IV. References

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Field Code Changed

V. Annex. Terms of Reference

Attachment A – Scope of Work

USAID | HAITI
FROM THE AMERICAN PEOPLE

TERMS OF REFERENCE

Production and harvest/post harvest operations of the banana industry

I. Background

The WINNER project aims to improve the living conditions of people in the Cul-de-Sac and Matheux corridors, and to expand agricultural production through a value chain approach that fits into the Feed the Future Initiative of President Obama and primarily focuses on four food crops: maize, rice, beans and plantains. WINNER includes three intermediate results:

- Agricultural Productivity Increased
- Watershed Stability Improved
- Agricultural Markets Strengthened

The project introduces and disseminates technical innovations to modernize Haitian agriculture, bolster agricultural productivity and increase farmers' incomes, all while protecting the environment and stabilizing upstream areas. WINNER works with more than 60,000 farmers to implement broad-based agricultural campaigns, rehabilitate rural infrastructures, carry out large soil conservation activities and link farmer organizations to buyers and markets. Farmers' yields have more than doubled in most cases, though improved access to irrigation water and inputs, proximity extension services and training, and mechanized land preparation.

To reinforce agricultural production in the Matheux corridor, USAID/WINNER will support the development of the banana industry, particularly for plantains. The project aims to revitalize and increase the production of plantains, while improving the current conditions of production and harvest/post harvest operations to increase revenues for the inhabitants harvesting this product. Plantain production is one of the key industries of this region, with harvests being greatly affected by disease (ex. sigatoka) and parasites (ex. nimatodes). WINNER plans to rectify this issue by providing those involved in the banana industry methods to produce a quality product, primarily by improving post-harvest operations.

Consequently, WINNER would like to recruit a consultant to organize and train key players in the production and harvest/post harvest of the banana industry, in order to reduce losses and improve local/export commercialization.

II. Tasks

The consultant shall complete the following tasks:

1- Train approximately fifty operators within the banana industry (large producers, associations, master farmers in Matheux, etc.);

Training will be held at the Cabaret/Cazals collection center.

III. Deliverables

The consultant shall provide the following deliverables:

- Summary of the assignment to WINNER staff at the end of the trip (PowerPoint presentation);
- Final report on the training sessions, written based on the WINNER template, an evaluation of the participants and recommendations for equipment/installations needed at the conditioning center;

The consultant shall bring the necessary utensils to train participants in their use for post-harvest operations (knives, scales, tools for sorting, etc.).

The consultant shall be accompanied by a WINNER agronomist, who will follow the assignment and transmit useful information to other beneficiaries.

IV. Timing/Duration/LOE

The duration of the consultancy shall be up to 9 days of LOE from May 1-May 19th, including travel to Haiti on or about May 13 – 19, 2012:

- **2 days** to travel to/from Haiti ;
- **5 days** to train (including field exercises) on plantain harvest/post-harvest operations, which shall include :
  - Theoretical training on combating Sigatoka, fertilization techniques, and grafting (2 days)
  - Practical training on harvesting techniques (2 days)
  - Installation of a demonstration plot (1 day)
- **2 days** to draft a trip report

V. Reporting

The contract shall be led under the supervision of the WINNER project. The consultant shall be supervised by Mr. Roosevelt Decimus. Mr. Jean Robert Estime, Chief of Party of the WINNER Project, shall provide guidance when necessary.

All field visits shall be made with WINNER vehicles according to standard project rules and procedures.

VI. Professional requirements

1. Solid experience in the banana industry
2. Solid experience in banana commercialization, both in local and international markets
3. General experience of the Haitian context is preferred
4. Capacity to draft reports in either French or English

5.1. Database of soil analyses of selected farms

File annexed