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Yam Improvement for Income and Food Security in West Africa: Effectiveness of a Multi-Disciplinary and Multi-Institutional Team-Work

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Abstract

The overall goal of the five year project “Yam Improvement for Income and Food Security in West Africa” (YIIFSWA) funded by the Bill and Melinda Gates Foundation and led by the International Institute of Tropical Agriculture, Ibadan, Nigeria was to: (a) increase yam productivity by 40% for 2,00,000 smallholder yam farmers in Ghana and Nigeria and (b) deliver key global good research products that will contribute to the 10-year overall vision to sustainably double incomes from yams for 3 million smallholder yam farming families and contribute to ensuring food security for producers and consumers. Implemented by scientists of twenty partner specialized organizations, comprising research institutes, Universities, governmental and non-governmental organizations, YIIFSWA has impacted yam value chain stakeholders through research and development interventions. The significant contributions made in the project during the past 18 months’ period are discussed in this paper. These include: a baseline survey conducted in key yam growing areas in Ghana and Nigeria, training of yam producers on adapted yam minisett technique and production of seed yam, undertaking in depth value chain assessments, developing the capacity of Farmers Organizations (FOs) by linking them to service providers (SPs), participatory evaluation of new yam genotypes, successful development of yam virus diseases diagnostics and development of novel techniques for high ratio yam propagation such as aeroponics and bioreactors.

Key Words: Yam, value chain, capacity development, seed yam, propagation, Ghana, Nigeria

Introduction

Yams (*Dioscorea* spp.) are important staple food and source of carbohydrate for millions of producers, processors and consumers particularly throughout West Africa (Hahn et al., 1987).Yam is cultivated mostly in the Derived and Southern Guinea Savannah. About 48 M t, which is more than 93% of the world production of yams (FAO, 2011), is produced on 4 M ha annually in this sub-region and it is also an important source of income in West Africa. Yams (*Dioscorea* spp.) play a very important part of the food security and livelihood systems of at least 60 million people in West Africa. While population is growing, significant amounts of yam productivity has remained stagnant or is declining. The decline in productivity is attributed to a combination of factors including the unavailability and affordability of clean seed yam. It has been predicted that this decrease could be catastrophic unless steps are taken soon to change the situation (Manyong and Nokoe, 2003). Seed yams are expensive (Ironkwe, 2005), accounting sometimes for as much as 63% of total variable production costs, and are bulky to transport (Manyong, 2000; Agbaje et al., 2005). Yam planting material is the edible tuber and differs from table tuber only in size. The seed yam system in West Africa is mainly informal and entirely market driven (Nweke et al., 2011). Low technologies and lack of appreciation by farmers of the consequences on yield of planting pest-infested or disease-infected seed yams are amongst the major constraints (Nweke et al., 2011) to improving the seed sector. Yam mosaic virus (genus *Potyvirus*), anthracnose disease caused by *Colletotrichum gloeosporioides* and nematodes, *Scutellonema bradys* and *Meloidogyne* spp., are major limiting factors for yam production (Thouvenel and Dumont, 1990; Abang et al., 2003; Ampofo et al., 2010). It is in this context in West Africa that the Bill and Melinda Gates Foundation has funded the project titled "Yam Improvement for Income and Food Security in West Africa (YIIFSWA)" aiming at addressing the above yam production challenges through the following seven interlinked objectives and three cross cuttings components:

1. Strengthen small-scale farmer and trader market linkages, particularly in less accessible production areas, to realise benefits from increased ware yam productivity and market demand.
2. Strengthen capacities and empower smallholder farmers in the yam value chain.
3. Establish sustainable availability of high quality seed yam on a commercially viable (price competitive) basis in targeted areas.
4. Reduce post-harvest losses and improve product quality.
5. Develop technologies for high ratio propagation of high quality breeder and foundation seed yam.
6. Evaluate and scale out yam production technologies with improved and local popular varieties.
7. Identify more effective prevention and management tools and strategies for pests and diseases.

These objectives are supported by cross-cutting components: monitoring, evaluation and learning; and communication, information dissemination and project coordination and management.

YIIFSWA is being implemented in Ghana and Nigeria. A total of twenty partner organizations led by International Institute of Tropical Agriculture (IITA) are involved in the implementation of this first high level funding on yam research for development in West Africa. These partners are composed of five research institutes, four governmental organizations, four non-governmental organizations and seven Universities. The up- to-date report of results and findings of the key project activities are presented in this paper.

Materials and Methods

The Project "Yam Improvement for Income and Food Security in West Africa" focussed on a series of activities. The preliminary activity was the identification of locations of project interventions which was done by conducting an implementation planning workshop. This was followed by the baseline survey in key yam growing areas where a total of 600 and 800 households were randomly selected in Ghana and Nigeria respectively using a sampling frame developed by extension agents in collaboration with community heads as a source list. The livelihood benchmark aimed to provide indicators against which the future interventions of YIIFSWA could be objectively measured. Regarding value chain analysis activity, preliminary and in depth value chain assessments and mapping were carried out in identified locations and characteristics of ware and seed yam production systems, principal markets, and relevant organisations and institutional actors were documented. The next activity was the training of farmers on minisett technique and seed yam production. This was done through establishment of demonstration plots by the Missionary Sisters of the Holy Rosary (MSHR), a non-governmental organization in three locations. To develop the capacity of Farmers Organizations (FOs) by linking them to service providers (SPs) that would offer demand-driven services, a profiling exercise was conducted on 77 and 44 FOs and 40 and 17 SPs in Nigeria and Ghana respectively. Participatory yam trials managed and evaluated by farmers laid out in two locations, one in each country included evaluation of pre-release hybrid yam varieties, test to drought and low soil fertility and assessment of improved agronomic models productivity. The evaluation of the genotypes were done by 18 male farmers and 16 farm women in location 1 and 32 male farmers and 27 farm women in location 2. The development of yam virus diseases diagnostics was carried out with the establishment of a cost effective multiplex RT-PCR assay for the simultaneous detection of three different mosaic viruses. High ratio yam propagation was attempted by effectively using novel techniques such as aeroponics and bioreactors. Frequency analysis and descriptive statistics were used to analyze and interpret the collected data.

Results and Discussion

Baseline survey

After the strategic implementation planning, the first field intervention was the baseline survey to characterize the yam production systems in all the locations for future intervention. The YIIFSWA baseline studies were conducted using 600 and 800 households in Ghana and Nigeria respectively. Among these households only 3% were female-headed in Nigeria against 10% in Ghana. In Nigeria the majority of households had completed the primary education, while in Ghana they had completed only the first three years of primary education. Land was by far the major natural capital for smallholder farmers in yam growing areas of Nigeria and Ghana. The average size of land available for farming was about 2.4 ha in Nigeria against 2.7 ha in Ghana. From the baseline studies in the two countries, it was evident that priority has been given by households to yam over cash crops and other food crops. The areas under yam cultivation in the cropping system are generally small and the primary objective of farmers was to meet the subsistence needs followed by income generation. Cereals were next to the yam in terms of relative importance, as reflected in the percentage of households growing them, especially maize. On the other hand, grain legumes and vegetables were not widely grown; the industrial crops being uncommon or absent. These baseline results varied among the different agro-ecological zones (AEZs) within each surveyed country as depicted on percentage distribution of crops grown (Fig. 1).

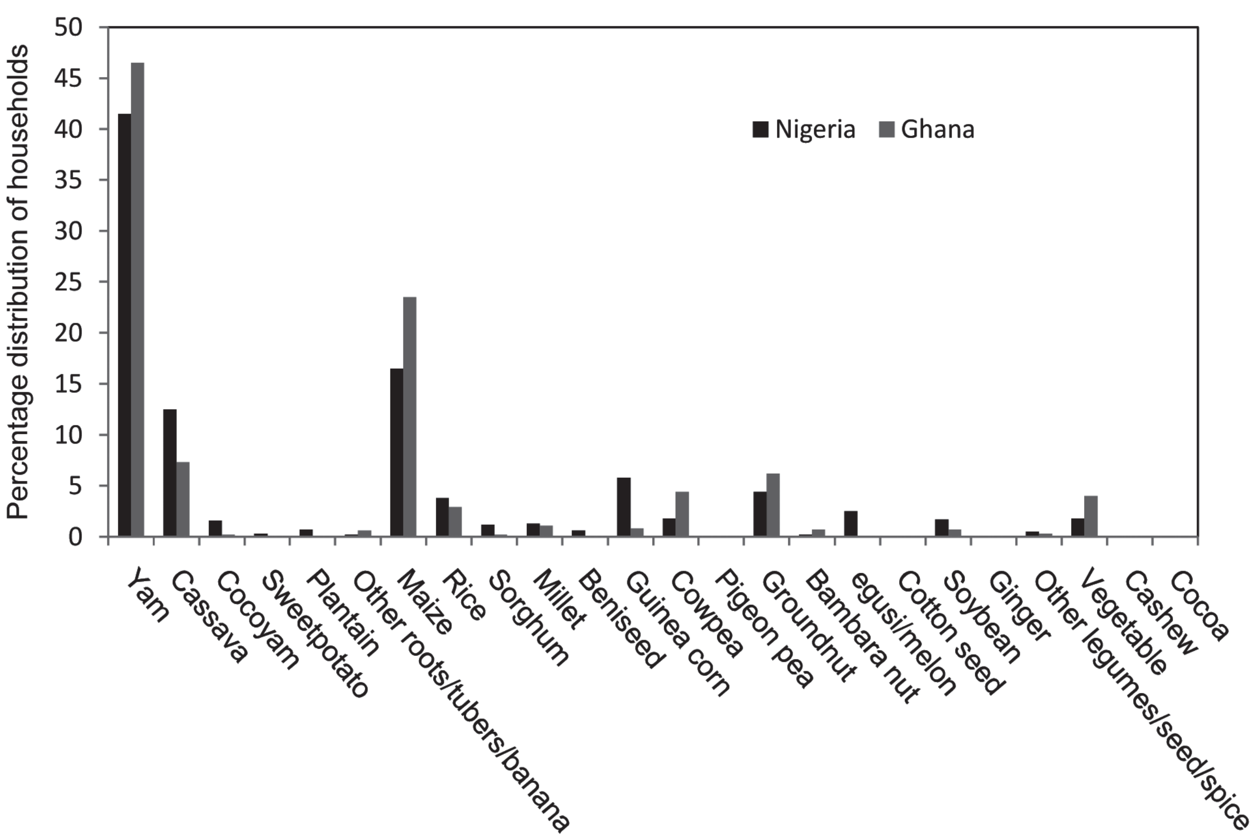


Fig.1. Relative importance of crops grown by country

After yam harvest, their transportation and storage were done manually and farmers were sometimes pushed to sell their tubers immediately after harvest, generally at uneconomical prices, to avoid postharvest losses. Post-harvest losses at the production level were estimated and in majority of households 14% and 20% of yams sprouted respectively in Nigeria and Ghana, while only 2% and 4% of yams were lost due to rodents and theft.

Key findings of value chain analysis

The Value Chain Analysis started by a scoping study through visits of production areas and markets in each of the cluster locations identified during the implementation planning. These visits included local yam stakeholder meetings around specific market location to assist in identifying the actors and their interrelationships, market linkages, critical points and potential innovations and interventions for the development of yam value chain. These interactions with farmers, marketers (including exporters), transporters, processors have helped to estimate the cost of production of ware and seed yam, to analyse costs and benefits of yam transactions and to identify major ware yam supply and distribution routes in both Nigeria and Ghana. Findings from in-depth value chain analysis have shown that yam production is a profitable business and yam farmers are able to generate substantial income from the production of tubers. But at the same time, production costs tend to be high (in particular for seed yam and hired labour) and yam selling prices were function of the season. There is significant price variability between the new yam season (August to October), the peak season (November to April), and the slack season (May to July). At the peak of the season there are lot of yam in the markets but because of unavailability of good storage facilities, the yams were sold at the lowest prices as shown in Fig. 2. The gross margins can be negative if farmers are unable to sell at times when prices are higher.

Farmers training on adapted yam minisett technique

The ‘Adapted Yam Minisett Technique (AYMT) is a practice on which a training activity was implemented through establishment of demonstration plots by MSHR. During 2011-2012 the project has trained in Nigeria

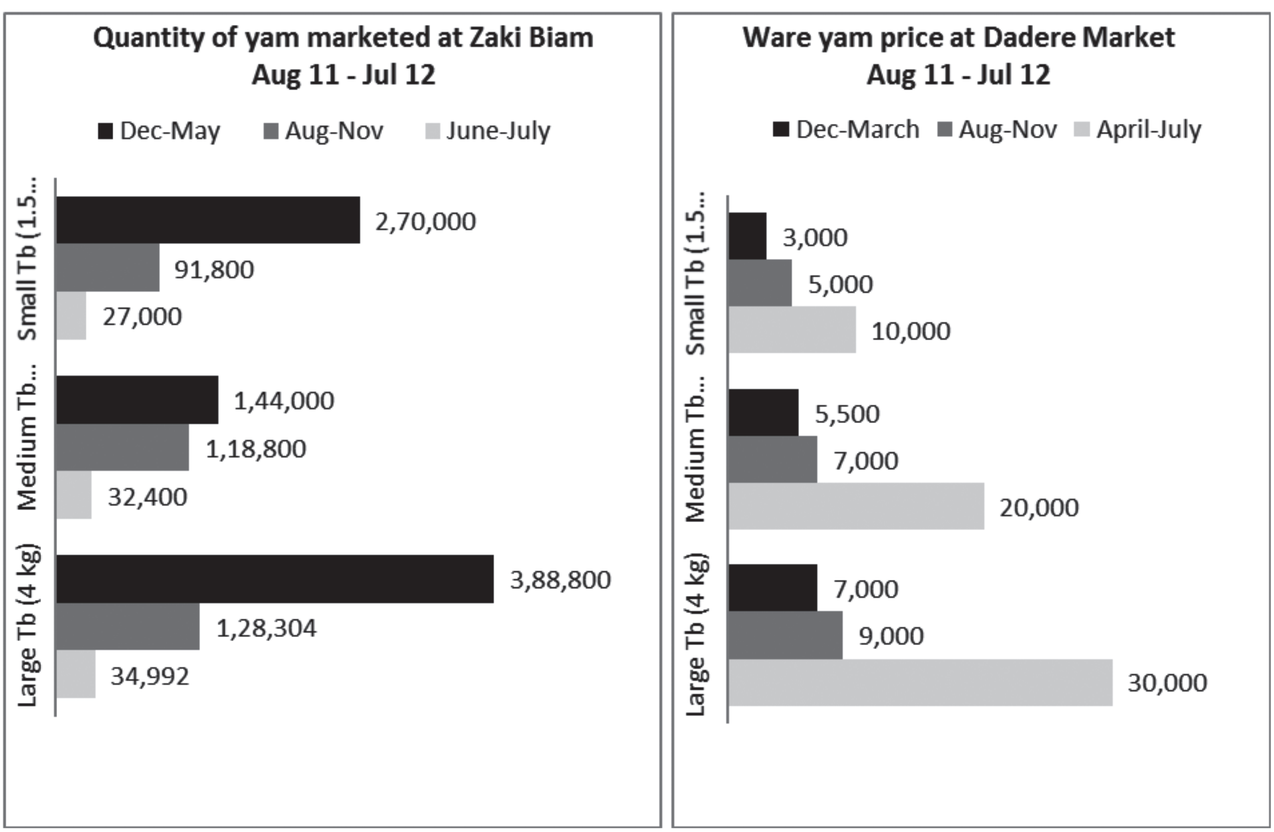


Fig. 2.Variations of quantities and prices during the three main period of yam supply in markets

over 3,600 yam producers using the adapted yam minisett technique and produced through the same technique over 5,00,000 seed yam in Ghana. In 2012 the AYMT demonstrations were established in three locations at Abuja in Federal Capital Territory, Agagbe in Benue state and Igalaland in Kogi state. A total of 26 demonstrations were established that helped to train 3,034 farmers in AYMT (Fig. 3). In all the three locations local popular yam cultivars were used namely *Ekpe* and *Oboko* in Kogi state; *Imola* in Benue state and *Mecakusain* in Abuja. Farmers were trained on different aspects of AYMT including land preparation, selection of clean mother tubers, cutting of mother tuber into minisetts, preparation of pesticide solution and treatment of minisetts, drying of treated minisetts, planting of minisetts and management of the field. At planting and harvesting a large number of farmers were called on to view the results of AYMT.

Participatory evaluation of new genotypes with farmers

Traditionally yam in West Africa favours the sub-humid environments where there is abundant moisture and fertile soils. They are also traditionally staked, a process which is labor intensive, costly and contributes to deforestation. However, with the current shrinking land in these environments and changes in weather, most of the areas are becoming drier than before and so yam cultivation has now expanded in the dry savanna agro-ecologies. These areas have low moisture and soil fertility, and do not have enough trees for staking but need for staking is low in savanna agro-ecology. Research efforts have been initiated to develop stress tolerant varieties, with a focus on drought tolerance, low soil fertility and virus resistance. However, new yam varieties that can grow well without staking have been developed by IITA in collaboration with National Agricultural Research Systems (NARS) partners in Nigeria and Ghana. YIIFSWA project through its national implementing partners namely National Root Crops Research Institute (NRCRI) in Nigeria, Crops Research Institute (CRI) and Savannah Agricultural Research Institute (SARI) in Ghana are currently evaluating and screening these new genotypes for their adaptability and farmers acceptance in participatory approach for wider agro-ecologies in Nigeria and Ghana. The results from the first year evaluations by farmers have shown good ranking of the improved genotypes in comparison to the popular landraces but significant difference was found between the choices of men and women. Table 1 shows the difference between men and women for selection of genotypes in both Ghana and Nigeria.

Tools for prevention and management of pests and diseases

The biology and ecology of several pests and diseases that limit yam productivity in the various production environments in West Africa are not well understood;

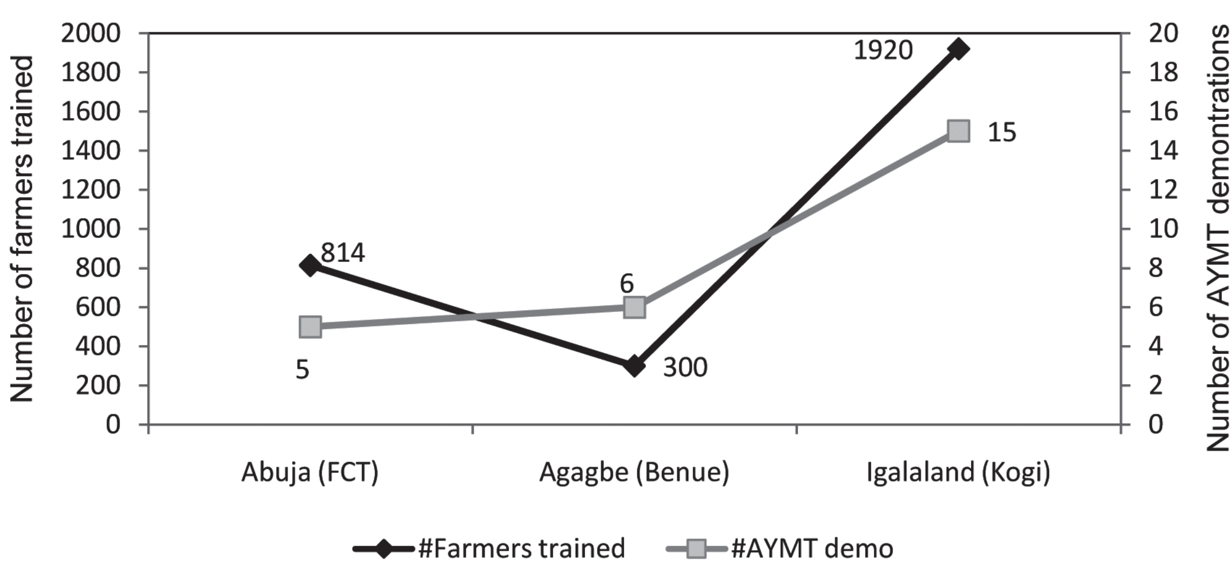


Fig. 3. Number of yam producers trained on Adapted Yam Minisett Technique in Nigeria in 2012

Table 1. Gender differences in participation selection of yam genotypes

Ranking	Atebubu (Ghana)		Zaki-Biam (Nigeria)	
	Variety selected by		Variety selected by	
	Male	Female	Male	Female
N	18	16	32	27
1st	TDr 99/02674	TDr 98/00933	TDr 89/02475	TDr 07/00873
2nd	TDr 98/00933	TDr 89/02665(M)	TDr 07/00168	TDr 98/00933
3rd	TDr 00/00403	TDr 99/02674	TDr 00/00362	TDr 00/00362
4th	TDr 03/00196	TDr 00/00403	TDr 89/02672	TDr 89/02672
5th	TDr 94/01108	TDr 96/00604	TDr 00/00539	TDr 89/02665
6th	TDr 96/00604	TDr 03/00196	TDr 94/01108	TDr 94/01108
7th	TDr 89/02665(M)	TDr 94/01108	TDr 89/02665	TDr ALUMACO
8th	TDr ALUMACO	TDr 89/02665(F)	TDr 96/00604	TDr 96/00604
9th	TDr 89/02665(F)	TDr ALUMACO	TDr ALUMACO	TDr 89/02475
10th	TDr 01/00405	TDr 01/00405	TDr 01/00405	TDr 01/00405

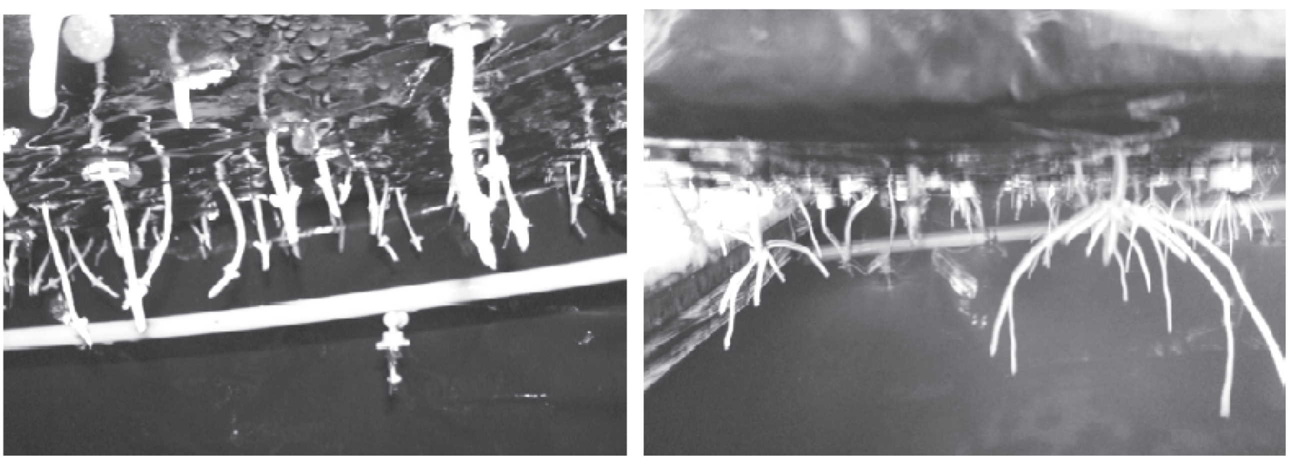
N = Number of respondents

therefore effective and sustainable management strategies are limited. A number of pests and pathogens affect yams in Nigeria and Ghana (Ampofo et al., 2010). Determining the risk posed by pests and diseases to breeder, foundation and certified seed yam production, and rate of re-infection of clean seed yams is critical to understanding the rate of deterioration of clean seed yams and seed replacement cycle for the formal seed system. This information is valuable for sustainable production and maintenance of quality seed yams. In addition, knowledge on risks to seed yams on-farm and storage contributes to development of effective risk mitigation steps. To address these questions, Pest Risk Assessment (PRA) surveys as per the framework for the ISPM-FAO 2007 were conducted in 2012 together with NARS partners in 41 fields from 31 locations in Ghana and 61 fields from 34 locations in Nigeria. This exercise targeted all states, districts and sites where the project established trials (breeding and agronomy) demonstrations and seed yam multiplication plots (seed production). For some pests and diseases, leaf and soil samples were collected in the field respectively for identification of virus and nematodes. Specifically for nematodes tuber samples were also collected in the market places and in the farmers' stores.

Among the other advantages the PRA has also helped to identify in each of the country sites of less infestation of pests and diseases that were appropriate for multiplication of 1st generations of seed yam. Virus infested leaf samples collected during the PRA were analysed to characterize the genetic diversity of important yam viruses. But the lack of robust and low-cost diagnostics however is a serious constraint. Sensitive diagnostic tools for yam potyviruses are well established at NRI/IITA and are based on a combination of antibodies to trap virus particles and the sensitive nucleic acid amplification Polymerase Chain Reaction (PCR) using primers that detect the wide diversity of potyvirus sequences. A single tube multiplex RT-PCR assay has been established for the simultaneous detection of Yam mosaic virus (YMV, genus Potyvirus), Yam mild mosaic virus (YMMV, genus Potyvirus), Cucumber mosaic virus (genus, Cucumovirus) and *Dioscorea alata* bacilliform virus (DaBV, genus Badnavirus). The cost effective multiplex RT-PCR test developed is for YMV, YMMV and CMV. Badnaviruses were not combined into this test and format of assay as they are known to be integrated in the host genome. This test was further validated to assess the sensitivity, robustness and specificity by testing a range of leaf and tuber samples harvested from yams in Nigeria and Ghana.

Technologies for high ratio propagation of seed yam

The multiplication ratio of yam in the field is known to be very low (less than 1:10). The methods developed to address this limitation include the minisett technique, vine propagation and micro-propagation *in vitro* following culture of apical meristems and nodal cuttings. These are well suited to rapid multiplication of seed tubers for new and other recommended varieties and are also amenable to the application of sanitary methods that ensure high seed quality. Other methods of rapid propagation developed at IITA include production of micro-tubers from *in vitro* plantlets, and the production of seed tubers using slips (sprouts) and peels. New techniques that offer even higher multiplication ratios and assurance of seed quality such as aeroponics, hydroponics, temporary immersion bioreactors systems, photoautotrophic culture, are known to be effective for other vegetatively propagated crops. Nevertheless, yam propagation using aeroponics system could be successfully achieved under this project. The experiments started with planting of pre-rooted vine cuttings in aeroponics and direct planting of vine cuttings of *D. rotundata* and *D. alata*. Both pre-rooted vines and direct vine cutting planting have produced viable micro-tubers in aeroponics system. The successful growth of yam in aeroponics system is reported for the first time. Up to now aeroponics system was used only for transplanting of rooted potatoes clean plantlets but never used for direct vine planting. Figs .4 and 5 showed yam in aeroponics system inside a screen house. The review of existing literature on use of Temporary Immersion Bioreactor system (TIBs) in general and for yam in particular has enabled YIIFSWA project to start using TIBs as high ratio propagation technique for production of both plantlets and micro-tubers.



Direct planting of 2 noces vine cuttings   Rooting of vine 2-3 weeks after planting

Fig.4. Rooting of vine cuttings in aeroponics system

Yam plants from vines on aeroponics system   **Development of seed yam tubers**

Fig. 5. Yam plants developing on aeroponics system and production of mini-tubers

Conclusion

In eighteen months of YIIFSWA project implementation by IITA and partners (NRI, FOSCA/AGRA, NRCRI, CSIR, MSHR, CRS, Universities in Ghana and Nigeria etc.) significant results were achieved on baseline studies, value chain analysis, farmers training, and participatory selection of new genotypes. New techniques on high ratio propagation (aeroponics and TIBs) and the Multiplex RT-PCR test for simultaneous detection of CMV, YMV and YMMV were successfully established and running. The multi-disciplinary and multi-institutional approaches established in implementing the project activities using complementarities and synergy of technical capacity of each organization have yielded good results. Significant challenges or gaps in knowledge concerning new techniques of high ratio propagation of seed yam (type and rate of fertilizers for aeroponics), pests (bio-control for nematodes) and diseases (effective control of viruses and fungi) constraining yam productivity still exist and need to be addressed.

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