Annual Report 2015

CSIR-CROPS RESEARCH INSTITUTE

Contents

For more information please contact:

Dr. Stella Ama Ennin

The Director

CSIR-Crops Research Institute

P.O. Box 3785
Kumasi.

Telephone

Director: 233(0)3220-60396, 62522
Offices: (Fumesua) 233(0)3220-60391, 60389, 60425
(Kwadaso) 233(0)3220-50221, 50222

Fax: 233-(0)3220-60396

E-mail: cridirector@yahoo.com

Website: www.cropsresearch.org

Compiled by: I.S. Baning, L.G.S. Nsafoah, R. Adu-Donyinah

Edited by: I.S. Baning, S.A. Ennin, J. Manu-Aduening

VISION

A Centre of Excellence for Agricultural Research, Innovation and Capacity Building for Development

MISSION

To develop and disseminate demand-driven technologies and build capacity for sustainable food and industrial crops productivity to enhance livelihoods

CORE VALUES

Excellence
Fairness
Commitment
Transparency and Accountability
Teamwork

List of Acronyms

AATF	- African Agricultural Technology Foundation
AAWID	- African Agricultural Women in Development
AfDB	- African Development Bank
AGRA	- Alliance for a Green Revolution in Africa
AVRDC	- Asian Vegetable Research and Development Centre
BMGF	- Bill and Melinda Gates Foundation
CARGS	- Competitive Agricultural Research Grant Scheme
CIAT	- International Centre for Tropical Agriculture
CIDA	- Canadian International Development Agency
CIP	- International Potato Centre
COTVET	- Council for Technology, Vocation Education and Training
CRS	- Catholic Relief Services
CSIR	- Council for Scientific and Industrial Research
CSIR-CRI	- CSIR- Crops Research Institute
CSIR-FRI	- CSIR-Food Research Institute
CSIR-INSTI	- CSIR- Institute of Scientific and Technological Information
CSIR-PGRRI	- CSIR-Plant Genetic Resource Research Institute
CSIR-SARI	- CSIR- Savanna Agricultural Research Institute
CSIR-SRI	- CSIR- Soil Research Institute
CSIR-WRI	- CSIR- Water Research Institute
CSUC	- Catholic Services University College (Ghana)
DFAT	- Department of Foreign Affairs (Australia)
EDAIF	- Export Trade, Agricultural Investment Fund
EMBRAPA	- Brazilian Enterprise for Agricultural Research
EPA	-Environmental Protection Authority
FAOSTAT	- Food and Agriculture Organization Statistical Database
FBO	-Farmer-based Organization
FOSCA	- Farmer Organization Support Centre for Africa

GAEC	- Ghana Atomic Energy Commission
GBUC	- Ghana Baptist University College
GEPC	- Ghana Export Promotion Council
GIPC	- Ghana Investment Promotion Centre
GIZ	- German International Cooperation
GLDB	- Grains and Legumes Development Board
GREL	- Ghana Rubber Estates Limited
ICRISAT	- International Crops Research Institute for the Semi-Arid Tropics
ISSER	- Institute of Statistical, Social and Economic Research
IFAD	- International Fund for Agricultural Development
IFS	- International Foundation for Science
IITA	- International Institute for Tropical Agriculture
INEA	- Innovation and Networks Executive Agency
IRRI	- International Rice Research Institute
KAC	-Kwadaso Agricultural College, (Ghana)
KTI	- Kumasi Technical Institute
KNUST	- Kwame Nkrumah University of Science and Technology (Ghana)
METASIP	- Medium Term Agriculture Sector Investment Plan
MoFA	- Ministry of Food and Agriculture
NCoS	- National Centre of Specialization
NCSU	- North Carolina State University (USA)
NRI	- Natural Resource Institute (UK)
PPRSD	- Plant Protection and Regulatory Services Division (of MOFA)
RDA	- Horticultural Research Institute(South Korea)
RDA-KAFACI	- RDA- Korea – Africa Food and Agricultural Cooperative Initiative
SARD-SC	- Support for Agricultural Research and Development - Strategic Crops
TDTC	- Technology Development and Transfer Centre
UCC	- University of Cape Coast (Ghana)
UDS	- University of Development Studies (Ghana)
UEW	- University of Education, Winneba (Ghana)
UoG	- University of Ghana
USAID	- United States of America International Development
USDA	- United States Department of Agriculture

VEPEAG - Vegetable Producers and Exporters Association of Ghana

WAAPP - West Africa Agricultural Productivity Programme

WACCI - West Africa Centre for Crop Improvement

YIIFSWA - Yam Improvement for Income and Food Security in West Africa

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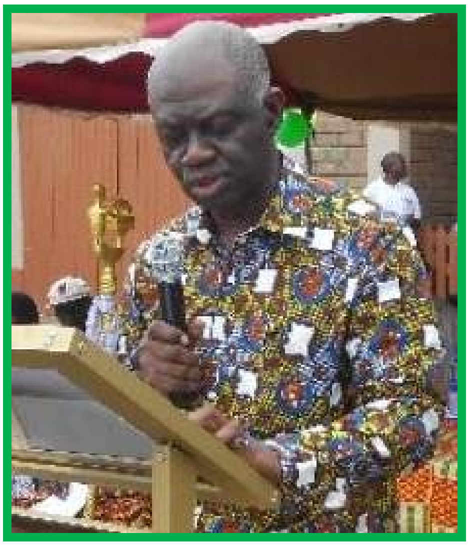
STATEMENT FROM THE BOARD CHAIRMAN



The year 2015 brought more impetus to the research drive of the CSIR-Crops Research Institute. A new Strategic Plan was prepared to re-focus CSIR-CRI work and organizational development for the period 2015-2019.

Having been in existence for over 50 years, CSIR-CRI is confronted with six major questions borne out of key strategic priority areas.

- How should CSIR-CRI effectively identify emerging researchable problems and continuously develop demand driven technologies and innovations?
- What are the strategic partnerships that CSIR-CRI need to establish?
- How should CSIR-CRI develop, improve and maintain an efficient communication system and other support services to fulfill the institute's mission and increase visibility?
- How should CSIR-CRI raise adequate and sustainable funding for research and technology dissemination activities?
- How should CSIR-CRI strengthen capacity across disciplines, among scientists, key agricultural value chain actors and support systems to increase productivity and technology?
- How should CSIR-CRI improve its Systems and Procedures to achieve greater employee motivation and productivity to fulfill its mission?

Through the Strategic Plan, it is my expectation that CSIR-CRI will marshal its strengths and resources to achieve its set targets in 2015 and the years ahead.

It has been an honor to be a part of the CSIR-Crops Research Institute's leadership and I look forward to a continued cooperation with staff and partners to make greater contribution to the nation's agricultural transformation.

FOREWORD FROM THE DIRECTOR

In line with our vision to be a Centre of Excellence for agricultural research, innovation and capacity building for development, CSIR-Crops Research Institute strives to meet its yearly target across all divisions, and 2015 was no exception. This is evident in the research projects that were undertaken within the year.

The drive to achieve excellence has reposed confidence in our development partners and collaborating institutions who continued to support our activities throughout the year.

Groundbreaking research took place across various divisions of the institute leading to varietal releases as well as production of planting materials. Various trials were conducted with very positive results. Preparations are far advanced to acquire the ISO 17025:2005 Accreditation for the Biotechnology Laboratory, to raise the standard of the laboratory to international level.

We will like to express our heartfelt appreciation to all our development partners, donors, collaborating institutions, scientists and all staff members whose immense contributions have spurred us on to such heights. We hope for more cooperation and collaborations in the coming years.

We look forward to 2016 because we believe the coming year holds greater prospects for us to achieve more than we did in 2015.

It is our pleasure to present the 2015 Annual Report.

EXECUTIVE SUMMARY

This report covers research and technology transfer activities carried out by the various commodity programmes and technical divisions of CSIR-CRI during the year 2015. The results or progress made under the various activities have been reported.

Under the West Africa Seed Programme (WASP), which is aimed at contributing to the sustainable improvement of agricultural productivity and production in the target countries, the institute was tasked to produce two metric tonnes (2MT) of quality breeder seeds of maize, cowpea and rice for subsequent multiplication into certified seeds. The institute produced 2.5 MT of breeder seeds. This amount is expected to plant 114 hectares and eventually yield 54,409MT of certified seeds.

The root and tuber crops division undertook a WAAPP project which was expected to multiply and disseminate high yielding varieties tolerant to biotic and abiotic stresses and suitable for different end-users. This project was able to produce enough planting materials expected to plant about 3,870 acres after multiplication. The division also out-doored six new cassava varieties after they had been endorsed by the National Variety Release and Registration Committee.

The institute was contracted by the International Institute of Tropical Agriculture (IITA) to generate 10,000 pre-basic seed yams under the YIIFSWA project. The project was able to generate 21,700 pre-basic yam seeds-more than double the contracted number.

A total of 6,650 breeder seeds, of the three yam varieties released by the institute were produced and supplied to the Ministry of Food and Agriculture (MoFA) for further multiplication and distribution to farmers.

Four water yam genotypes obtained from IITA were evaluated alongside a local material. All the introduced materials produced about double the yield of the local material and had better tolerance to anthracnose disease. They were identified as potential candidates for varietal release.

As part of the institute's efforts to increase availability of seed yams to farmers in Ghana, 120 seed yam growers were trained in the yam vine and Minisett techniques used in the rapid multiplication of yam planting materials.

In the Biotechnology, Seed Technology and Post-Harvest division of the institute, tissue culture techniques were used to produce seed yams for farmers. Some of the secondary seed yams were big enough to be classified as ware yams. The same techniques were also used to produce a clean stock of planting materials of five promising lines of taro - a crop threatened with extinction.

In a WAAPP-sponsored research to assess the yield output of tissue culture derived primary seed yam for *Mankrong Pona*, a released yam variety by the institute, results indicated that the primary seeds were viable sources of planting materials. The mean yield of secondary tubers from small, medium and large primary seeds were 402.0 g, 589.0g and 1037.0 g respectively.

Under the CAY-Seed Project, tissue culture techniques were also used to generate clean seeds of local yam landraces for farmers and for degeneration and storage life studies. Preliminary results on virus indexing revealed the plantlets produced to be disease-free. This is encouraging because once clean cultures are established, it takes about 7 months to produce clean tubers which will sprout after the normal dormancy period.

Demonstrations of the minisett technology for rapid multiplication of yam planting materials, were set up for farmers in some communities in the Ejura and Atebubu districts. This was done under the CAY-Seed project. A workshop was also organised for extension workers on the identification of diseases that affect seed yam quality, rating of severity of disease symptoms and labelling of healthy-looking plants (positive selection).

A total of 8,125 breeder and foundation seeds of the *Aburohemaa* and *Omankwa* maize varieties were produced to meet farmers' requirements.

Eight rice lines were evaluated, at three locations, under the African Rice Breeders' Taskforce programme. At harvest three of the lines (SIK9-164-5-1-3, SIK 350-A150 and WAB 2075.WAC5. FKR1-1-TGR1) were identified for further evaluation and possible release as varieties.

Four improved cowpea varieties namely *Crops Hans Adua, Crops Agyenkwa, Crops Nketewadɛ and Crops Zamzam* were approved for release by the National Varietal Release Committee. These varieties are tolerant to fungal diseases such as Cercospora Leaf Spot and Anthracnose.

Under the auspices of WAAPP, a team of scientists paid a working visit to Burkina Faso to interact with scientists there and study their systems of tomato production and collect some of their improved genetic materials for evaluation and adoption in Ghana. During the visit some commercial cultivars were collected for evaluation in Ghana. These included *Jaguar, Kiara F1, Mongal F1* and *Tropimech*. Two of the varieties (*Mongal F1* and *Tropimech*) not only produced the highest yields per plant but also showed the best tolerance levels to the Tomato Yellow Leaf Curl (TYLC) disease. These varieties will be recommended to farmers after these attributes have been confirmed with further tests and evaluation.

The institute continued its commercialization activities and managed to raise extra income through the production and sale of plantain suckers (48, 252 plantlets), rubber seedlings (100,000 grafted materials) and mango seedlings (59,845 seedlings).

An exhibition was organised to promote an aquaponics-based food production system that has been set up at the Institute.

Efforts were made towards acquiring ISO 17025: 2005 accreditation for the test method used in the detection of the African Cassava Mosaic Virus in the Biotechnology Laboratory.

Under the year under review, the institute recorded a number of publications. These included 55 refereed journal papers, 10 technical reports, 5 conference papers, 2 book chapters, 2 manuals and 1 production guide. This was a 23 percent increase on the previous year's number.

There were also a number of staff promotions in 2015. Seven (7) senior members were promoted. Twenty nine (29) other promotions were in the senior staff category while 22 were in the junior staff category. A total of 30 monthly rated staff were also promoted within the year.

RESEARCH REPORTS

Genotyping of released and elite crop varieties in Ghana

Research Team: M.D. Quain, R.N.A. Prempeh, A. N. Bosompem and L.N.A. Allotey

Collaborating Institution: Nil

Source of funding: WAAPP

Introduction

Genotyping can also be referred to as fingerprinting which is the process of determining the genetic constitution – the genotype – of an individual by examining their DNA sequence. This provides information necessary to characterise germplasm. This kind of information is vital to document the identity of crop varieties released to facilitate the ability to trace individuals at any point in time. Currently, methods of genotyping, used by breeders include morphological, agronomic and biochemical systems. Characterization based on morphological characteristics alone may be limited since the expression of quantitative traits is subjective to strong environmental influence. Alternatively, molecular characterization techniques are capable of identifying polymorphism represented by differences in DNA sequences. This has the ability of analyzing variations at the DNA level during any stage of the development of the plant, where environmental influences are excluded. In genotyping molecular tools would be used to characterize and document fingerprints of crop varieties.

Objective

- To characterise and document fingerprint of released and elite crop varieties

Materials and Methods

Fingerprinting was carried out for yam, sweetpotato, cowpea, soybean and rice as follows:
Approximately 0.2g of the samples were crushed with liquid nitrogen for isolation of genomic DNA from young tender leaves of the Breeders' collections. In the laboratory, the Sweetpotato DNA extraction protocol modified from De la Porte (Egnin et al., 1998) was used to extract genomic DNA from the samples. The Nano Drop spectrophotometer was used to estimate the quantity and quality of DNA at 260nm (OD_{260}) and 280nm (OD_{280}). The DNA was resolved on 0.8% agarose gel in 1x TAE buffer stained with ethidium bromide. The DNA in the gel was visualized with an ultra violet trans-illuminator in an alpha imager. The agarose gel electrophoresis was also used for the determination of DNA quality and quantity.
Genomic DNA was diluted to an approximate concentration of 50ng/µl^{-1}, prior to being used for PCR. The PCR cocktail volume of 10µl was used and the composition (final concentration) of cocktail was 50ng/µl DNA, 5.0µl of thermo scientific 2x dream taq green master mix (2x dreamTaq buffer, 0.4mm each of dATP, dCTP, dGTP and dTTP and 4mM $MgCl_2$), 5µM forward and reverse primer, and nuclease free sterile water to top up to the 10µl volume and spin down. The thermo scientific PCR kit was used for the preparation of cocktail. The 100 base pair marker was loaded alongside the PCR samples. Electrophoresis (1.5% agarose) was run at 100volts and bands were visualized using ethidium staining.

Results and Discussion

- **Yam**

Fingerprinting was done for the three released varieties (*Mankrong Pona, CRI Pona* and *CRI-Kukrupa*) alongside seven local accessions (*Labreko, Muchumudu, Dente, Pona, Labako, Kpuno* and *Kperingo dente*). A set of Microsatellite developed based on *Dioscorea alata* genetic domains was screened to determine the appropriate annealing temperatures at which they produce reproducible bands/allele at estimated sizes. All 20 primers were selected and used for PCR. Fig 1 shows an example of gel that were generated. Amplicons generated from PCR products were manually scored (as present or absent). The scored data were yet to be analysed.

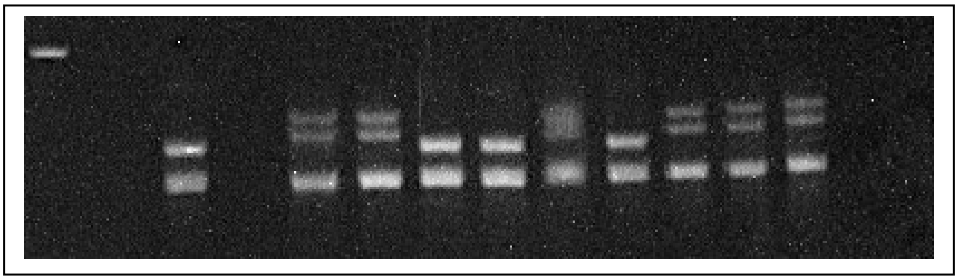


Fig 1: PCR amplicons using *Dioscorea* SSR primers (DA1C12) and 10 yam accessions

- **Sweetpotato**

DNA was isolated from the 12 released varieties of sweetpotato (*Apomuden, Sauti, Ogyefo, Ligri, Okumkom, Santom Pona, Faara, CRI Otoo, CRI Hi-Starch, Bohye, Dadanyuie* and *Patron*) and 24 sweetpotato elite varieties. Genotyping, using 20 SSR markers and 14 Expressed Sequence Tags (EST) SSR markers, has been completed. PCR amplicons have been scored and analysis using DARWINS and POPGEN will be carried out. DNA has been isolated from 34 foreign lines and these will be genotyped with SSR and EST SSR marker systems.

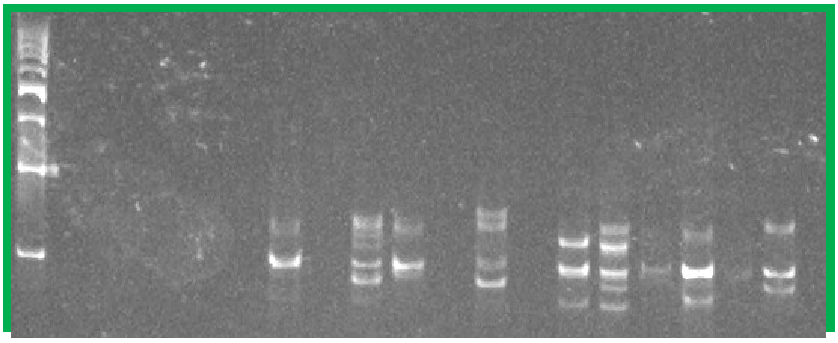


Fig. 2. PCR Amplicons of released sweetpotato varieties fingerprinting using EST SSR

- **Rice**

DNA has been extracted from eight released rice varieties (*Bouake 189, R1 AGRA, D1 GANG, Jasmine 85, Sikamo, Amankwatia, IDSA, and TOX 3377*). Fifty rice SSR primers were screended and 35 were selected for the fingerprinting study based on the production of scorable band from the PCR products. PCR amplicones (Fig 3) have been scored and analysis using DARWINS and POPGEN will be carried out.

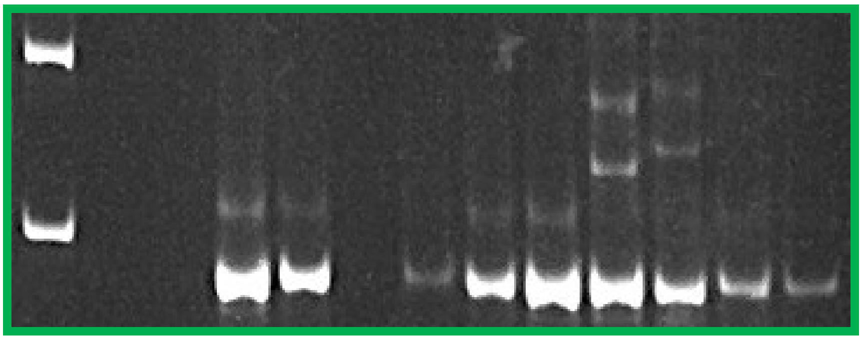


Fig. 3. Amplicons of released rice varieties

- **Soybean**

Genomic DNA has been isolated from six released varieties and five elite line. PCR is yet to be initiated. 36 SSR markers have been identified and purchased to be used for analysis. The 11 accessions have also been established on the field so that data can be collected on genomic characteristics to enable us to establish association linkage maps between morphological and genomic data. Five redox markers have been identified, to be used to screen germplasm responses to drought under screenhouse conditions.

- **Cowpea**

Genomic DNA has been isolated from 19 released varieties and one each of landrace, exotic and advanced line. PCR is yet to be initiated. 20 SSR markers have been identified to be used for analysis. The 22 accessions have also been established on the field to collect data on genomic characteristics to enable us to establish association linkage maps between morphological and genomic data.

Reference

Egnin, M., A. Mora, C. S. Prakash. (1998). Factors Enhancing *Agrobacterium* tumefaciens-Mediated Gene Transfer in Peanut (*Arachis hypogaea* L.). In Vitro Cell. Dev. Biol.-Plant 34:310-318.

Production of Cassava *in-vitro* plants and the development of a regional initiative for the « Diffusion of Integrated Management Approaches to control Major Cassava Pests and Diseases in West Africa » (DALIMA)

Research Team: M. D. Quain, A. Aubyn, D. Appiah-Kubi, V. Amankwaah, J. Manu-Aduening and M. Bissah* (*CSIR-PGRRI)

Collaborating Institution: Nil

Source of funding: CORAF/WECARD - USAID

Background

This project emanates from the West-African regional project 'Using in vitro tissue culture methods to preserve, multiply and distribute ACMV free cassava cuttings to farmers in West and Central Africa.'

Objectives

- To support CSIR-CRI to produce cassava cuttings *in vitro* (under WAAPP)
- To develop a project on the « Diffusion of Integrated Management Approaches to control Major Cassava Pests and Diseases in West Africa » referred to as "the DALIMA Project".

Activities to implement

Strengthen the production of African Cassava Mosaic Virus (ACMV) free cassava cuttings in Ghana:

1. Produce cassava vitro-plants :

   i. Micro-propagate *in vitro,* cleaned cassava varieties available at the CRI "*in vitro* cassava collection"

   ii. Acclimate and multiply vitro-plants, *in vivo*

2. Multiply and distribute cuttings to the national Innovation Platforms (IPs) Farmer-based Organizations (FBOs):

   i. Animate the IPs put in place for the project

   ii. Train (at the country level) cassava cuttings producers in acclimating and *in vivo* multiplication of vitro-plants

   iii. Multiply and distribute cuttings to the IPs and FBOs at the national level.

3. Communicate results of project activities.

Results and Discussions

Certified clean cultures of four improved cassava varieties from Ghana (*Ampong, Otuhia, Broni bankye* and *Sika bankye)* were multiplied on the routine cassava multiplication medium. Well-developed cultures were sub-cultured onto rooting media and later acclimatised in the screenhouse, following development of whole plantlets (Table 1). *In vitro* rapid multiplication of *Broni bankye* and *Ampong* are on-going to provide clean planting materials for breeding programs and innovation platforms. Field establishment of cleaned materials as a source of pre-basic seed will be carried out in February, 2016, after the harmatan season. About 200 seedlings were lost to pests (scale insects) in the screenhouse, and efforts are being made to manage the pests. Work was slowed down by frequent power outages and the breakdown of the standby generator.

Table 1. Quantities and location of cleaned planting materials

Genotype	Quantity on multiplication media	Quantity on rooting media	Total quantity *in vitro*	Quantity maintained in the screen house
Broni bankye	1482	136	1618	1384
Otuhia	294	274	568	300
Sika bankye	641	119	760	100
Ampong	196	-	196	189

Plate 1. Tissue culture derived certified clean cassava seedlings growing in the screenhouse

Determining the most cost-effective multiplication rates of *in vitro* cassava under screenhouse conditions

Objective

- To determine the best organic media for acclimatisation of cassava plantlets.

Materials and Methods

The experiment set up in September, 2015, in the screen house, using complete randomised design. There media used (treatments) were fibre, fibre with top soil, compost, compost with topsoil and peat pellet. Peat pellet was the control in this experiment. The cassava varieties used were *Broni bankye, Sika bankye, Otuhia and Ampong*. Forty plantlets were planted in each media. Data were collected on number of surviving plantlets, plant height, number of leaves, fresh weight, dry weight, leaf colour (appearance), number of branches, number of internodes and chlorophyll content.

Results

Data collected were yet to be analysed but visual observation showed that plantlets on peat pellet gave the best results, followed by those on fibre and compost with topsoil. All plantlets planted on compost died. The trial will be repeated early next year and data analysed for interpretation.

Rooting of acclimatized cassava cuttings using growth regulators (auxin) – Napthelic acetic acid (NAA) and Indole acetic acid (IAA).

Objective

- To ascertain if screenhouse acclimatized plantlets can be rapidly multiplied in *in vivo* to hasten their multiplication

Materials and Methods

The experiment was conducted in September 2015. Treatments used were four levels (0, 0.005, 0.01, 0.015 mg/L) of each auxin. Data were taken on survival, number of roots and vigour. The plantlets were later transferred into pots filled with topsoil (Plate 2) and data taken on their performance after the transfer.

Results

Callus formation was observed few minutes after the transfer into the auxins. Root formation was observed two weeks later. At three weeks some of the treatments produced roots that were not well developed. Generally IAA gave the best rooting. Data collected are yet to be analysed.

Plate 2. Cassava plantlets growing in pots filled with top soil

Project activities for Liberia

The Biotechnology team is assisting Liberia in *in vitro* rapid multiplication of clean planting materials. Five varieties of cassava from Liberia have been established *in vitro. In vitro* generated cultures were virus indexed as clean. Mass propagation has generated some quantities of cultures (Table 2).

Table 2. Quantities of *in vitro* cultures of Liberian cassava varieties

Genotype	Quantity on multiplication media
MH 95/0414	508
95/0259	203
MATARDI	6
Bassa girl	76
95/0259	6

New Project Proposal

To ensure continuity of the project a new project proposal was prepared with the assistance of a consultant (Prof. J.P. Tetteh of UCC), to solicit for funding. The proposal has since been submitted to the Biotechnology Program manager at CORAF/WECARD.

YIISFWA Supported Project (Develop technologies for high ratio propagation of high quality breeder and foundation seed of yam)

Rapid multiplication of clean planting materials and establishment of Aeroponics system for high ratio propagation

The YIIFSWA project has asked the Biotechnology Team to:

- produce at least 2000 seed yams using *in vitro* rapid multiplication of certified clean tissue culture yam varieties.
- put up a functional aeroponics screen house (25m - 30m length) x 8m (width) x 4m height) with appropriate ground work and insect lock (anti aphid net) and entrance foyer.

Specific Objectives

- In vitro rapid multiplication of clean yam planting materials
- Enhancement of Aeroponic system for the generation of clean planting material

Summary of progress

In vitro rapid multiplication of yam varieties received from IITA is on course. Other Yam varieties required by the CSIR-CRI yam breeding program are also being multiplied *in vitro*. All yam accessions being multiplied have been certified as clean by the Molecular biology laboratory using PCR-based virus diagnosis test. Cultures were also established on rooting media for production of whole plantlets, which were established in the screen house for production of macro tubers. Power outages and the breakdown of the stand-by generator, however, led to the loss of thousands of cultures. A number of cultures were, however salvaged, multiplied and established in the screen house for macro tuber production (Table 3). Cultures on multiplication medium are being subcultured onto rooting medium for screen house establishment to generate clean shoots, some of which will be used as sources of planting material for the aeroponics system. Some tubers have also been generated from tissue culture plantlets (Plate 3), and they will be given to the yam breeding team for field establishment.

Table 3: Project cultures currently available for breeding and aeroponics system

Yam Variety	Number In-Vitro	Number of screenhouse generated tubers
TDr 89/02565 (received in bioreactors)	176	457
TDr 89/02665 (received in-vitro in culture vessels)	45	-
TDr 89/02665 (received in bioreactors)	1032	-
Muchumudu	317	-
Matches	476	-
Mankrong Pona	454	550
Totals	2500	1007
Grand Total	3507	

Plate 3. Macrotubers generated from Tissue culture plantlets

Construction of the screen house is in progress and the plumbing and electrical works are about 70% complete.

Acknowledgements

- The Biotechnology laboratory received laboratory supplies in the form of chemicals, reagents, supplies and culture vessels from IITA, Ibadan to facilitate project activities.

- With financial support from WAAPP, a 450 KVA electricity generator was purchased to serve the Biotechnology Lab. An old 15kva standby generator was also repaired.

Using Silica Gel to Preserve DNA of Plant Tissue Prior to DNA Isolation

Research Team: R.N.A. Prempeh, M.D. Quain, D. Appiah-Kubi, H. Doku, L.A. Abrokwah, B. Akomeah, L. Allotey and A.N. Bosompem

Collaborating Institutions: Nil

Source of funding: WAAPP

Introduction

Obtaining high quality DNA is the first critical step in any genetic study. Working with fresh material is usually the best option (Bhattacharjee *et al*., 2009). However, this is difficult to manage on extended field trips. The DNA molecule is stable, but sensitive to DNA-degrading enzymes (nuclease) present in the organism's cells and in the environment. A water-free environment is often sufficient to at least partially inhibit this enzymatic activity. A deep freezing temperature, or a liquid buffer solution can also denature and inactivate nucleases (Jofuku and Goldberg, 1988), thereby preserving DNA integrity until the time of extraction. Over the years, the Biotechnology laboratory has used liquid nitrogen in preserving DNA integrity. However, with the frequent power outages, it is now difficult to get access to liquid nitrogen and the price has also been increased by 500%. It has therefore become necessary to look out for other alternatives ways to preserve DNA. Silica gel is the preservative of choice for most geneticists working away from the greenhouse. It is made of white, orange or blue crystals, packaged as dust-sized powder or larger beads up to 5 mm across. The crystals have a high capacity for absorbing moisture. It is cheap, easy to handle and most importantly, can dry a leaf sample in 12-24 hours, fast enough to preserve enough high-quality DNA for most applications.

Objective

- To determine if silica-gel dried samples could produce high quality DNA and yield.

Materials and Methods

Two accessions each of five crops were used for the study (Table 4).

Table 4: Crops used for the study

Crop	Accessions
Plantain	Apantu, Apem
Cassava	Ampong, Agbelifia
Cocoyam	Mayeyie, Akyede
Groundnut	Adepa, Yenyawoso
Yam	Kukrupa, Labreko

Fresh young leaf samples were harvested and some were put in plastic bags and immediately stored on ice while the remaining were put into containers containing silica gel at a ratio of 1:10 (i.e. 1 g of leaf sample to 10 g of silica gel).

In the laboratory, samples were stored at room temperature (25°C) until the DNA was extracted. Genomic DNA was extracted from stored samples taken at different times: immediately after harvest (Day 1) and at weekly intervals up to four weeks (week 1, week 2, week 3 and week 4). Three different weights (50 mg, 80 mg and 100 mg) of starting material were used for this study. Samples were ground in mortar and pestle and DNA was extracted using Egnin *et al* (1998) protocol. Samples were electrophoresed on 0.8% agarose gel to assess the quality of DNA. The NanoDrop 2000 spectrophotometer (Thermo Scientific, Wilmington, DE, USA) was then used to determine the quantity and quality of DNA. It uses the same absorbance principle as in any other spectrometric analysis in which the ratio of absorbance at A260/A280 is 1.8 for a pure DNA sample and a decrease in this value indicates the presence of contamination by mostly proteins, while an increase in the ratio indicates the presence of RNA (Sambrook and Russell, 2001). DNA concentration was estimated by employing the following formula:

Amount of DNA (µg / µl) = (OD) 260 *50 * dilution factor (1000).

Results and Discussion

- **DNA Quality**

Leaf samples of all five crops yielded DNA of similar quality for samples of day 1, week 1 and week 2 although some of the crops performed better than others. High-molecular-weight DNA with minimum signs of degradation was detected (Plate. 4). Storage of leaf samples on silica gel for 3 and 4 weeks before extraction resulted in degraded DNA. It may therefore be important to process samples as soon as possible upon return to the laboratory.

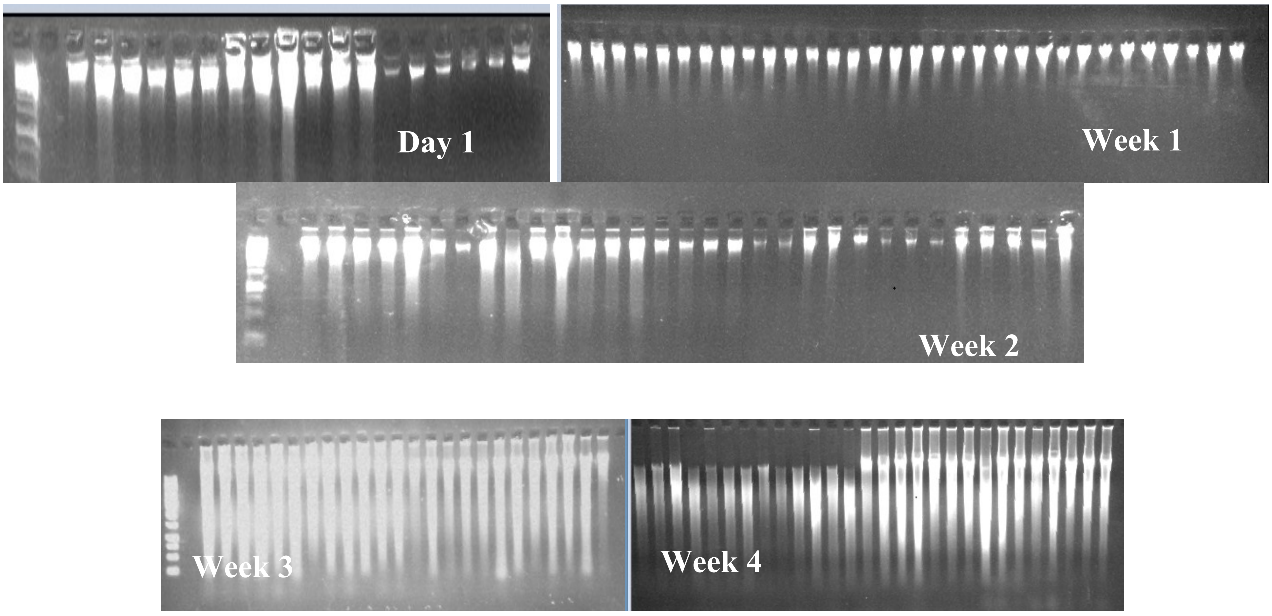


Plate. 4: Comparative analysis of DNA from different crops conserved over 4 weeks

DNA quality/purity was in the range of 1.27 (yam) to 3.74 (groundnut) with cassava having the best purity value of 1.81 for day 1 (Table 5). With the exception of yam whose purity was lower than 1.8 for weeks 1, 2, 3 and 4, an indication of protein contamination, all other crops had most of their purity values higher than 1.8 for day 1, weeks 1 and 2, an indication of RNA contamination. For weeks 3 and 4, purity values were mostly below 1.8. The protein and RNA contamination could be due to inadequate purification. This suggests that the purification step for this genomic DNA extraction method must be modified to get rid of all cellular components in order to obtain high quality genomic DNA.

Table 5: Quality of DNA extracted from different crops

Crop	Variety	Purity at 260/280 (Day 1)	Purity at 260/280 (Week 1)	Purity at 260/280 (Week 2)	Purity at 260/280 (Week 3)	Purity at 260/280 (Week 4)
Plantain	Apantu	1.84	1.85	1.90	1.81	1.67
		1.85	1.83	1.92	1.83	1.81
		1.86	1.89	2.01	1.81	1.78
	Apem	1.88	1.84	2.02	1.83	1.83
		1.88	1.82	1.85	1.81	1.90
		1.82	1.91	1.87	1.95	1.92
Cassava	Ampong	1.81	1.80	1.23	1.90	1.80
		1.88	1.87	1.87	1.74	1.83
		1.84	1.81	1.81	1.76	1.88
	Agbelifia	1.88	1.83	1.83	1.85	1.85
		1.87	1.84	1.85	1.80	1.79
		1.86	1.79	1.85	1.84	1.81
Cocoyam	Ma ye yie	2.01	1.79	1.29	1.83	1.85
		1.93	1.77	1.76	1.56	1.73
		1.97	1.83	1.89	1.96	1.64
	Akyedie	1.89	1.92	1.87	1.68	1.78
		1.92	1.83	1.88	1.76	1.74
		1.90	1.82	1.85	1.70	1.63
Groundnut	Adepa	2.39	2.24	1.00	1.78	1.74
		2.16	1.92	1.85	1.76	1.78
		1.98	1.96	1.88	1.78	1.74
	Yenyawoso	2.24	2.17	1.92	1.98	1.83
		3.74	1.96	2.09	1.77	1.81
		2.53	1.86	1.95	1.84	1.87
Yam	Kukrupa	1.94	1.51	1.02	1.55	1.41
		1.53	1.58	1.74	1.46	1.58
		1.27	1.52	1.56	1.42	1.57
	Labreko	1.73	1.63	1.75	1.45	1.49
		1.90	1.68	1.64	1.37	1.48
		1.84	1.71	1.65	1.41	1.59

- **DNA Quantification**

DNA yields were in the range of 75.7 – 2340.7ng μl^{-1} with cassava giving a higher yield (Table 6). Across the different storage periods, cassava and plantain had the best DNA yields. DNA yields were generally low for all the crops for day 1. The low yields observed on day 1 could be attributed to the long stay on the field during leaf sampling since these samples were stored on ice and not on silica gel like the other samples. In most cases, with the exception of week 3, yields increased as the duration of storage increased for weeks 1 and 2. The same trend was observed for the different quantities of starting material used. As the quantity of starting material increased DNA yields also increased. This could be due to the fact that as the duration of storage increased, the water content decreased thereby increasing the dry matter content, thus increasing the starting material quantity and subsequently resulting in high DNA yield. It must, however, be noted that an optimum weight/quantity of the starting material results in high DNA yield and quality, with zero or minimum contamination, and beyond this optimum weight both the yield and quality reduce. This suggests the need to establish the optimum quantity of starting material as well as how long the dehydrated sample could be stored prior to extraction for high quality and yield of DNA. From this study the optimum quantity of starting material for dehydrated leaf sample (using silica gel) was between 50 mg and 80 mg and these dehydrated samples could be stored for up to two weeks.

Conclusion and Recommendations

The results of this study has shown that high yield and quality of DNA can be obtained from 50 - 80 mg samples of silica-gel dried leaf samples which have been stored for not more than two weeks. Silica-gel is an attractive low-cost alternative for preservation of samples for DNA extraction. The yields and quality of DNA obtained would be equivalent to that obtained from fresh or frozen tissue.

The method described in this study is both rapid and cost-effective when a large number of samples is to be collected from remote locations for DNA needs to be extraction. It is recommended that, this study be repeated in order to establish the optimum amount of dehydrated sample to use for DNA extraction.

Again, since this study looked at different crops it will be more appropriate to establish the DNA extraction protocol that would produce the best yield and quality of DNA across all the crops, then subsequently, this DNA extraction protocol would be used for the study.

Table 6: Concentrations of DNA extracted from different crops

Crop	Variety	Lab Code	DNA Conc (ng/µl) Day 1	DNA Conc (ng/µl) – Week 1	DNA Conc (ng/µl) – Week 2	DNA Conc (ng/µl) – Week 3	DNA Conc (ng/µl) – Week 4
Plantain	Apantu	1a	99.3	244.8	439.8	420.5	224.9
		1b	104.5	296.2	367.9	343.1	401.3
		1c	92.1	386.8	477.2	345.7	582.6
	Apem	2a	190.6	361.1	555.0	253.1	347.2
		2b	118.7	376.5	384.2	477.0	291.0
		2c	98.6	516.6	798.9	372.7	445.3
Cassava	Ampong	3a	456.1	550.7	686.5	534.1	943.3
		3b	728.6	746.8	856.1	1490.2	1374.2
		3c	902.0	1002.5	1941.2	1567.2	1501.9
	Agbelefia	4a	679.8	422.5	2340.7	795.4	1001.2
		4b	553.3	1116.3	1631.8	1788.8	1747.8
		4c	713.6	2155.7	1954.1	1053.9	1844.5
Cocoyam	Ma ye yie	5a	145.6	477.4	403.4	317.4	249.0
		5b	75.7	295.5	822.7	113.1	184.4
		5c	87.7	211.4	632.1	179.4	253.4
	Akyedie	6a	76.8	147.7	683.5	277.1	151.9
		6b	161.8	611.3	414.7	196.8	198.8
		6c	235.7	668.3	1000.3	404.2	200.6
Groundnut	Adepa	7a	519.7	234.2	354.6	854.0	1046.4
		7b	619.5	478.7	553.1	582.1	1217.2
		7c	413.2	743.3	561.0	1183.9	1764.3
	Yenyawoso	8a	399.2	363.8	695.5	566.0	797.7
		8b	179	280.4	511.7	1103.0	1153.2
		8c	287	1050.8	616.7	885.1	945.6
Yam	Kukrupa	9a	288.1	346.5	165.5	294.4	357.7
		9b	228.8	258.2	281.9	540.1	673.9
		9c	106.3	477.9	384.2	735.2	472.8
	Labreko	10a	188.5	392.8	531.5	500.1	377.6
		10b	259.1	303.5	765.3	680.6	431.7
		10c	90.5	736.2	705.9	756.9	492.5

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Molecular Characterization of cassava accessions conserved in the cassava gene bank

Research Team: R.N.A. Prempeh, J.A. Manu-Aduening, A. Aubyn, E. Lotsu, O. Ohene Djan and L.A. Allotey

Collaborating Institution: Nil

Source of funding: WAAPP

Introduction

Cassava is a major food crop in sub-Saharan Africa and an important calorie provider for more than 200 million people constituting about one-third of the population (FAO, 2008). A high level of diversity exists on the field due to spontaneous seedlings from natural hybridization (Montero Rojas *et al*., 2011). The assessment of the levels of genetic diversity in cassava is important for the identification of diverse parental combinations to develop segregating progenies with maximum genetic variability for further selection. Numerous studies have used morphological descriptors to determine the genetic diversity among cassava genotypes (Rimoldi *et al*., 2010; Asare *et al*., 2011). Morphological descriptors permit easy identification and differentiation of accessions. Generally, these descriptors have high heritability, suggesting that they are expressed in different environments (Rimoldi *et al*., 2010). The use of molecular markers may permit the detection of genetic differences among closely related genotypes that are not affected by the environment (Collard *et al*., 2005). Different types of molecular markers have been developed, however, simple sequence repeats (SSR) have been identified to be among the most efficient markers for diversity studies in cassava because they provide more information due of their high levels of allelic variation and co-dominant character. These are very useful in characterization and have been used extensively to characterize genetic diversity in cassava (Haysom *et al*., 1994).

Objectives

- To assess the genetic diversity among cassava accessions conserved *in vivo* using molecular tools
- Conserve germplasm *in vitro*.

Specific objectives

- Characterize cassava germplasm using molecular tools
- Identify duplications among cassava germplasm conserved in the gene bank
- Create a core collection of cassava germplasm

Materials and Methods

A total of 195 accessions comprising 126 landraces and 69 exotic materials were established at Fumesua, Ohawu and Ejura. One of the accessions failed to germinate hence 194 accessions were used for the study. Leaf samples were collected from the 194 cassava accessions and genomic DNA was extracted immediately using standard procedures according to Egnin *et al.* (1998) with slight modifications. Genomic DNA was stored at -20 ^{O}C till polymerase reaction was carried out. A set of 36 simple sequence repeat (SSR) markers which were widely distributed across the cassava genome were screened and 34 SSR markers that gave reproducible bands/alleles were selected for the molecular characterization. So far 15 of the SSR markers have been used for genotyping all the 194 cassava accessions.

Way Forward

This activity is on-going and the rest of the SSR markers will be used for genotyping.

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Evaluation of elite cassava clones for delayed Postharvest Physiological Deterioration (PPD) in cassava storage roots

Research Team: R. N. A. Prempeh, J.A. Manu-Aduening, E Lotsu, O. Ohene Djan and L. A. Allotey

Collaborating Institution: IITA

Source of funding: WAAPP

Introduction

Despite the importance of cassava as a crop, a major abiotic stress that affects its production is its short shelf life known as postharvest physiological deterioration (PPD). PPD is a physiological process where the roots deteriorate 24 -72 hours (*Beeching et al*., 1994) after harvest when they are detached from the mother plant. The deterioration starts from the central vascular bundles of the root, spreads to the adjacent storage parenchyma and subsequently stored starch undergoes structural changes (*Plumbley and Rickard, 1991*). Visible signs of PPD are vascular streaking with blue or black discoloration rendering the roots unpalatable and unmarketable thereby reducing its market value. It is therefore important that for every elite cassava clone that will be released to farmers, PPD evaluation is carried out to determine how long the material can be stored before they deteriorate.

Objectives

To determine:

- the reaction of elite clones to PPD
- the effect of time of harvest on PPD

Materials and Methods

Six elite cassava clones (12/0245, 12/0236, 12/0197, AW3/10/008, AW3/10/11 and ANKA/003) and two checks (*Debor* and *Ampong*) were established at Fumesua, Ejura and Ohawu in May, 2015, using RCB design with three replicates.

Roots will be harvested monthly from 8 months after planting (MAP) to 12 MAP, taking care to minimize wounding since it accelerates PPD. Data would be collected on storage root number per plant (SRN); fresh storage root yield (FRY); biomass yield (BY) and disease severity and incidence. Harvest index (HI) and Dry matter will also be estimated. Ten storage roots from each genotype will be selected and stored as intact roots (*Booth, 1977*) on shelves in a barn under ambient conditions where air circulates freely through the shelves. Five of the roots will be evaluated for incidence of PPD three days after harvesting and the other five will be evaluated seven days after harvesting using standard methodology for PPD quantification (*Wheatley* and *Gomez, 1985; Sanchez et al., 2006; Morante et al., 2010*). Data collected shall be analysed using Analysis of Variance (ANOVA) and GENSTAT version 12. Separation of means will be carried out using Fisher's Least Significance Difference (LSD) at 5% probability levels. Pearson's correlation will be carried out to determine the linear relationship between PPD and other important traits.

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ISO 17025:2005 Accreditation of the Biotechnology Laboratory

Team: R.N.A. Prempeh, M.D. Quain, A. Oppong, D. Appiah-Kubi, B.M. Dzomeku, M.O. Adu-Gyamfi, L.A. Abrokwah, L. Allotey and A.N. Bosompem

Source of funding: WAAPP

Introduction

In migrating from a National Centre of Specialization (NCoS) to a Regional Centre of Excellence (RCoE), nine qualification criteria have been identified which include acquisition of International Organization for Standardization (ISO) accreditation. ISO has a specialized system for worldwide standardization and the Biotechnology laboratory of the CSIR-CRI is seeking to be accredited for ISO 17025:2005. The scope of this standard specifies the requirements for the competence to carry out tests and or calibrations. It covers testing and calibration performed using standard methods, non-standard methods, and laboratory-developed methods. In achieving the RCoE status, it has become necessary that the NCoS attains the ISO status in 2016. The objective of this activity is to prepare towards the attainment of ISO 17025:2005 for at least one of the test methods used in the laboratory.

- **Scope of Accreditation**

The scope is the "detection of viruses in planting materials". The test method is "detection of African Cassava Mosaic Virus (ACMV) and East African Cassava Mosaic Virus (EACMV) in cassava using Polymerase chain Reaction (PCR)".

- **Documentation and Improvement of the Quality Management System**

A team was set up to assess the Laboratory's current documentation system and determine if there were documentations relating to ISO 17025:2005. One internal audit was conducted to determine if the Quality System was being implemented and improved.

Progress so far

It came out that the Lab. had none of the documentations related to ISO 17025:2005. This led to the development of manuals, policies, procedures, forms, schedules and work instructions with assistance from Sky Portal Consults. These documents have subsequently been reviewed by the Quality Team. Currently, in addition to the Quality and Technical Manuals, the Lab. has four mandatory policies, 20 procedures and 10 forms. All these documents have unique identity. Based on the findings of the Internal Audit, all equipment were calibrated by Ghana Standard Authority (GSA). Corrective and Preventive actions had also been carried out to ensure improvement of the Management System.

Way Forward

The team will ensure the implementation and improvement of the Quality System. Identify and maintain the reference material for the test method, subsequently, develop a procedure for the storage of reference material.

TISSUE CULTURE

Production of clean seed yam of *Mankrong Pona* through tissue culture micropropagation techniques

Research Team: D. Appiah-Kubi, V.A. Amankwaah, M.D. Quain, A. Aubyn, A. A. Aboagye and M.E. Ted-Coffie

Source of funding: WAAPP

Introduction

Yam production is constrained by lack of clean seeds, incidence of pest and diseases, low soil fertility and unavailability of labour. Among these constraints, access to clean seeds is one of the most critical to ensure sustainable yam production. The existing seed yam system has been the traditional method of using farmers' saved seeds; and is characterised by pest and diseases (Aighewi et al., 2014). The farmer uses this same parent seed stock year after year which inadvertently carries with it high loads of pest and disease pathogens leading to low productivity and low income. It is in this light that the use of clean and certified seeds from tissue culture micropropagation is being advocated; especially in the dissemination of released yam varieties to farmers (Mignouna et al, 2014).

Objective

- To access the yield output of tissue culture derived primary seed yam of *Mankrong Pona* (a released variety) on secondary seed production.

Materials and Methods

- **Categorization of primary seed-yam tuber**

Primary seed yam tuber is the first tuber derived from acclimatized tissue culture plantlets. Harvested tubers from potted plants were stored in ambient conditions of temperature at 29-31^{0}C and relative humidity at 53-79%. The tubers were sorted out and categorized into small (0.01-10.00 g), medium (10.01-20.00 g) and large (>20.01 g) sizes, when the period of dormancy was over (when buds started sprouting at week fifteen of storage). Only 8% of the total number tubers was considered to be large.

- **Production of secondary seed yam under screen-house chambers**

Three chambers (each measuring 3m x 3m) were filled with sterile soil, and classified loamy soil (top soil, sand, poultry manure mix in 3:1:1). Three rows of ridges were made in each chamber with (a planting distance of 30 cm intra rows and 50 cm inter rows. The primary seeds of all three sizes (small, medium, large) were planted on the ridges at a planting distance of 30 cm intra rows and 50 cm inter rows, using complete randomised design with three replications. Staking was done with sticks to direct foliar growth above ground for enhanced photosynthesis and to avoid soil borne diseases. All other agronomic practices including weeding, watering, a monthly routine spraying with pesticides were also carried out. Disease incidence on the foliar parts of each plant was scored. Secondary tubers were harvested after eight months. Fresh weight of tubers was recorded. Data collected were statistically analysed using Genstat (9th Ed.).

Results and Discussion

Preliminary results indicated that tissue culture derived primary seeds were viable sources of planting material. The mean yield of secondary tubers from small, medium and large primary seed yams were 402.0 g, 589.0 g and 1037.0 g respectively (Table 7).

Table 7: Yield (g) of secondary tubers from primary seed yam

Primary seed	Mean secondary yield
ST	402.0 ab
MT	589.0 ba
LT	1037.0* c
Lsd (5%)	330.5
cv%	21.6

ST = Small sized tuber (0.01 – 10.00 g), MT = Medium sized tuber (10.01 - 20.00 g), LT = Large sized tuber (> 20.01 g). Means with same letters are not significantly different; * significantly different

The analysis of variance of data showed that, yield outputs from small and medium sized tubers were not significantly different but were different from yields from the large tuber size. There were appreciable sizes of secondary yam tubers obtained from the three categories of primary seeds which could be used as minisetts (Plates 4a and 4b); Some of the secondary tubers with a mean weight of 1037.0 g, would hardly be used by farmers as seed yam.

Plate 4a: Small tuber size (0.01-10.0 g)

Plate 4b: Secondary seed yam from small tubers

Conclusion and Recommendations

Mean yield of secondary yam tubers increases with increasing seed sizes. Yields from large-sized primary tubers was significantly different at 0.05 % probability. For good management purposes, the use of screen-house or a small plot on farmers' fields is being recommended for quality seed yam production. In a controlled or confined area with access to water it will be easy to maintain high quality hygiene for seed yam production. Tissue culture derived primary seed yam of *Mankrong Pona* weighing more than 20.0 g has the potential to be ware yam after secondary growth.

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In vitro production and rapid multiplication of clean seed yams of three local landraces of Yam (*Pona, Dente* and *Labariko*)

Research Team: D. Appiah-Kubi, M.D. Quain, J.N.L. Lamptey, A. A. Aboagye and E. Marfo

Collaborating Institution: Nil

Source of funding: CAY-Seed Project

Introduction

The traditional method of producing seed yam has been the farmer-saved seeds (Aighewi, 2014). The quality of these seeds is determined by the farmers' own standards and experience. To improve the farmers' practice of producing seed yam, a positive selection method has been adopted by CAY-Seed project; where symptom-less plants are tagged on farmer's field and are monitored (with the farmers) so that harvested tubers are stored as seed for the next cropping season.

Objective

- To use tissue culture micropropagation techniques, to generate clean seed of local yam landraces for farmers and for degeneration and storage life studies.

Materials and Methods

Mini-setts of *Dente*, *Labariko* and *Pona,* yam varieties were obtained from the yam breeding programme and established under screen-house conditions in polybags. Explants (both meristem and axillary buds) of these varieties were initiated *in-vitro* on MS medium. After six months of *in vitro* initiation from nodal and meristem explants, rescue from tissue sprouting was done for in-vitro establishment of plantlets. The first multiplication of plantlets has been done for all the three varieties (Plate 5). To ensure regeneration of clean true-to-type planting materials, cultures were coded for easy tracking of virus tested plantlets from their respective lines of pedigree.

Results and Discussion

Adequate cultures have been established and multiplied (Table 8). Portions of plantlets are being rooted and acclimatized for the production of microtubers. Preliminary results on virus indexing indicated that plantlets produced are disease free.

Table 8: *In vitro* production of seed yam of three yam landraces

Variety	Number in multiplication	Number on rooting media
Dente	218	90
Pona	282	130
Labariko	206	80
Total	706	300

Plate 5: *In vitro* multiplication of yam plantlets

Conclusion

Yam tissue culture initiation, establishment and rapid propagation towards production of clean planting material (plantlets/tubers) take a lot of time (approximately 18 months). However, once clean cultures are established it takes up to seven months to produce clean tubers. Clean tubers will also sprout after the normal dormancy period.

Reference

Aighewi, B.A., Maroya, N. G., and Aseidu, R. (2014). Seed yam production from minisetts: A training manual. IITA, Ibadan, Nigeria. 40 pp

In vitro establishment, multiplication and acclimatization of five promising taro lines

Research Team: D. Appiah-Kubi, M.D. Quain and G. Osei-Diko

Collaborating Institution: Nil

Source of funding: WAAPP

Introduction

Taro [*Colocasia esculenta* L. (Schott.)] is an important food security crop in Ghana. Over the years the years, it has been regarded as a neglected and under-utilized crop thus becoming “orphan crop” (Akwee et al., 2015). According to Ashanti Regional RELC 2015 planning session report, there appears to be extinction or unavailability of improved planting materials (Berchie and Nasarah, 2015). Based on previous work by CSIR-CRI scientists five promising lines of taro have been selected and established *in vitro* to generate a stock of clean planting materials.

Objective

- To produce 6,000 (1,200 for each line) clean stock of planting materials of the five selected promising taro lines during 2016 planting season.

Materials and Methods

Meristem explants of five taro lines (BL/SM/16, BL/SM/115, BL/SM/151, BL/SM/158 and CE/IND/12) were surface-sterilised under aseptic conditions in a laminar flow hood. Excised meristems were initiated on MS medium supplemented with auxin, cytokinins and adenine sulphate. Cultures were incubated at 16hr photoperiod, and temperature of 25±1°C. Subculturing was carried out at eight weeks intervals on rapid multiplication medium.

Results and Discussion

Work is progressing satisfactorily. The various stages reached in the process are summarized as Table 9. Acclimatized seedlings would be available to the agronomists for field evaluation.

Conclusion and Recommendations

In the era of climate change and its challenges, the use of tissue culture derived planting materials to produce healthy planting materials all year round, should be promoted.

Table 9: In vitro production of taro planting materials

Taro line / accession	Number on multiplication media	Number on rooting media	Number in screen house
BL/SM/16	154	55	131
BL/SM/115	228	185	218
BL/SM/151	242	169	208
BL/SM/158	490	197	139
CE/IND/12	408	355	101
Total	1,522	961	797

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Assessment of Protocol for Medium Term *In vitro* Conservation of two Taro (*Colocassia*) Genotypes (SAO 002 and CE/MAL/32)

Research Team: D. Appiah-Kubi, M.D. Quain, and G. Osei-Diko

Collaborating Institution: Nil

Source of funding: WAAPP

Introduction

Conservation of plant genetic resources is important for the continuous use and improvement of crops especially an "orphan" crop like taro. Traditionally, taro is conserved *in-situ* and is susceptible to pests and diseases, extreme high temperatures and drought. The need to identify appropriate conservation systems becomes paramount in this era of climate change. *In vitro* slow growth for short and medium term has been used for conservation of several species (Negash et al. 2001).

Objective

- To assess protocol suitable for *in vitro* taro conservation using mannitol and White medium (1963).

Materials and Methods

Shoot-explants of cultures of two high performing *in vitro* taro lines (SAO 002 and CE/MAL/32), which had established and were growing on MS multiplication medium were used for the conservation experiment. The explants were cultured on MS medium supplemented with various concentrations of mannitol at 0.0g/l (control), 20g/l, 25g/l, and 30g/l and White medium [Phyto Technology laboratories brand; contains the macro- and micronutrients as described by White (1963)] as treatments. Growth parameters such as number of leaves and height of shoot were measured for six months under conditions of 20±1^{0}C and 12 hour photoperiod. Data were analysed using Genstat (9th ed.) and a line graphs plotted for respective treatments.

Results and Discussion

There was initial growth response with all the media treatments (Figs. 5a – 9b). Growth response to the control treatment was highly profuse (Plate 6), however, plant cultures on White media were dead by the sixth month as depicted by an apparent straight line (Figs. 5a and 5b). White media might not be the treatment of choice for slow growth of taro. Treatments with mannitol produced varying slow growth responses. A greater slowed growth was seen on treatments with 25 g/l and 30 g/l mannitol indicated by reduced plant height and smaller leaves (Fig. 9a and 9b). In spite of the slow growth observed in treatments with 25 g/l and 30 g/l mannitol, there was high plant vigour expression even at the sixth month.

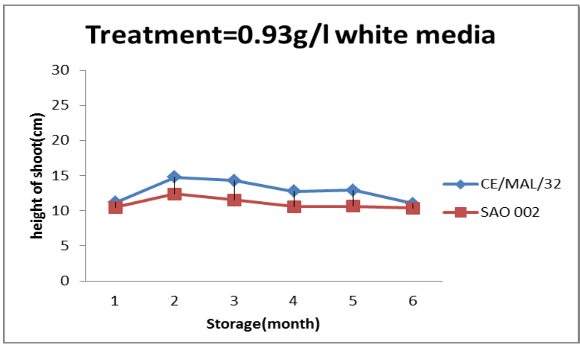

Fig. 5a

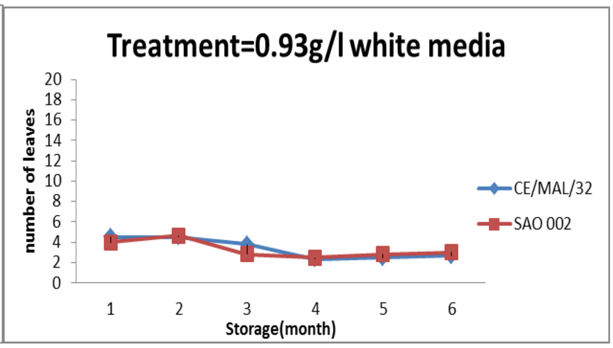

Fig. 5b

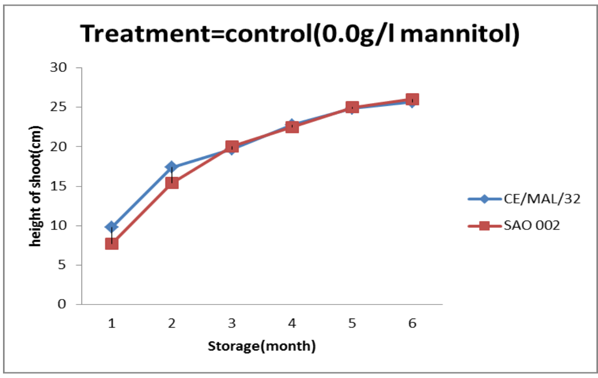

Fig. 6a

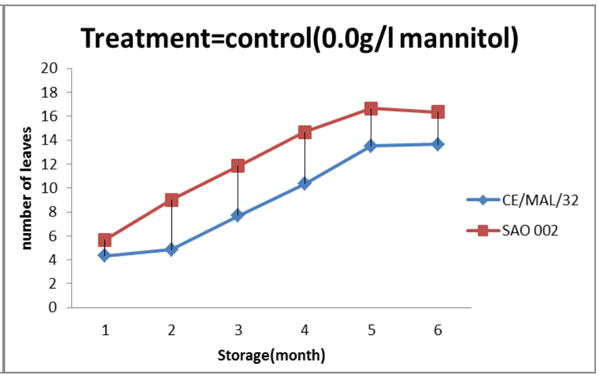

Fig. 6b

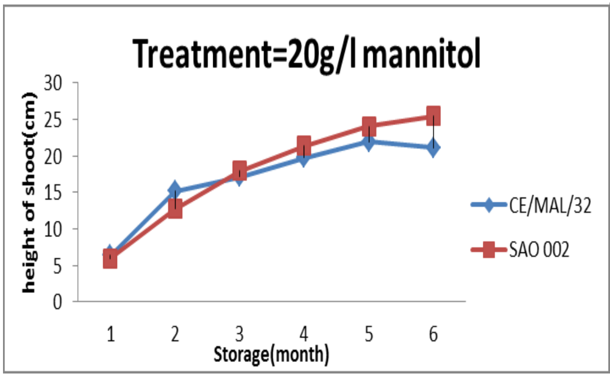

Fig. 7a

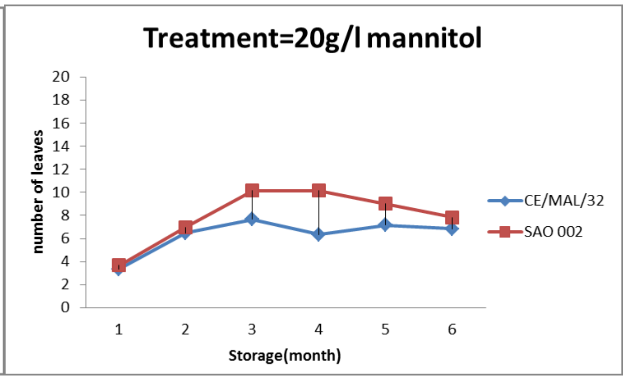

Fig. 7b

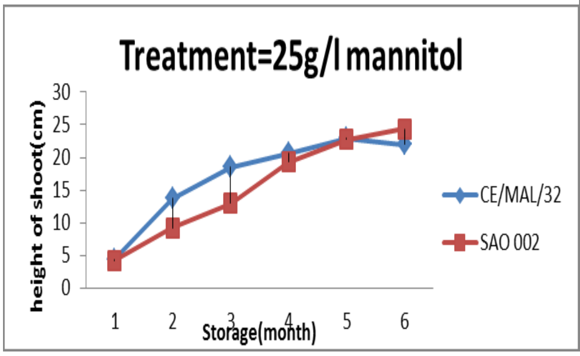

Fig. 8a

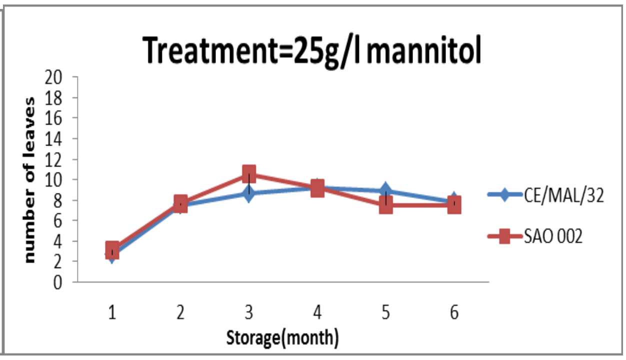

Fig. 8b

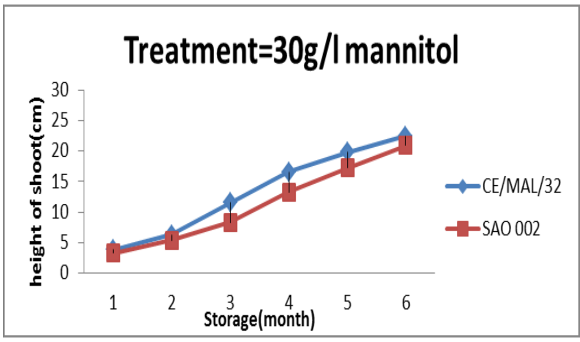

Fig.9a

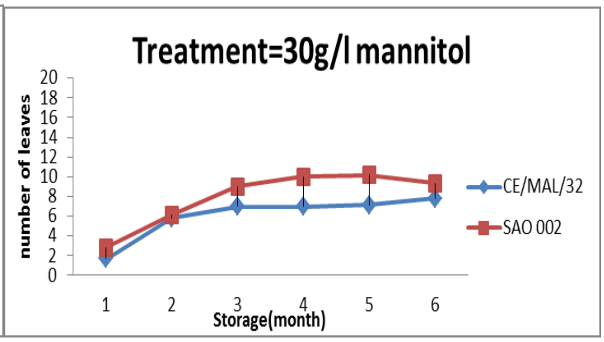

Fig. 9b

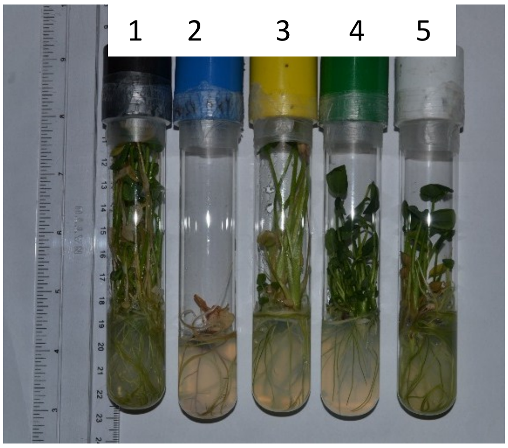

Plate 6: In vitro conservation of taro under different treatments
Legend: 1 = Control; 2 = white media; 3 = 20g/l mannitol; 4 = 25 g/l mannitol; 5 = 30 g/l mannitol

Conlusion and Recommendation

White media was not the appropriate media protocol for slow growth conservation of taro. It was evident that treaments with 25 g/l and 30 g/l mannitol produced *in-vitro* slow growth in taro and therefore could be ideal for medium term conservation.

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Effect of seed size on seed yield and quality of six maize (*Zea mays*) genotypes

Research Team: H.M. Bortey, O. A. Sadia and E. Adjei Asamoah

Collaborating Institution: None

Source of funding: Nil

Introduction

Seed size is an important physical indicator of seed quality that affects vegetative growth and is frequently related to yield and harvest frequency (Ambika *et al*., 2014). Seed size is one of the important yield components which has an effective role in cultivar adaptation to different conditions with effect on seed vigour (Morrison and Xue, 2007). Grant and James (2000) and later Farokh and Gdesh (2005) reported that there is a negative correlation between soybean tolerance to climatic factors and its seed size, because large seeds require more water resources for their vital activities and consequently they can be damaged by reduction of osmotic potential.

Roozrokh *et al.,* (2005) on chickpea showed that large seeds had high germination percentage, more seedling dry weight and better electrical conductivity compared to small seeds. A study by Mazum *et al*., (1994) to investigate the effect of seed size on sprouting of Maize revealed that, by increasing the seed size from 7.5 to 8.5mm, the seedling germination was increased and the germination fluctuations were decreased. It was thus recommended that for improving seedling germination, seeds should be graded.

In Ghana, most seed producers who condition their Maize seeds (by drying, shelling, cleaning, etc.) usually keep seeds of the average/medium size for sale. Consequently, seeds categorized as "over size" and "under size" (from Spouts 1 and 2 of ASC) are often kept as grains for food. This practice reduces the quantities of seeds available for sale as Certified or Foundation seeds. This study thus, sought to determine whether the seed size categories as obtained from the Air Screen Cleaner (ASC) processing machine has any seed quality or yield effect.

Objectives

- To determine how seed size affects the quality and yield of maize genotypes
- To establish the influence of genotype and seed size on germination and seedling growth under different cropping seasons.

Materials and Methods

Seeds of six maize genotypes, four medium-late maturing maize varieties (*Obatanpa, Abelehi, Dobidi* (White) and *Honampa* (Yellow), and two early maturing varieties (*Omankwa* and *Aburohemaa*) were obtained from the Institute's Maize breeding programme and screened for different seed sizes using an Air Screen Cleaner (ASC) at the Seed Processing Centre at CSIR-CRI, Kwadaso Station. The screen sizes of the ASC for the top and bottom were 10.5mm and 7.5mm respectively. Seeds of different sizes, obtained from spouts 1, 2 and 4 of the ASC, were randomly sampled and used for the study. Seeds from spouts 1, 2 and 4 seeds were categorized as "over-sized", "under-sized" and "average/medium sized, respectively.

- **Laboratory Experiment**

  Seed samples were taken to determine their diameter according to the size categories. Basic seed quality tests including, seed moisture content, 1000 seed weight, percent seed vigour, based on 1st count of germination test, percentage seed germination (SGP) were conducted according to ISTA (2007) rules.

- **Field Experiment**

  Samples of the three seed size categories from each of the six genotypes were planted on a 5m x 5m plot in a RCB design with three replicates. The maize genotypes were planted at a spacing of 70 x 40cm with two seeds per hill and thinned to one after two weeks of emergence. Data were collected on plant stand at 2 weeks after planting (WAP), plant diameter before and after fertilizer application, days to 50% tasseling, days to 50% silking, foliar diseases (Blight, Rust and Maize Streak) score, plant height at tasseling, ear height, stem lodging, root lodging, Total lodging, plant stand at harvest, total grain yield, seed moisture content at harvest, Germination percentage at harvest. First NPK fertilizer was applied at 2 WAP followed by Sulphate of Ammonia at 4 WAP.

Seedling diameter was measured 2 weeks after fertilizer application. Data were collected on plants in the two middle rows. Field maintenance activities (including weed and pest control) were carried out as and when necessary.

Results and Discussion

Data collected are being analysed.

Way Forward

The results would be reported after data analysis has been completed.

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Influence of Farmers' Seed Mixtures on Selected Postharvest Characteristics of Tomato (*Lycopersicon esculentum*)

Research Team: H. M. Bortey and E. Adu-Kwarteng

Collaborating Institution: None

Source of funding: KAFACI

Introduction

Smallholder farmers in Ghana generally rely on their own saved seeds for tomato production (Bortey *et al.,* 2011). This could be attributed to the unavailability of seeds of improved vegetable crops. Unfortunately, the seeds saved by the farmers for replanting are of poor (physical and genetic) quality. They are mixed and impure and germination percentage is often low. Harvested fruits from these seeds are non-uniform (different shapes and sizes) and they have different shelf lives. It is thus hypothesized that these seed mixtures affect fruit uniformity (shape and sizes) and storage life. This study seeks to determine the link (if any) between seed mixtures and some fruit quality characteristics (shape, shelf life). It is expected that information generated from this study will be used to educate farmers on the need to use quality and improved seeds.

Objective

- To establish the effect of seed mixtures on selected postharvest characteristics of tomato fruits

Specific objectives

- To evaluate and identify the level of seed mixtures within a harvested lot of tomato fruits from different sources
- Establish the possible link between the mixtures and their postharvest characteristics.

Materials and Methods

Tomato (*Lycopersicon esculentus*) fruits from five farmers' fields at Agogo (Forest zone) and three farmers' fields at Akumadan (Transition zone) were used for the study. Fruits were randomly harvested, and fruits from each farmer's field were kept in a plastic basket, labelled and conveyed to the Institute for fruit characterization and storage studies. Fifty fruits (out of 200 harvested) were randomly selected and scored to determine the level of distinctness. The UPOV Text guideline for Tomato (TG/44/11 Rev.) was used for scoring fruit characteristics (fruit shape in longitudinal section, ribbing at peduncle end, depression at peduncle end, fruit shape at blossom end and locule number).

- Determining differences among varieties

  Four quantitative characteristics - ribbing at peduncle end, depression at peduncle end, fruit shape at blossom end and number of locules - were examined, in addition to fruit shape in longitudinal section - a pseudo-quality characteristic.

- **Shelf life determination**

  To determine the shelf life of each fruit type, the initial weight was recorded and repeated four times at five days intervals. Rotten fruits were taken away from the lot as storage time progressed.

- **Determining number of locules**

  For locule number, five fruits from each category, were cut in transverse section and the number of locules was counted and the average recorded.

Results and Discussion

Generally, a minimum of four fruit shapes were recorded across the farmers' fields. Most of the fruits from fields at Agogo had Oblate shape, ranging from (48 to 76%) though fruits from one farmer (Farmer 4)'s field were mostly (76%) circular in shape (Fig. 1). This depicts the prevailing situation in the seed system in Ghana, particularly the vegetable seed system. An earlier study (Bortey *et al.,* 2011) revealed that although approximately 52% of tomato farmers save their own seed for replanting in the subsequent years. The other farmers obtain seeds from the local market (28%), agro-store (15%), neighbours/friends (4%) and NGOs (1%). Further investigations revealed, that almost all these seeds obtained from these sources are farmer-saved seeds. Fruit shapes such as Cordate, Ovate, Obovate, Pyriformm and Obcordate were unique to farmers in Akomadan area (Fig. 2), and the level of seed mixture ranged from 10 to 30% across all farms.

Fruit shapes at blossom end further revealed 10 different genotypes of tomato in the study areas. The level of mixture ranged from 2 to 76% in the Forest zone and 10 to 30% in the Forest-Transition zone. This can be attributed to the sources of seeds and the non-existence of a formal seed system for the vegetable industry compared to the cereals. The practice of seed exchange has several implications - introduction of pest and diseases to new fields and low crop yields among others. This also reveals a rich gene pool for crop improvement and development.

- **Shelf life**

Generally, fruits of the flattened shape stored poorly among the others from both locations (Fig. 4 and 5). The rate of weight loss was higher compared to oblong or circular fruit shape. Visually, the flattened shape fruit has a thin skin (epidermis) compared to the oblong and circular shaped fruits. Fruit shape (genotypes) that stored well (up to 20 days with good appearance) were the pyriform, oblong, obcordate.

These types had thick fruit skin which felt firm (in the palm). Water loss in fruits is partially restrained by the fruit skin. Thus, the observed rates of deterioration could be attributed to differences in skin thickness among the different fruits.

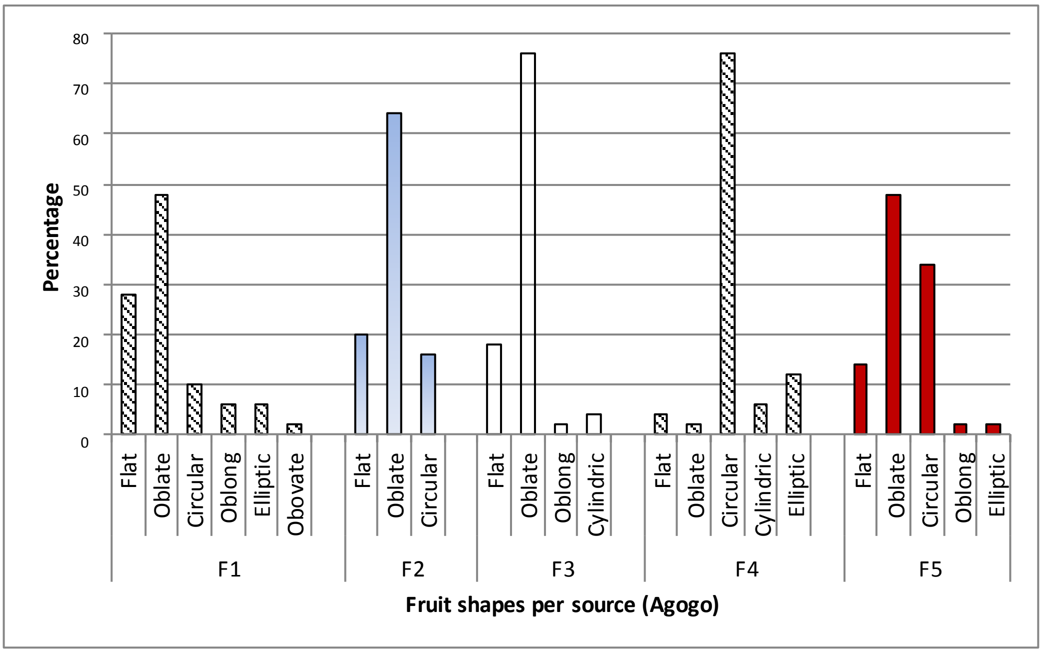


Fig. 10: Seed mixtures evidenced by fruit shapes per farmer (Agogo)

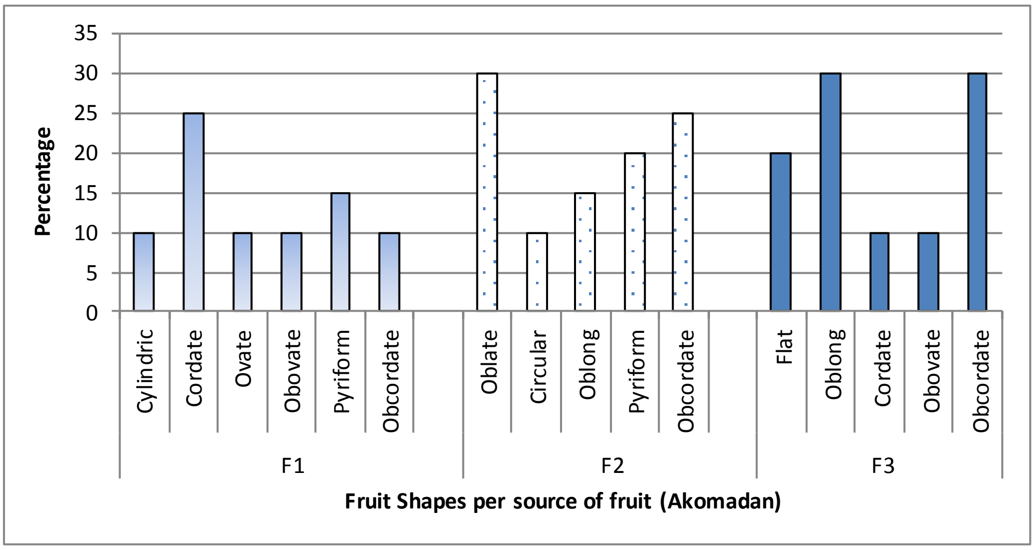
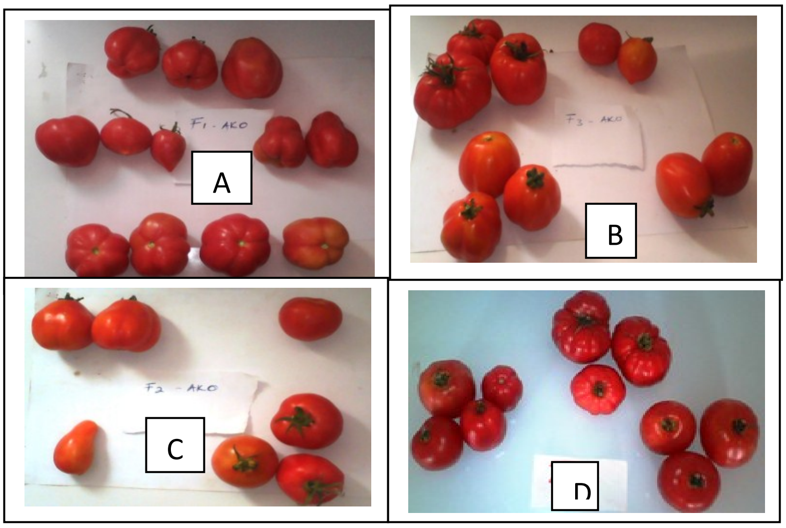


Fig. 11: Seed mixtures evidenced by fruit shapes per farmer (Akumadan)



Plates 7 A, B and C show fruit shapes from Akomada area;
Plate D shows fruits from Agogo area

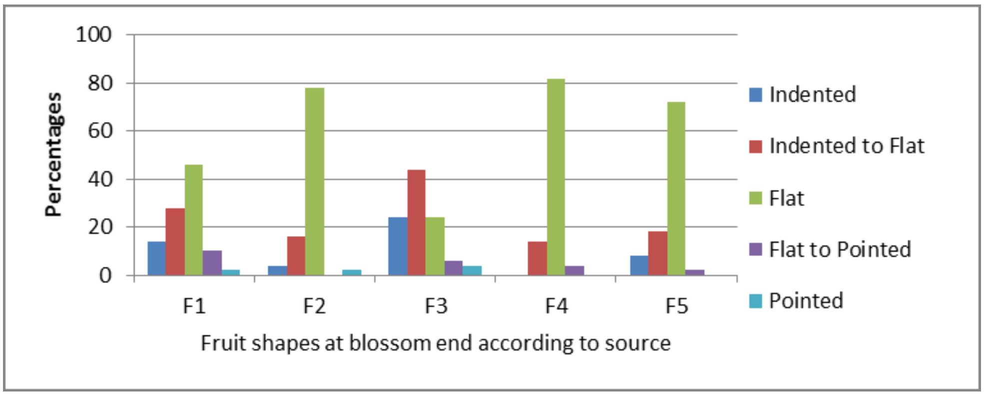


Fig. 12: Seed Mixtures according to fruit shape at blossom end (Agogo)

- **Number of locules**

Number of locules in the fruits from the Forest zone ranged averagely from 6.8 to 8.6 compared to 3.2 to 3.8 from the Forest-Transition zone. This could be the reason for fruits obtained from the Forest zone being bigger than those from the Forest-Transition zone. Locule number has been linked to fruit size of tomato via changes in the number of carpels in the flower. Tanksley (2004) and Cong *et al.,* (2008) have also reported that the locule number and *fascinated* (FAS) affect both the final size and shape of tomato fruit.

Plate 8: Differences in number of locules among tomato fruits

Conclusion

The level of seed mixtures evidenced by the variations in physical attributes of fruits obtained from such seeds in the study areas have been observed and documented. These findings corroborates the findings of earlier work done elsewhere. While this situation does not auger well for commercial production of tomatoes the study has brought to the fore the rich gene pool in farmers' possession that could be exploited for crop improvement to meet specific needs

Recommendation

The author recommends a further and extensive study on this subject starting from determining the quality of seed from different sources. Other seed quality variables such as physical purity, germination capacity, health status of the seeds must be investigated. Other possible areas of study might include identifying postharvest characteristics such as sugar and brix levels, vitamin and mineral contents of the various genotypes.

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WEST AFRICA SEED PROGRAMME (WASP)

Research Team: E.A Asamoah, M.D. Asante, K. Obeng-Antwi, S. Amoah, A. S. Osuman and H.M. Bortey

Collaborating Institutions: CSIR- SARI, MOFA, Seed Producers Association of Ghana and IITA

Source of funding: USAID (through CORAF/WECARD)

Introduction

Inadequate supply of quality seeds is a major challenge to achieving food security in most developing countries including Ghana. There is the urgent need to produce and make quality seeds accessible and affordable to farmers. The West Africa Seed Program (WASP) in collaboration with CORAF/WECARD has secured USAID grant to support WASP to increase the availability of quality seeds from the current 12% to 25% over a five year period (2013-2017). The aim of WASP is to contribute to the sustainable improvement of agricultural productivity and production in the target countries. CSIR-CRI is expected to produce quality breeder seeds of maize, cowpea and rice for subsequent multiplication into foundation and certified seeds.

Maize breeder seed production

Objectives

- To produce two metric tonnes of good quality maize breeder seed.
- To make breeder seeds affordable and accessible to seed growers.

Material and Methods

Due to inadequate processing equipment, maize and cowpea seed production was scheduled for the minor season so that harvesting would coincide with the dry period and thereby reduce seed deterioration associated with seed production in the major season. An early-maturing, drought tolerant, open-pollinated, quality protein maize variety - *Omankwa* - was planted at Mampong (forest zone) in the Ashanti Region.

Regeneration materials were obtained both CSIR-CRI and IITA maize breeding programmes. A 2.8ha plot was sprayed with herbicide, slashed, ploughed and harrowed. Planting was done on 14th September, 2015, at a spacing of 0.75m x 0.25m with two seeds per hill and later thinned to one. Plant establishment at two weeks after planting (WAP) was about 96%. NPK fertilizer was applied at the rate of 150kg per acre and top-dressed with urea at the rate of 100kg per acre at 4 WAP. Weeds were controlled by both manual weeding and herbicide application. Rogueing and all other recommended agronomic practices were undertaken throughout the growing period. A fire belt was constructed around the field to protect the field against bushfires. Regeneration material for the next planting was selected based on ear height, cob size, resistance to diseases and lodging, among other traits.

Seed Inspectors from Ghana Seed Inspectorate Division of MoFA visited the field before harvesting and during processing. The field was harvested on January 4 -7, 2016. Processing, involving sorting, shelling, drying, hand picking, chemical treatment and bagging, was completed in February 2016.

Results and Discussion

The total quantity of *Omankwa* breeder seed produced was 2.5mt, expected to plant 114 hectares and yield 342mt of foundation seed. The 342mt of foundation seed, in turn, is expected to plant 15,545 ha and yield an estimated 54,409mt of certified seed. With an estimated average farm size of 0.80ha in Ghana, the estimated 54,409 mt of certified seed that would be produced would meet the seed requirements of 3,091,426 households. This quality protein maize variety will also improve the nutritional status of these households and prevent diseases associated with malnutrition in children such as *kwashiorkor* which is prevalent in rural communities. There are indications that quality maize seed will be in high demand because of poor rainfall in 2015, which affected food crop production, especially maize. This quantity of breeder seed produced will therefore go a long way to reduce the shortage of seeds along the production chain.

Conclusion and Recommendations

Omankwa which is drought tolerant was able to perform well under the harsh climatic conditions that prevailed during the production period. Farmers who planted similar drought tolerant varieties such as *Abontem, Aburohemaa, Tintim* were able to harvest appreciable yields compared to farmers who planted non-drought tolerant varieties in the neighbourhood. There is the need therefore, to intensify the dissemination of these drought tolerant maize varieties to farmers through establishment of demonstration fields outreach programmes via radio and television.

Plate 9: Cobs of O*mankwa* (breeder seed) spread on a tarpaulin to dry

Indirect benefits

During the production of the breeder seed, about 100 people (40% men and 60% women), aged between 18 and 65 years*,* were engaged to undertake various activities such as land clearing, planting, thinning, fertilizer application, weeding, harvesting and processing. Besides the financial benefits, the youth who were mostly students on vacation also benefited from the practical experience in the field. The older women did the hand picking and drying of the seeds.

Cowpea Breeder Seed Production

Introduction

Cowpea is an important food security crop. It is a cheap source of plant protein which can improve the nutrition of farm households and reduce malnutrition which is prevalent among poor households. Population increase coupled with continuous cropping and reduced fallow periods deplete soils of their nutrients. Incorporation of cowpea into cropping systems contributes to sustainable soil fertility management (Adjei 2007).

Objectives

- To produce one metric ton of good quality cowpea breeder seeds.
- To make cowpea breeder seeds accessible and affordable to seed growers.

Materials and Methods

One acre of improved cowpea variety (*Asomdwee)* was established at Kwadaso while one acre each of *Hewale* and *Videza* were also established at Fumesua in the minor season. During land preparation, the plots were sprayed with herbicide, slashed, ploughed and harrowed. Planting was done in September and October, at a spacing of 0.6 m x 0.2m, with two seeds per hill and later thinned to one seed per hill. Plant establishment was about 95%. Fertilizer was applied at two weeks after planting. Insecticides were applied on weekly basis because the fortnightly spraying regimes were not effective. Rogueing was done throughout the growing period to ensure complete removal of off types. Supplementary irrigation was applied to the *Hewale* field to prevent crop failure. Seed Inspectors from Ghana Seed Inspectorate Division of MoFA visited the field before harvesting and during processing of the seed. The fields were harvested in January, 2016. Threshing was done manually by beating the harvested pods on the floor.

Results and Discussion

A total of 10 bags (50kg/bag) of breeder seed, weighing 0.5mt, was obtained after processing. This was far below the expected yields and the deficit could be attributed to poor rainfall which affected podding especially at the Kwadaso field. The rains ceased just when the flower buds were about to open resulting in flower abortion. Pest infestation and lack of potent pesticides to control or prevent their spread also contributed to the reduction in yield. The 0.5mt cowpea breeder seed obtained is expected to plant 23ha with an estimated yield of 46mt of foundation seed. This amount of foundation seed can plant 2,091 ha to produce 4,182mt of certified seed. Farmers can access this quantity of certified seeds to plant 190,090ha and get 380,180mt of grains for human consumption. Besides its nutritional value, the crop can contribute to soil fertility improvement through nitrogen fixation especially in crop rotation systems. Resource poor households who cannot afford inorganic fertilizers can benefit from the use of cowpea in rotation.

Rice breeder seed production

Breeder seed of Jasmin 85 rice variety was produced at Nobewam in the Ashanti region. Production was staggered due to lack of labour and inadequate processing facilities. Planting, thinning, weeding, irrigation, fertilization and other practices were carried out on schedule. Processing of harvested paddy was completed in April, 2015 and a total of 3.0mt was obtained.

Results and Discussions

The quantity of rice breeder seed produced is expected to plant 50ha of foundation seed field with an estimated seed yield of 200mt of quality rice foundation seed. This will in turn plant 5,000ha to produce 25,000mt of certified seed. This quantity of certified seeds will be able to plant 625,000ha and produce 3,750,000mt of paddy rice (grain). Ghana imported 550,000mt and 600,000mt of rice in 2014 and 2015 respectively with a percentage growth rate of 3.77% and 9.09% (USDA, 2015). Ghana spent $467million on rice imports in 2014, with consumption increasing at a steady rate. Increased domestic rice production will contribute to savings in foreign currency and improving farmers' income.

Conclusion and Recommendation

The rice breeder seed produced should be enough to meet farmers' seed requirements to produce enough grain to meet national requirements and thus reduce rice importation considerably and conserve foreign exchange. There is the need therefore to promote local rice production and patronage. Marketing of seeds should be done at both the national and sub-regional levels. The challenges listed above should be addressed since they are major threats to the overall achievement of project objectives.

The Institute's seed processing, storage and laboratory facilities need renovation to ensure high quality of seeds produced.

Challenges

Challenges encountered during project implementation included:

- Poor rainfall distribution which adversely affected production.
- Delayed release of funds disrupted planned activities.
- High cost of inputs and labour affected the budget of planned activities.
- Power outages affected the quality of seeds stored in cold rooms

References

Adjei 2007

USDA (2015). Ghana milled rice import by year.

POSTHARVEST PROGRAMME

Product diversification of water yam (D. *alata*) for income and health

Research Team: E. Adu-Kwarteng, P. P. Acheampong, E. Owusu Danquah and A. Amoah Owusu

Source of funding: WAAPP

Introduction

Water yam (*D. alata*) has the potential to enhance food security and create wealth in West Africa, and impart unique health benefits to the consumer. It is relatively low-priced, unable to command a premium on the market and therefore an excellent candidate for value addition. In Ghana, most studies on yam product diversification have majored on the pastries industry (flour in composite with wheat). In this work, however, the approach was 'no-wheat' yam products, with simplified processing methods and higher potential profits. Innovative product concepts (not restricted to bread, pastries, etc.) were designed to improve consumer acceptability success rate and enhance quick adoption by target beneficiaries.

Objectives

- Assess pricing systems for water yam within the Kumasi Metropolis, as a guide in estimating potential profit margins from value addition
- Characterize available water yam varieties in terms of functional and compositional properties (Ash and protein contents, flour and starch Rapid Visco Analyzer (RVA) analysis and starch granule morphology)
- Develop innovative ‘no-wheat’ products from water yam, targeted at various levels of industry

Materials and Methods

- **Market assessment**

  A rapid market assessment was conducted on water yam availability and trade within Kumasi and surrounding areas. Markets visited were Asafo Market, Ejisu Market, Kumasi Central Market, Ahwiaa Yam Market, Morro Yam Market (Tafo) and Kontompo Yam Market (Asokore Mampong). Five yam varieties (*Pona, Dente, Matches, Akaba* and an unnamed water yam) were purchased and weighed. The unit price per kilogram was calculated from the market prices.

- **Functional and compositional properties**

Total ash and total protein contents were determined for all the varieties using standard methods of A.O.A.C. (1990). Two types of flour (oven-dried and air-dried) were prepared from each variety and analyzed using RVA. The profiles obtained with RVA analysis give a helpful picture of the cooking and functional properties of the food material. In this study, profiles of cassava and wheat flour (pastry type) were also obtained by RVA analysis to compare with the yam flours. Pure starch samples were extracted from all the varieties for characterization (granule morphology and RVA pasting properties).

- **Product Development**

Fried crispy chips made from three types of water yam (*D. alata)* were compared to similar products from the popular *D. rotundata* varieties ('Pona' and 'Dente'). Sensory profiling was carried out on-station to profile important attributes of the products, which is targeted at the snacks industry. Different types of formulated snacks and breakfast cereal products were also developed with water yam in combination with banana, coconut flakes and other selected constituents.

Results

- **Market assessment**

Results showed that generally water yams were cheaper than *Pona* and *Dente*, water yams appeared to command higher prices in specialized yam markets compared to the other (general) markets (Fig.1). The timing of this study (lean season, June) may be a factor; therefore repeating the study close to the major harvesting season may help gather more information on the pricing systems for water yam. Profitable value addition to water yam was found to be very feasible, as price per kilogram of fresh tuber was GHC 0.85 - 1.45, compared to GHC 1.87 – 4.23 for *Pona* and *Dente.* The unknown water yam was excluded from the price assessment.

- **Ash and Protein contents**

Ash represents the total mineral content of a food substance or any other biological material. Water yam variety *Akaba* and *Pona* had the lowest ash contents (1.70%). The other two water yam varieties had relatively high ash contents (2.77% and 2.84%). Protein contents were above 4% for all varieties except *Pona* which had 3.78%; *Akaba* had the highest (5.88%) protein content (Figs 2 and 3).

- **RVA Pasting Characteristics**

Air-dried flours of water yam had relatively low peak viscosities, and for *Matches,* peak viscosity was closer to that of pastry wheat flour. Oven-dried yam flours had much higher peak viscosities closer to that of cassava, indicating more suitability for high-viscosity products such as fufu. Negligible or zero breakdown of viscosity was observed only in the profiles of air-dried water yam varieties indicating good stability and resistance to stress factors during processing.

Air-dried flours of water yam, which are inexpensive and require no oven-drying nor the use of energy (eg electricity, LPG, fuel wood, etc) may find excellent cost-effective use in the production of gluten-free cookies, chips, soft bread rolls, etc. Their brown colour was found to be an advantage in various products, contrary to previous expectations. They showed very low retrogradation tendency (i.e. viscosity at the end of the cooling phase) compared to the oven-dried samples. This is a desirable attribute since most root and tuber crops experience high retrogradation which reduces the shelf-life of processed products, especially baked products. Flours from *Pona* and *Dente* had extremely high retrogradation, no matter the drying method used; this could be a disadvantage compared to cassava flour and air-dried water yam flour, in applications apart from fufu preparation. Both the air-dried and oven-dried water yam flours must be given more attention as they hold great potential. Further studies are required, and other water yam varieties must be included in the study. The actual cost of producing both types of flour must be calculated and compared, vis-à-vis the differences in quality and potential applications. Pictures of samples of water yam based products are presented as Fig 4.

- **Sensory Evaluation**

  Focus group sensory evaluation of fried crispy chips from *D. alata* (three varieties) *Pona* and *Dente* was conducted on-station. Various palatability indices of *D. alata* fried crispy chips had very high scores compared to *Pona* and *Dente*, indicating very high potential for successful commercialization.

Way Forward

Characterization of starches extracted from the three *D. alata* varieties, *Pona* and *Dente* is currently on-going. This information is needed to complement data obtained from a flour characterization exercise. Elite clones will be included in this study as they become available. Clinical determination of Glycemic index of *D. alata* products will be carried out in 2016 in collaboration with a Dietician/Nutritionist to ascertain claims of special health benefits. Wider consumer acceptability studies will be conducted on selected products from the 2015 studies.

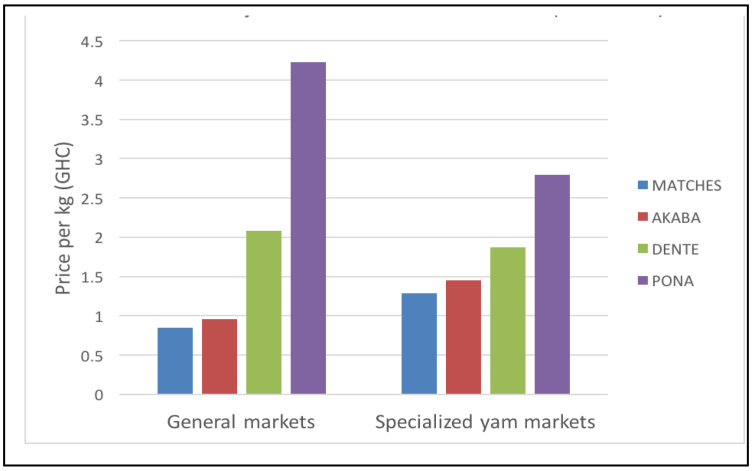
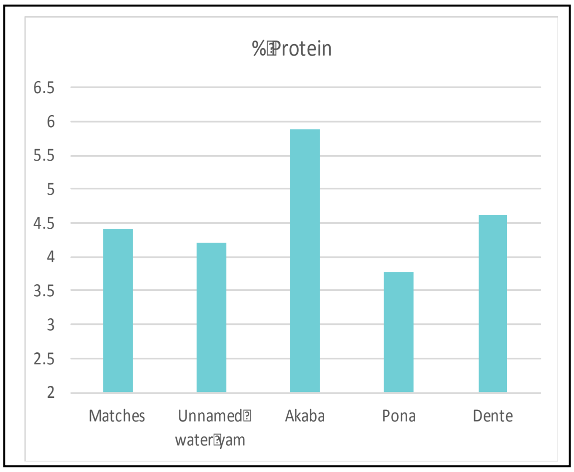
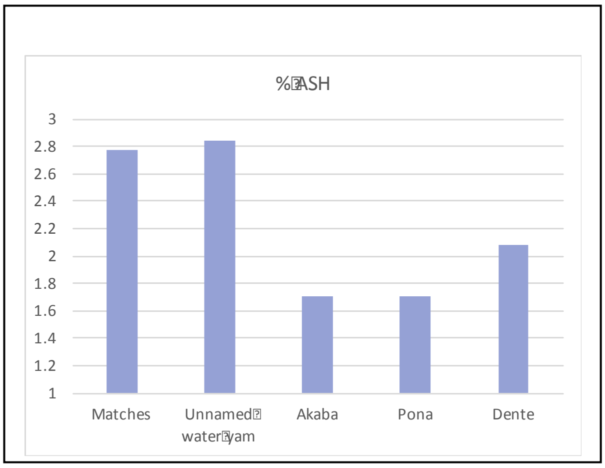


Fig. 13. Overview of average price per kilogram of selected yam varieties in major markets within Kumasi area (June 2015)





Figs. 14 and 15. Protein and ash contents of three water yam varieties compared to 'Pona' and 'Dente'

Plate. 10. Innovative water yam (*D. alata*) based products: A: crunchy breakfast flakes, B: assorted snack type products and C: fried crispy chips (different flavours)

Development of Appropriate Storage Strategies to Extend Shelf-Life of Sweetpotato Fresh Produce

Research Team: E. Adu-Kwarteng, H. M. Bortey and N. Asamoah-Obeng

Source of funding: WAAPP

Introduction

High perishability of harvested sweetpotato is a challenge to its utilization under ambient tropical conditions where it often lasts for only up to a month. In other parts of the world, cold room storage and other high-end storage facilities are able to extend the shelf life of sweetpotato fresh roots to eight months or more, thereby making the fresh produce available throughout the year. In Ghana and many parts of Africa harvested roots are traditionally stored in pits, clamps, rooms or mudhouses, among others. These methods of storage predispose the roots to rodent and weevil attack and dehydration and after a few weeks the roots become unmarketable (Teye 2010; Rees et al, 2003). There is the need to generate sustainable storage practices to stabilize the availability of the commodity in Ghana and thereby enhance its industrial use in general.

Objectives

- Develop innovative, simple and applicable storage technologies on-station to prevent excessive moisture loss and reduce or prevent weevil infestation
- Test the best identified storage strategy on-farm
- Determine storage characteristics of selected varieties released by CSIR-CRI

Specific objectives

- Assess the influence of different micro-environments on weight loss of fresh roots during storage
- Determining the storage characteristics of selected improved varieties

Materials and Methods

Fresh roots of six released sweetpotato varieties *(Faara, Okumkom, Apomuden, Hi starch, Ligri* and *Bohyɛ*) were placed in micro-environments (in a storage barn) created by use of four materials - Plastic bowl, Sack (fertilizer type), Sack lined with polysheet and barn ambient (no packaging) - as treatments. Weights of the tubers were recorded weekly.

Results and Discussion

Weight loss in sweetpotato during storage, though a varietal trait, is also influenced by storage conditions. Under normal tropical conditions there is considerable loss of weight, during storage, through a combination of respiration and transpiration activities (Picha, 1986). Total weight loss after 41 days in storage was higher in open bowls than in enclosed sacks (Fig. 8), indicating better protection against dehydration in the sacks. *Apomuden*, which has the highest beta-carotene content, had considerably higher (25% to >30%) weight loss than the other varieties. In tropical climates temperature management is critical in the efficacy of any storage system designed for perishable produce. For sweetpotato fresh roots the optimal environment for long-term storage is low temperature (13-15°C) and high relative humidity (85-95%) (Kushman, 1975; Picha, 1987; W. M. Walter & Schadel, 1982). Comparing storage under barn ambient conditions (i.e. no packaging) and storage in sack or sack with polysheet, sack with polysheet offered the best protection against weight loss, followed by sack storage. In the sack/polysheet treatment the variety 'Ligri' surprisingly had a slight weight gain instead of a weight loss (Fig. 9). This could be due to the fact that some sweetpotato varieties are capable of 'de novo synthesis' of more nutrients during the postharvest phase (Hagenimana et al, 1994). This may be further investigated for verification. Barn ambient conditions predisposed the fresh roots to relatively high weight loss within two weeks (Fig. 9). The sack/polysheet treatment was, however, dropped from the study due to excessive sprouting of roots stored in it for just two weeks. Among all the tested micro-environments, sack storage inside the barn was the method selected for long-term assessment of shelf-life of the improved varieties.

Larger roots were more resistant to weight loss than smaller roots (Fig. 10). Different varieties showed different responses to the influence of maturity on storage quality. At 4 months maturity, *Hi-starch* lost more weight than the others; it was followed by *Apomuden*, At 5 months maturity, *Apomuden* was the most susceptible (Figure 12). *Faara* was the best storing variety.

Way Forward

Controlled atmosphere storage with reduced oxygen concentration for brief periods will be studied as a means of inhibiting weevil infestation of fresh roots. This approach, in combination with protection of the roots from dehydration, will be refined on-station and then applied on-farm under farmer storage conditions.

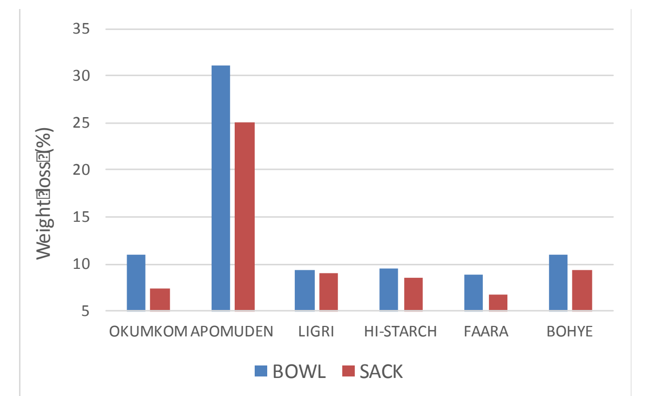


Fig.16. Influence of two packaging materials (micro-environment) on fresh root weight loss in six (6) sweetpotato varieties after 41 days' storage in a barn

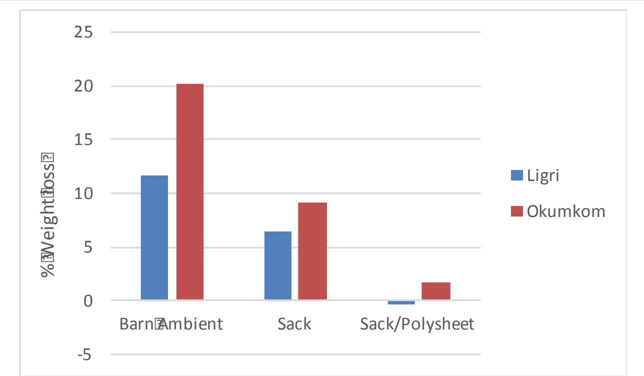


Fig. 17. Influence of three storage environments on weight loss in two sweetpotato varieties after two weeks in storage

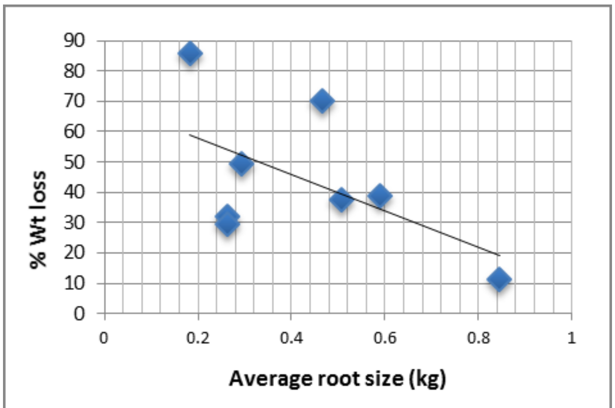


Fig. 18. Relationship between fresh root size and weight loss during 64 days in storage period

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ROOT AND TUBER CROPS

YAM BREEDING

Dissemination of yam vine technology

Research Team: E. Otoo, K. Osei, A. Danquah, K. Alhassan and I. Dufie

Source of funding: WAAPP.

Introduction

Expansion in yam cultivation in Ghana is limited by the low multiplication ratio of yams (1:6 compared to 1:300 of cereals). The yam vine technology has the potential to increase this ratio to 1:240. This novel approach to yam multiplication has been developed and needs to be disseminated to farmers especially seed yam growers to enhance availability of seed yams.

Objective

- To increase the availability of seed yam in Ghana through the introduction of cost effective and efficient yam multiplication techniques.

Materials and Methods

The major activities planned for 2015 were identification and training of potential seed yam growers, setting up of vine multiplication systems on-farm and technical backstopping of MOFA Agricultural stations.

Results

One hundred and twenty (120) seed yam growers were trained in both the minisett and yam vine multiplication techniques in 2014. Sixty-one (61) out of these trainees were further trained in the yam vine multiplication at Fumesua in 2015 (Table 10). Fields were also established at Ejura, Nyomoase, and Soglibor but they could not be used for the vine cuttings due to severe drought at the optimal time for vine cuttings.

Table 10. Number of farmers trained in yam vine multiplication in Fumesua in 2015.

Activity (For all key activities) *Training*	**Estimated Area/Qty (Ha/No.)**	**Beneficiaries**			**No of Youth** *(up to 35yrs)*	**% Youth**	**Remarks**
		Male	Female	Total			
Yam vine technology		21	40	61	10	16.7	
	Total						

Discussion

The success of yam vine technology hinges on availability of water. The serious drought conditions experienced in 2015 negated the efforts to establish the vine cuttings at farmer level. Similarly, the MOFA Agricultural stations could not establish the vine set ups.

Conclusion

Unavailability of water is the single most important limiting factor in the yam vine multiplication technology.

Recommendation

It is recommended that the project should provide boreholes to assist seed yam growers.

Mass Propagation and Dissemination of Released Varieties and Quality Declared Seeds

Research Team: E. Otoo

Source of funding: WAAPP

Introduction

Yam production and marketing in Ghana is saddled with low numbers of released varieties and admixtures resulting in misrepresentation of yam varieties. This negatively affects the yam trade. This work therefore aims at generating seeds of the released varieties as well as true-to-type local landraces (Quality Declared Seeds).

Objective

- To generate seeds of improved and local landraces for dissemination to farmers.

Materials and Methods

Minitubers were generated using minisetts; while microtubers were generated using vine cuttings. The varieties used were the three released varieties - *CRI-Pona, CRI-Kukrupa* and *Mankrong Pona.* Quality Declared Seeds (QDS) of *Dente, Afebetua, Pona, Muchumudu, Serwa* and TDr_95/19177, a promising improved genotype were also produced. The multiplication was done at Dromankese, Baniantwe, Frante Ahontor, Bayere Nkwanta and Fumesua.

Results

A total of 6,650 breeder seeds were generated and supplied to MOFA for further multiplication (Table 11). QDS produced totaled 5357 (Table 12) and were also made available for dissemination

Table 11. Number of breeder seeds generated for dissemination in 2015.

Variety	Minitubers	Microtubers
CRIPona	250	2000
CRIKukrupa	300	2000
Mankrong Pona	100	2000
Grand Total	650	6000

Table 12. Number and weight of QDS generated at various locations in 2015.

Local Landrace	Dromankese	Baniantwe	Frante	Ahontor	Bayere Nkwanta	Fumesua	Total
Dente	298	196	0	553	642	200	889
Afebetua	115	306	0	71	311	0	803
Pona	240	0	0	18	54	50	362
Muchumudu	0	0	155	0	0	0	155
TDr95/19177	0	0	1148	0	0	0	1148
Serwa	0	0	0	0	0	1000	1000
Grand Total	653	502	1303	642	1007	250	5357

Discussion

The erratic rainfall pattern contributed to a high loss of planted material during the season. Inadequate resource allocation also hindered the achievement of set targets.

Conclusion

The vine cutting technique was effectively used in combination with the minisett technique to generate the seed yams.

Variety Development

Research Team: E. otoo

Source of funding: WAAPP.

Introduction

Dioscorea alata (L) is growing in importance in Ghana due to its long shelf life and its demonstrated potential use as a functional food to supplement the fiber and mineral needs of consumers. Research and development efforts on *D. alata* in Ghana are therefore on the ascendency. There has not been any formal release of water yam varieties in Ghana and therefore no improved water yam variety in Ghana. The need therefore to introduce new and improved varieties cannot be over-emphasized. To exploit the genetic diversity of the crop, 49 genotypes of *D. alata* including 14 from IITA were evaluated on-station for three years.

Objective

- To evaluate improved water yam genotypes for release as varieties.

Material and Methods

Using a selection pressure of 90%, the best four genotypes in terms of yield potential, pest and disease tolerance and culinary characteristics were selected and further evaluated on-farm in the Forest- Savanah Transition zone. *D. alata* cv "Matches" was used as a check. The promising introductions from IITA studied were TDa_00/0003, TDa_01/0004, TDa_01/0029, and TDa_00/0046.

Results

Plant establishment was 90-100% for the materials evaluated. TDa_00/0046 had 100% establishment, which was significantly higher than the rest of the genotypes except TDa_01/0029. In terms of growth vigour no significant difference was observed among the genotypes. All the promising genotypes had significantly better ($p<0.05$) tolerance to both virus and anthracnose than the check. TDa_00/0046 was the best yielding genotype followed by TDa_00/0003, TDa01/0029, TDa_00/0004 and "Matches" in that order. The mean performance of the genotypes are presented as Table 13.

Table 13. Mean performance of four yam genotypes

Variety	Percent Establishment	Vigour	Virus Severity Score	Anthracnose Score	Yield (t/ha)
TDa_00/0003	90	1.2	1.3	1.2	50.9
TDa_01/0004	93.8	1.3	1.3	1.2	43.4
TDa_01/0029	96.2	1.5	1.6	1.2	48.7
TDa_00/0046	100	1.4	1.3	1.2	51.3
D. alata cv Matches Check)	90.1	1.4	3.2	3.4	22.1
SED (Variety)	2.2	0.1	0.1	0.1	2.4

Conclusion

Genotype TDa_00/0046 was the best among the four materials evaluated, followed by TDa_01/0029, TDa_01/0004 and TDa_00/0003. All of them are potential candidates for release as varieties.

Pre-basic Seed Production at CSIR-CRI

Introduction

CSIR-CRI is a lead partner institution in Ghana participating in the YIIFSWA project that is being conducted in Ghana and Nigeria. YIIFSWA is a five-year programme aimed at increasing yam productivity (yield and net output) of 200,000 small-holder yam farms (90% with less than 2 acres) in Ghana and Nigeria, by 40%. In 2015, CSIR-CRI was contracted by IITA to generate 10,000 pre-basic seeds.

Materials and Methods

The vine multiplication technique and minisett technique were used to generate microtubers and macrosetts respectively. Table 14 shows the projections made at the onset of the project to generate 10,000 setts at four locations -Fumesua, Ejura, Kintampo and Atebubu. Farmer field days were conducted at all locations during the vegetative and harvesting stages to serve as a training process for stakeholders.

Results and Discussions

A total of 21,700 seed yams were generated at the four locations (Table 15) and 110 farmers were also trained during the period. Sustantial numbers of seed yam were generated through the vine multiplication technique indicating that the technique is a plausible alternative for seed yam generation. The availability of irrigation facility enhanced the achievement of the results. Tables 16-19 show the breakdown of the various categories of seed yam generated per variety.

Conclusion

The project was able to generate more than double the contracted number of seed yams.

Table 14. Projections for Seed Production

Varieties	Projections	Location
CRI Pona	200	Fumesua
Mankrong Pona	2,500	
CRI Kukrupa	2,300	
Sub-total	5,000	
Muchumudu	1,000	Ejura, Atebubu and Kintampo
Afebetua	1,000	
Dente	1,000	
TDr_95/19177	1,000	
Chenchito	1,000	
Sub-total	5,000	
Grand Total	10,000	

Table 15. Quantity of pre-basic seed yam generated in 2015.

Seed Type	Setts	Microtubers	Number
Released varieties	1,200	5,000	6,200
Local Landraces	2,500	13,000	15,500
Grand Total	3,700	18,000	21,700

Challenges

The erratic rainfall pattern threatened to derail the planned activities. The Institute's dams which contributed immensely in achieving these results is silted and need to be de-silted in 2016.

Table 16. Number of setts of released varieties generated through minisett technique

Variety	Number
Mankrong Pona	200
CRI Pona	500
CRI Kukrupa	500
Total	1200

Table 17. Number of setts of local landraces generated through minisett technique

Variety	Number Harvested	Number to be supplied to GLDB
Dente	1680	1000
Pona	660	500
Afebetua	1325	1000
Total	3665	2500

Table 18. Number of microtuber of released varieties generated through vine cuttings

Variety	Number
Mankrong Pona	1000
CRIKukrupa	3000
CRIPona	1000
Total	5000

Table 19. Number of microtubers of local landraces generated by vine cuttings

Variety	Number
Chenchito	2000
*TDr.95/19177	2000
Serwa	5000
Pona	1000
Dente	2000
Muchumudu	500
Maama Komba	500
Total	13000

*Earmarked for release

Yam improvement programme and seed system

Introduction

The direction of the Yam Improvement programme is to develop, distribute and train farmers in the new innovations and technologies.

Research Team: E. Otoo, P. Appiah-Danquah, K. Alhassan and I. Dufie

Activity 1

Multiplication of improved / released yam varieties

Source of funding: WAAPP

Introduction

There has not been enough planting materials of the released yam varieties – *CRI-Kukrupa, Mankrong Pona* and *CRI-Pona* - to meet the demand by farmers across all the yam growing areas; therefore, special attention was given to the multiplication of these improved varieties.

Objective

- To multiply and distribute disease free planting materials to farmers.

Materials and Methods

Selected quality declared materials of released varieties - *Mankrong Pona, CRI Pona, Kukrupa* – and local varieties - *Pona, Muchumudu* and *Afebetua* - were planted between April and June, 2015 at Fumesua and in the Atebubu, Nkoranza, Ejura and Kintampo districts for multiplication (Table 20). Field size was one acre at each location. Plants infected with pests and diseases were rogued out. The minisett technology and vine technology were used to produce micro- tubers of the released varieties. Yam farmers were involved in the exercise.

Table 20. Yam varieties planted and the locations

Location	Varieties
Fumesua	Dente, Muchumudu, Kukrupa, CRI Pona, Afebetua, Mankrong Pona
Atebubu (Ahontor)	Dente, Afebetua, Muchumudu
Nkoranza(Dromankese)	Dente, Afebetua
Kintampo(Baniantwe & Ahenakom)	Dente, Afebetua
Ejura (Frante)	Dente, Afebetua, Muchumudu

Results and Discussion

As a result of late planting and poor rains, 50 % or more of materials did not do well at the various locations. The materials harvested have been given out for distribution to MoFA stations at Mampong, Wenchi and Asuansi.

Activity 2

Multiplication of improved / released yam varieties

Source of funding: YIIFSWA

Objectives

- To produce and distribute disease- free and pest-free planting materials to farmers
- To train farmers in seed multiplication to produce clean and quality seed yams

Materials and Methods

Fields of Quality declared materials were established and used to train farmers (Table 21). The training covered multiplication of planting materials using the minisett and vine technologies and identification of yam diseases and pests.

Table 21. Locations and sizes of yam multiplication fields.

Location	Field size (acre)	Varieties
Fumesua	1.5	Dente, Afebetua, Muchumudu, TDr 95/19177
Ejura (Hiawoanwu)	1.5	*Dente, Afebetua* and materials from IITA
Kintampo (Sogliboi)	1.0	*Dente, Afebetua* and materials from IITA
Atebubu (Nyomoase)	1.5	Dente, Afebetua and materials from IITA

Results and Discussions

Late planting and poor rains impeded the seed production work. About 50% of the materials planted did not do well. Materials harvested have been given to GLDB.

COCOYAM BREEDING

Development and dissemination of end-user preferred *Xanthosoma* and taro varieties

Research Team: E. Baafi**,** R. Sagoe, K. Agyeman, E. Adu-Kwarteng, A. Oppong, Z. Appiah-Kubi, E.N. Tetteh, H. M. Bortey, S.A. Osman, A. Agyeman, P. P. Acheampong, B. Amoabeng, S.O. Ekyem and S.G. Boakye

Collaborating Institutions: MoFA, CSIR-PGRRI, INEA and GREL

Source of funding: WAAPP

Introduction

The name 'Cocoyam' is used collectively for the genus *Colocasia* and *Xanthosoma* (Onyeka, 2014). *Colocasia* species are called 'taro' and *Xanthosoma* species are called 'tannia' (Manner and Taylor, 2010). Cocoyam is a very important food security crop for West and Central Africa, particularly in Ghana, Nigeria and Cameroon. Nutritionally, it is superior to cassava and yam in protein, minerals and vitamins as well as digestible starch (Splittstoesser et al., 1973; Parkinson, 1984). The future of cocoyam in Ghana depends on availability of improved cultivars since productivity is low and increase in production is mainly due to increase in area under cultivation. Persistent decline in soil fertility, loss of forest and excessive use of herbicides have accelerated the decline in the diversity of cocoyam, which already has a narrow genetic base. Susceptibility of all clones collected from Ghana to Cameroon for improvement against the cocoyam root rot and the threat from taro leaf blight disease (Tambong et al., 1997; .Opoku-Agyeman et al., 2004; Onyeka, 2014), further points to the lower potential the crop has for improvement through breeding and selection in Ghana. Inadequate planting materials of the three released *Xanthosoma* varieties to farmers may also have contributed to the overall low production of the crop. Studies on rapid seed production systems to enhance supply of high quality planting materials to farmers is therefore critical.

Objectives

- To produce and disseminate high quality breeder seeds of the three released *Xanthosoma* varieties - *Gye me di, Ma ye yie* and *Akyede.*
- To conserve *in vivo* the three released *Xanthosoma* varieties.
- To develop farmer and consumer preferred *Xanthosoma* varieties through genetic improvement.
- To evaluate five elite taro lines that are tolerant to the taro leaf blight disease for yield and farmer- and consumer-preferred traits.

Materials and Methods

- **Objectives 1 and 2**

  One acre (0.4ha) of primary breeder field of the three released *Xanthosoma* varieties was established in May 2015, at Fumesua, Assin Fosu, Kukuom, Begoro and Aiyinase. The field at Fumesua also served as *in vivo* conservation of the varieties. Primary breeder fields of the three released *Xanthosoma* varieties established in 2014 were harvested and disseminated.

- **Objective 3**

  A pot experiment was set up at Fumesua with 40 plants each of the three released *Xanthosoma* varieties using 10g corms. These were treated, at three months after planting, with gibberellic acid at the rates of 500ppm, 750ppm, 1000ppm and 1250ppm (on 25/09/15) to induce flowering. The acid was applied at the middle of the plant from where new leaves emerge. Flowering responses of the three varieties were observed and recorded.

- **Objective 4**

  Five elite taro lines were tested on-farm along with farmers' varieties, as checks, at Bechem and Bomaa (Brong Ahafo region), Bipoa and Amponsakrom (Ashanti region), Busoso and Anyinasin (Eastern region), Assin Kushea and Assin Asempanaye (Central region) and Aiyinase and Bonsaso (Western region). The trials were established between September and November, 2015. Taro farmers will be invited at both vegetative and harvesting stages to observe the performance of the lines. Harvesting will be staggered at six, eight, ten and twelve months after planting and taro farmers, traders, processors, consumers and other stakeholders will be involved in sensory evaluation of the lines after harvest.

On-farm trials established in 2014 to evaluate the five elite taro lines, alongside farmers' varieties at Bipoa and Abrakaso (Ashanti region), were harvested in November, 2015. A field day was held during the harvest at each of the locations. There were 30 participants (20 males and 10 females) at Bipoa and 29 (20 males and 9 females) at Abrakaso. Data were collected on corm yield and corm dry matter at harvest. The data were analysed using Genstat. Sensory evaluation was also done with the participants at both locations.

Results

- **Objectives 1 and 2**

  The primary breeder fields established at Assin Fosu, Fumesua, Kukuom, Begoro, and Aiyinase in 2015 were maintained. Planting materials (enough to plant 1.5ha) produced from fields established in 2014 were supplied to MoFA for multiplication at secondary multiplication sites for distribution to farmers.

- **Objective 3**

  The pot experiment set up at Fumesua was maintained after flower induction. There were no flowers at the time of reporting.

- **Objective 4**

  On-farm trials established in 2015 were maintained at all the locations. Data from the 2014 on-farm trials at Bipoa and Abrakaso showed significant differences in corm yield between the lines (Table 22). Corm yield ranged from 2.25 t/ha to 5.86 t/ha. All the lines, except CE/IND 12, had significantly higher corm yield than the local/farmer variety. G x E interaction was significant, and the mean yield of the lines, except CE/IND 12, was higher than the local across the locations. Yield performance of the lines was better at Abrakaso than at Bipoa. There were significant differences between the lines for dry matter content. Their mean ranged from 18.98 % to 46.60 % (Table 23). G x E interaction was significant for dry matter content. Dry matter content was significantly higher for the local than all the lines. However, three of the lines (BL/SM 157, BL/SM 115 and BL/SM 16) had relatively higher dry matter content. Results of sensory evaluation showed high preference for four out of the five lines as for the local (Figs. 19 and 20). At Bipoa none of the lines was scored bad, unlike at Abrakaso where there were some respondents showed non-preference across the lines and the local variety.

Table 22. Corm yield (t/ha) of taro lines across locations

Line	Location		Mean
	Abrakaso	Bipoa	
BL/SM 158	5.96	5.76	5.86
CE/IND 12	1.85	2.64	2.25
BL/SM 157	8.00	3.56	5.78
BL/SM 115	6.76	6.08	6.42
BL/SM 16	7.28	3.20	5.24
LOCAL	2.99	1.54	2.27
Mean	5.47	3.80	
Lsd (5%) Line=2.61; Loc=1.51; Line x loc=3.70			

Table 23. Corm dry matter content (%) of taro lines across locations

Line	Location		Mean
	Abrakaso	Bipoa	
BL/SM 158	33.30	33.24	33.27
CE/IND 12	15.45	22.50	18.98
BL/SM 157	43.20	31.10	37.32
BL/SM 115	38.20	47.00	42.60
BL/SM 16	39.11	42.96	41.03
LOCAL	46.57	46.67	46.60
Mean	36.03	37.24	
Lsd (5%) Line=2.77; Loc=1.60; Line x loc=3.91			

Figure 19. Cooking quality prefernces of the taro lines by famers and consumers at Bipoa

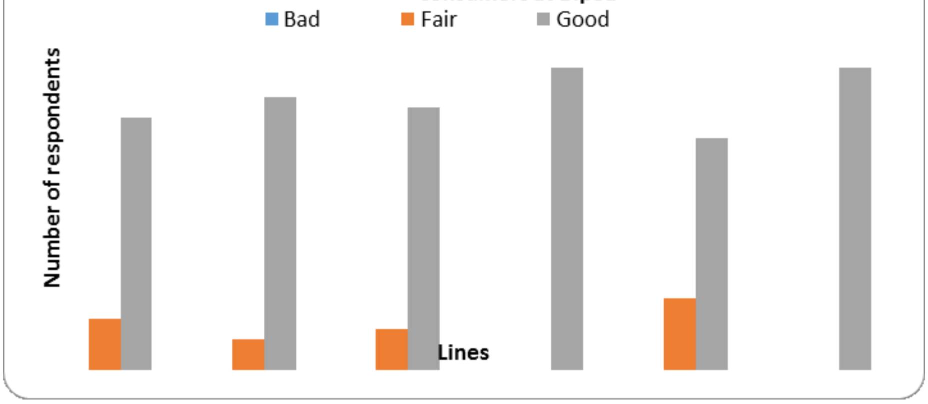
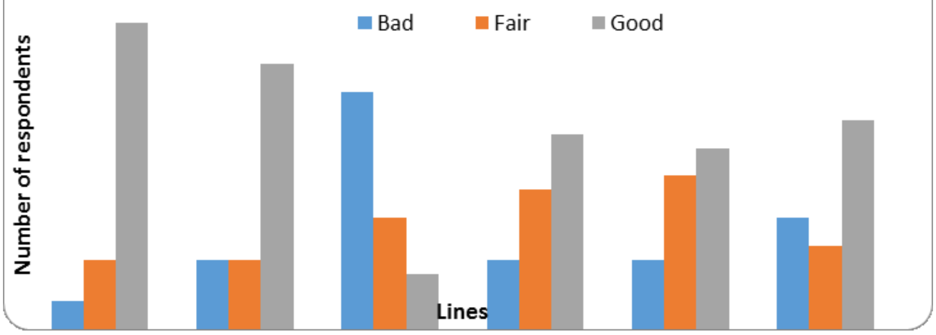


Figure 20. Cooking quality preferences for the taro lines by farmers and consumers at Abrakaso



Conclusions/Recommendations

Three of the taro lines (BL/SM 157, BL/SM 115 and BL/SM 16) showed outstanding performance in yield and dry matter content. They were also highly preferred by farmers and consumers, and therefore, could be proposed for release in 2017 after further testing in 2016.

Way forward

- **Objective 1 and 2**

  The breeder seed fields established in 2015 at Fumesua, Assin Fosu, KuKuom, Begoro and Aiyinase would be maintained.

- **Objective 3**

  Observation for flowering will continue and crosses will be carried out among the three released varieties if the flower induction is successful.

- **Objective 4**

  On-farm trials established in the five regions will be maintained for data collection. Field days shall be organized for farmers, consumers, traders and MoFA staff, across the locations at harvesting.

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COCOYAM AGRONOMY

Evaluate the Soil Nutrient Levels Requirement of Released Cocoyam Varieties

Research Team: R. Sagoe, S.Yeboah, K.Agyeman, J. N.L Lamptey and R.N. Isaaka

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

Cocoyam production levels have increased from 5.94 mt/ha to 6.36 mt/ha between 2006 and 2010 (SRID, DADU; 2012). This increase in has been attributed to extensive production. Any sustainable growth of Ghana's agricultural sector requires resources other than 'more land'. The use of improved varieties and fertilizers has been observed to substantially and economically increase root crop yields on farmers' fields (Lahai et al., 1994; Jindia and Dahniya, 1985). Fertilizer use has been an essential component of modern agricultural production and for sustainable productivity of cocoyam on poor soils, the nutrient requirements of released varieties have to be established under different soil conditions. There is therefore the need to determine the appropriate levels of fertilizers for efficient crop use to give high yields and good quality cormels**.**

Objective

- To determine the optimal rates of poultry manure and mineral fertilizer for high and economic productivity of the released cocoyam varieties.

Materials and Methods

- On - station trials

On-station trials were established for each variety at Fumesua under irrigation and laid out in a RCBD
with three replications.

- On - farm trials

With assistance from MoFA extension agents, Bechem-Ohia and Breme communities (in the Tano South district) and Asesewa community (in the Upper Manya Krobo district) were identified for selection of interested farmers. Community mobilization, sensitization and orientation workshops were conducted. A trial was established in each community and owned by a farmer-based organization (FBO), with an average of 22 farmers per FBO. The trials were established in the Bechem communities in May 2015 and Asesewa communities in June 2015. Treatments were applied and growth parameters (plant height and leaf numbers) were assessed at monthly intervals beginning at four months after planting up to harvest time when yields were assessed.

The treatments (fertilizer rates and times of application) were as follows:

F1: No fertilizer application
F2: 30-30-30kg N-P_2O_5-K_2O/ha (applied at 10 g/plant at 4 WAP and 10 g/plant at 12WAP)
F3: 45-45-45 kg N-P_2O_5-K_2O/ha (applied at 15 g/plant at 4 WAP and 15 g/plant at 12 WAP)
F4: 4.0 t/ha Poultry manure (applied at 400 g/plant at planting)
F5: 2.0 t/ha Poultry manure + 15-15-15 kg N-P_2O_5-K_2O/ha (applied at 200g PM /plant at planting; 5g NPK / plant at 4 WAP and 5 g NPK /plant at 12 WAP)

Spacing: 1 m x 1 m Plot size: 5m x 5m

Varieties used: *Gye me di* and *Akyede* (purple varieties)

Results and Discussions

Shoot growth was assessed as plant height and leaf number. Plant height was measured from the base of the plant, at soil level, to the point where the last opened leaf is attached to its stalk. Leaf number was counted by counting the fully opened leaves. In all the treatments shoot growth increased with time and then decreased after it reached its peak. Plant height for *Gye me di* peaked at 24 weeks after planting (WAP) at all locations (54 – 74.3 cm) and reduced to 16.8 – 43 cm at 48 WAP. Rate of growth reduction was higher at Fumesua and lower at Asesewa - an indication of shoot growth beyond 24 WAP at Asesewa. Leaf growth was delayed at Asesewa, reaching its peak at 28 WAP and declining to an average of 1.3 at harvest. The mean leaf number per crop at Bechem (6.3) and Fumesua (4.8) reached its peak at 20 WAP and declined to 1.1 and 0.4 respectively at harvest.

Yield was assessed at harvest by counting and weighing corms and cormels. Location generally influenced cormel yields at harvest and yields were highest at Asesewa and lowest at Bechem (Table 24). The highest yield of 8.2 t/ha was recorded on plots that received a combination of 2.0 t/ha Poultry manure and 15-15-15 kg N-P_2O_5-K_2O/ha at Fumesua and this was higher than the global average yields of 6t/ha recorded by Onwueme (1991). Except for the control plots and plots that received inorganic fertilizer at a rate of 30-30-30 kg NPK/ha that recorded yields below the mean in Fumesua, all other fertilized plots recorded significant yields increases of 15 – 34% over the mean cormel yields. The highest percent increase (34%) was on plots that received a combination of organic and inorganic fertilizers. *Gye me di* also showed similar trends in Bechem and Asesewa. The results showed an increase in cormel yields (23.5%) with an increase in NPK rates, an indication of the need to identify the economic optimal rate of inorganic fertilizer application for profitable yields. About 61 - 78% of the cormels produced were of marketable sizes.

Conclusion

Since soil conditions and health are vital for agricultural production (Hota et al., 2014) and soil fertility in balance, as observed in this study, is recognised as one of the important factors that limit crop growth and yield, it will be important to evaluate the data further to establish its economic viability. It is also important to encourage the promotion of a combination of inorganic and organic amendment to promote yields of cocoyam on continuously cropped soils in the study area; especially when it has been established that cocoyams are heavy soil nutrient miners exploiting greater volumes of soil for nutrients and water (Osundare, 2004).

Table 24: Effect of fertilizer treatments on the cormel yield of cocoyam variety (*Gye me di*) across three locations

Treatment	Total cormel yield (kg/ha)			
	Asesewa	Bechem	Fumesua	Average across locations
F1	4933	4833	4000	4588.7
F2	5800	5033	4467	5100.0
F3	6067	5367	7333	6255.7
F4	6933	5600	7067	6533.3
F5	7733	5900	8167	7266.7
CV	5.6	10.7	3.3	6.5
SED	285.4	484.3	169.6	313.1
Mean	6293	5547	6207	6015.7

Yield assessment for trials established at *Bechem, Asesewa and Fumesua* in May and June 2014 were completed and data analysed.

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Optimizing stand density within taro cropping system for effective weed management and high productivity

Research Team: R. Sagoe, K. Agyeman, E. L. Omenyo, J.N. Lamptey, P. Acheampong, A. Agyeman, E. Moses, H. Aggrey.

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

Taro (*Colocasia esculenta (L.) Schott*) of the family *Araceae* is the fifth most important root crop consumed worldwide. This shade loving crop, which is highly productive and profitable is associated with some ethnic cultures and revenue generation in fragile ecosystems across Asia, Oceania, Africa and South America.

It can be distinguished as wetland and upland crop according to water management. This notwithstanding, taro production in Ghana relies on age-old, traditional methods. Low yields of the crop have been attributed to incorrect spacing, weedy fields and poor planting materials for field establishment in low lying areas, among others. There is evidence that plant spacing influences vegetative growth and corm yields of taro (Liou, 1984; Tumuhimbise et al., 2009). Earlier studies (Pardales and Villanueva, 1981; Pardales et al., 1982; Villanueva et al., 1983) have shown that the total corm yields increased with an increase in population but individual corm sizes become smaller as plant stands become denser. This study, therefore, aimed to investigate the economic feasibility of different row arrangements within the taro cropping system for optimal yield.

Objective

- To evaluate the influence of spacing on growth and yield of taro and determine the economic feasibility of the optimal spacing**.**

Methodology

Field experiments were established at Fumesua in April 2015 and at Mankranso-Wiowso and Bekwai-Dadease in July 2015, using RCB design replicated three times. Initial soil samples were collected from the fields for analysis. Young suckers, of a mixture of local varieties from the localities, were cleaned and used as planting materials at all locations. Plants were established at the following spacing: S1 - 1m x 1m; S2 - 1m x 0.6m; S3 - 0.9m x 0.6m; S4 - 0.5m x 0.5m on a plot size of 5m by 5m. A random sample of five plants were tagged for growth data collection at monthly intervals starting from 12WAP until harvest. Growth data collected included plant height, leaf count and number of suckers. Plant height was measured from the ground level to the base of the last leaf attached to the stalk. At harvest two middle rows were harvested and data collected on corm numbers, corm weight and shoot weight. All data will be statistically analysed using the computer software GENSTAT.

Results and Discussion

Data on vegetative growth are presented as Table 25. Vegetative growth was consistently higher for plants established at 1m x 1m and least for those established at 50cm by 50cm. Plant height increased with time and peaked at six MAP for all the spacings used. Number of suckers also increased with time till it reached a mean peak of 35.9 - 45.6 (x 10^3) per hectare beyond six MAP. The highest number of suckers was on taro crops established at 50 cm x 50 cm. Leaf growth was generally inconsistent, reaching a peak of 3 - 5 and declining to an average of 1.4 at eight MAP. Data on yield and yield components at harvest from the trial at Fumesua are presented as Table 26. Yield data from Mankranso and Bekwai were not ready for reporting due to late planting.

Table 25: Effect of spatial arrangement on vegetative growth of taro at critical growth periods – Fumesua.

Spacing	Plant height (cm)			Leaf count/plant			Sucker count / ha (x 103)		
	3 MAP	6 MAP	8 MAP	3 MAP	6 MAP	8 MAP	3 MAP	6 MAP	8 MAP
S1	71.1	81.7	46.6	4.5	2.9	1.3	11	25	23.2
S2	64.7	69.2	39.0	3.7	2.6	1.5	8.7	25	39
S3	64.7	70.6	42.3	4.3	2.6	1.6	12.2	33.7	42.6
S4	65.3	64.9	41.9	2.7	2.3	1.3	13.6	60	77.6
Mean	66.5	71.6	42.5	3.8	2.6	1.4	11.4	35.9	45.6

Table 26: Effect of spacing on yield and yield components of taro – Fumesua, 2015

	Mkt Tubers /ha	Mkt Yield (kg/ha)	Non Mkt Tubers/ha	Non Mkt Yield (kg/ha)	Mkt Tuber size (g)	Non Mkt Tuber size (g)
S1	9473.7	5600.9	1035.1	138.6	591.7	83.3
S2	12282.2	5521.5	4076.2	782.3	440.3	199.1
S3	15237.8	6483.1	2596.5	390.	430.2	156.1
S4*	21305.6	7105.6	16666.7	2758.3	346.7	169.7
Mean	14574.8	6177.8	6093.6	1017.5	452.2	152

The marketable tuber sizes ranged from 346.7g to 591.7g with an average of 452.2g. The highest tuber size (591.7g) was obtained from taro planted at 100cm x 100cm. The highest number of marketable tubers was recorded on plots established at a spacing of 50cm x 50cm, which had the highest plant density and a moderate tuber size of 346.7g. Increasing population density decreased tuber size but increased final marketable yields. The bigger tuber sizes could not compensate for higher yields. Non marketable tuber sizes on the 50cm x 50cm plots were also high with an average weight of 169.7g as against 83.3g obtained on plots established with a spacing of 100cm x 100cm. Total corm yields ranged from 5.7t/ha to 9.8t/ha, increasing with increased population density which could be explained by the high number of plants established per unit area and the high corm or tuber size not being able to compensate for the number of corms registered on plots with closely spaced plants. Taro leaf blight, caused by *Phytophthora colocasiae,* was observed on the fields. The mean incidence was 82% with a severity of 2.6. It was also observed that taro planted at a closer spacing were severely affected though they produced higher yields.

Conclusion and Way forward

Planting taro at a closer spacing may increase yield - from the results of this study. There will be the need to assess the economic feasibility vis-a-vis weed management practices in order to make conclusive recommendations.

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Developing Low Input Technology for Rapid Multiplication of Taro Planting Materials

Research Team: R. Sagoe, B. M. Dzomeku. A.S. Osman, K. Agyeman, E.L. Omenyo and J.N.L Lamptey

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

Taro (*Colocassia esculenta (L) Schott)* is usually propagated vegetatively using daughter suckers, volunteer suckers (which sprout when a new field is cleared) and the corms which are of economic importance. This results in low multiplication ratio (which reduces availability of planting materials), reduces yield and crop quality as well as the genetic diversity of the crop and favours the accumulation of pest and pathogens. Thus diminishing its adaptability to environmental change and hampering the production of the crop. The conventional methods of propagation are costly, labour intensive and require a longer period of time and land area to produce. Availability of good planting materials is essential for sustained high production of taro in Ghana. Since its multiplication is constrained by the vegetative nature of the planting material, coupled with its bulkiness and perishability and low multiplication ratio, commercial production of planting materials become unattractive. Demand for good planting materials would be heightened by the release of improved cocoyam varieties. The focus of this research was to develop a workable system to make quality planting materials available to farmers and researchers and to establish a protocol for rapid multiplication.

Objective

- To rapidly produce good quality taro planting materials using the growth chamber technique - specifically, to identify the best rooting media and portion of the crop which has the potential to produce more seedlings.

Methodology

A total of 36 growth chambers (100 cm x 100 cm) were constructed at Fumesua and filled with river sand or saw dust to serve as rooting media. A two factor (media and planting material type) pre-sprouting experiment was laid out in a completely randomised design, replicated three times. Planting materials (local) were sourced from taro growing communities. Different portions of the taro plant were prepared and used as planting materials as follows:

a. The apical meristem of the corm was destroyed and the corm was cut into two parts - the lower and upper portions. These were further cut into pieces of a standard size of 100-500 grams.

b. The huli, which is the apical 1-2cm of the corm, with a basal 15-20cm of the petioles attached were also prepared in two batches – one lot had its apical meristem destroyed and the other had its meristem intact.

c. Young suckers that sprouted from mother plants were cleaned and grouped into two – one batch had their apical meristem destroyed and the other batch had their apical meristem intact.

All the planting materials were treated with a fungicide and nursed (pre-sprouted) in river sand or sawdust in a growth chamber. Ninety pieces were nursed per growth chamber and the chamber was covered with a clear polyethylene sheet. The experiment was initiated on February 6, 2015 and at regular periods, two-leaf plantlets were excised and transplanted into polybags filled with soil and watered as and when necessary. Response variables assessed were days to start of sprouting, number of sprouts per harvest and survival rate after transplanting into polybags filled with soil. At 2 - 3 months after sprouting, the plantlets were planted in the field in a RCB design replicated three times, to evaluate the effects of the various treatments on their growth and yield performance. A random sample of five plants were tagged for growth data collection starting from 12WAP and at monthly intervals till harvest. Data collected included plant height and leaf and sucker count. At harvest two middle rows were harvested and data collected on corm number, corm weight and shoot weight. All data shall be statistically analysed using GENSTAT.

Results and Discussion

The number of days to sprouting in both media was 10 - 65 days after planting. Materials in the river sand sprouted earlier than those in the sawdust. More seedlings were however obtained, within the one month of study, from the corms sprouted in the sawdust. The upper part of the corm (from treatment a) produced more seedlings than the lower part. The suckers and huli (treatments b and c) performed better when sprouted in the river sand. A multiplication ratio of 6 - 10 per corm has been established so far. A total of 2813 seedlings obtained within one month of the study were established in the field to assess their growth and yield performance. Seedlings from the growth chambers were healthy looking (Plates 11 and 12).

Plate 11. Samples of sprouted plantlets

Plate 12. Seedlings growing in a screenhouse

The total number of seedlings produced as influenced by the growth media used and type of planting material are presented as Table 4. Seedling counts gave an indication of the performance of the planting materials used. Destroying the apical meristem increased the number of sprouts from both the suckers and huli and there was not much difference between the two sources. Corms and suckers with destroyed apical meristem performed better in sawdust. Sprout count from the river sand was 1237 compared to 1170 from the sawdust. Growth of seedlings established in the field (expressed as plant height and leaf count) increased with time and at harvest corm and biomass yield were different (Table 27). An average yield of about 10t/ha with only 3.5t/ha as non-marketable yields was recorded. Biomass at harvest also ranged from 370.4kg/ha for plants established from huli to 1525 t/ha for plants established from suckers with apical dormancy destroyed. Seedlings from suckers with apical meristem destroyed expressed prolonged shoot yield but lowest corm yield of 7.5t/ha. It was also observed that plants with higher total yields have a greater percent of the corm yields being non marketable (100-260g sizes). Marketable tuber sizes ranged from 291 to 433 g. It was observed that treatments that produced high biomass had lower tuber yields at harvest, an indication of the possibility of prolonged growth if environmental conditions were favourable.

Table 27: Growth and yield of sprouts as influenced by treatments – 2015

Source of planting material	Seedling Count		Yield (kg/ha)	
	River sand	Sawdust	Corm yield (NMY-%)*	Biomass at harvest
Huli (N**)	155	116	10555.6(44)	370.4
Huli (K***)	199	152	11365.3(43)	980.4
Suckers (K)	255	155	7503.6(26)	1525
Suckers (N)	103	144	8796.3(28)	487
Lower corm	131	178	12345.7(37)	823
Upper corm (K)	433	487	9876.5(19)	648.1

N** - apical meristem intact or not destroyed: K*** - apical meristem destroyed.
NMY* - non marketable yields expressed as a percentage of total corm yield

Conclusion

So far the study has supported the notion that nutritional predisposition of the planting material influence the final yield. Healthy planting materials are able to withstand diseases and pests since yields ranging from 7.5 to 12.3t/ha were obtained after the crops were attacked by the Taro leaf blight disease. Supplementary nutrients will have to be applied to plantlets to boost their growth at the nursery stage. The need to repeat this study to confirm results and establish the economic feasibility is imperative.

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Establishing optimal soil nutrient levels for increased taro productivity

Research Team: R. Sagoe, S. Yeboah, K. Agyeman, E.L Omenyo, J. N.L Lamptey and R. N Isaaka*(*CSIR-SRI)

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

In the rain forest ecology, intensive cropping has become more common and the primary function of soil productivity and fertility restoration is becoming less effective (Okigbo, 1982). There is evidence that bush fallow, which had been an efficient, balanced and sustainable system for soil productivity and fertility restoration in the past, is presently unsustainable due to high population pressure (Steiner, 1991). Taro (*Colocassia esculenta (L) Schott)* develops large leaves that accumulate large amount of dry matter in the corms when soil nutrients are not limited. To support this high biomass production, one needs to provide supplementary soil Nitrogen in tropical soils for high productivity. This notwithstanding, nutrient use efficiency has also been reported to increase through the combination of poultry manure and mineral fertilizer (Murwira and Kirchmann, 1993 and Ayoola and Adeniyan, 2000). Taro, as a root crop, has a high requirement for potassium which is usually high in manure but depending on the animal type, feed ration, storage and handling. While fertilizer application can greatly increase yields and product quality, it is very difficult for farmers to determine application rates that will be cost effective. During field days organized for farmers and staff of MoFA in the Bekwai and Mankranso districts, declining soil fertility was identified as a key factor contributing to reduce taro productivity in the districts. This study therefore aims at determining the correct soil nutrient amendments for optimal taro productivity.

Objective

- To evaluate the effect of different levels and combinations of organic and inorganic fertilizes on the growth and yield of taro.

Methodology

Seven field experiments were established in April, 2015, at Fumesua; and in July, 2015, at Mankranso-wiowso, Bekwai-Dadease and Ahwiren, using RCB design. Suckers of local varieties were planted at a spacing of 90 cm x 60 cm. Plot sizes were 10m x 10m.

Fertilizer treatments applied were:

F1- 30:30:30 (N: P2O2:K_2O) kg/ha (24g/plant applied at 4 weeks after planting)

F2 - 4t/ha of poultry manure (265g/plant applied at planting)

F3 - 2t/ha poultry manure (132g/plant applied at planting) plus 15:15:15 (N: P2O2:K_2O) kg/ha – 12g/plant applied at 4weeks after planting

F4 - No Fertilizer (control)

Soil samples were collected from the fields for analysis before the fertilizer treatments were applied.
A random sample of five plants were tagged for collection of growth data from 12 WAP and at monthly intervals till harvest. Growth data collected included plant height, leaf and sucker counts. At harvest two middle rows were harvested data collected on corm numbers, corm weight and shoot weight. Yield data from Mankranso and Bekwai were yet to be assessed due to late planting. All data will be statistically analysed using the computer software GENSTAT.

Results and Discussions

Yield assessment for 2014 trials were done with farmers at harvest and data collected. Taro yields ranged from 5.3 t/ha to 7 t/ha. Fertilizer application increased taro yields from 59% to 106% depending on the fertilizer type. Application of 30:30:30 NPK increased taro yields by 106% while a combination of 15:15:15 NPK and 2t/ha poultry manure increased yield by 88%. Fields that received only 4t/ha poultry manure produced yield increase of 59% over the control (unfertilized) field which produced 3.4t/ha.
For the 2015 trials, data from Fumesua showed inconsistent marketable corm yields ranging from 3.1t/ha to 4.5t/ha. Fertilizer application increased biomass at harvest by about 37% and also increased tuber rotting and suckering ability as shown in Table 28.

Table 28: Fertilizer effect on percent suckering, biomass at harvest, tuber rot and total corm yield – Fumesua, 2015

Fertilizer Treatment	Biomass x 10 (kg/ha)	% suckering	Tuber rot (%)	Total corm yield (kg/ha)
F1 (30:30:30 NPK)	23.0	15.3	18.2	3958.1
F2 (4t/ha PM)	18.8	7.5	2.5	4602.7
F3 (2t/ha PM +15:15:15 NPK)	18.1	14.2	6.5	4684.9
F4 – control	16.7	1.0	6.9	4914.8

Marketable tuber sizes recorded ranged from 291 g to 358 g while non-marketable sizes were between 134 to 150 g. Total corm yields were similar for all treatments. Incidence and severity of Taro Leaf Blight disease on fertilized plots were found to be insignificant when compared with the high incidence on unfertilized plots. There were no differences between plant height and leaf numbers among the treatments at Fumesua for the 2015 field study. Differences in yield were also not consistent.

Conclusion

Fertilizer application effect could not be established and there will be the need to analyse data from the other locations as well. Data from the previous years' trials will be assembled and analysed to provide the basis for any recommendation.

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CASSAVA IMPROVEMENT

Research Team: J. Manu-Aduening, B. Peprah, R. Prempeh, E. Lotsu and O. Ohene Djan

Introduction

Cassava is currently ranked as the number one food staple and the most widely cultivated crop in Ghana (Manu-Aduening *et al*., 2013). It occupies 840,000 ha of farmland (FAOSTAT, 2011) and contributes about 22% of Ghana's Agricultural Gross Domestic Product (AGDP) (Otoo, 1998). Production is estimated at 12.5 million metric tonnes and majority of Ghanaians consume cassava in various forms (fufu, ampesi, gari, agbelima and tuo zaafi). Its potential to supply raw materials for local and international starch-based industries is gaining prominence. Currently, cassava is being processed into industrial starch, high quality cassava flour (HQCF), adhesives for wood industry, alcoholic beverages and feed for livestock. Eighteen improved varieties have been released and disseminated to farmers since 1993. However, the expected benefits from these improved varieties have not been realized by different stakeholders along the cassava value chain. Adoption of these varieties by stakeholders has been low because of the perception that the improved cassava varieties do not meet their food requirement (i.e. suitable for fufu). The improved varieties have yields ranging from 20 to 45t/ha under farmer management and practices and this, in most cases, are over 30% higher than farmers' preferred varieties, whose yields range 6 – 15t/ha. Eight of the released varieties are also good for fufu whilst the rest are good for intermediate products such as HQCF for starch-based industries.

The main focus of the Cassava Improvement Programme at CSIR-CRI is to develop and disseminate improved varieties and appropriate production technologies to farmers and other end-users.

Activity 1

Multiplication and distribution of four released cassava varieties

Source of funding: WAAPP

Introduction

Multiplication and distribution of breeder planting materials of four improved cassava varieties released by CSIR-CRI and adopted by WAAPP during phase 1, continued in 2015. The four varieties are high yielding, high dry matter, resistance to African Cassava Mosaic Disease (CMD) and adaptable to wider ecological environments. They also form wider canopies at early stages of development and able to compete favourably with weeds thus reducing labour input and cost of production for farmers. The cultivars have very low cyanide levels (i.e. < 0.95µmol/g of fresh root) which make them safe for fresh consumption.

Objective

- To multiply and disseminate high yielding varieties tolerant to biotic and abiotic stresses and suitable for different end-users

Materials and Methods

Breeder/multiplication fields were established at Fumesua, Ejura, Aworowa, Ohawu, Begoro and Adawso between April and June, 2015. Field sizes and varieties differed at different locations according to land availability and varietal preferences. Post planting field maintenance (including refilling, fertilizer application and weed control) was done at all locations. Fertilizers (NPK at 200kg/ac and P_2O_5/K_2O at 100kg/ac) were applied at 4 and 16 weeks respectively. Coppicing and distribution of planting materials to stakeholders also continued in 2015.

Results and Discussion

A total of 33 acres (13.2 ha) of breeder/primary multiplication fields were established (Table 29) whilst materials estimated to plant 387 acres (154.8 ha) were supplied to 16 different stakeholders for further multiplication to farmers and other beneficiaries (Table 30). Over 50% of the planting materials supplied, went to MoFA stations and MoFA district offices in the Ashanti and Volta regions whilst the rest went to different farmer groups, individuals and processors. The planting materials supplied are expected to be multiplied to planting at least 3,870 acres (1,548 ha) in 2016.

Table 29. Cassava multiplication fields established in 2015

Location	**Field size (acres)**	**Varieties**
Fumesua	2	Sika and Broni
Ejura	7	Sika, Ampong and Otuhia
Aworowa	8	Ampong
Ohawu	12	Ampong, Sika, Broni and Otuhia
Begoro	2	Ampong
Adawso	2	Ampong
Total	**33 (13.2ha)**	

Table 30. Cassava planting materials supplied in 2015

Recipient	Location	Quantity (acre)	Variety
MoFA station	Kpeve	45	Ampong
MoFA district office	South Tongu	54	Ampong and Sika
MoFA district office	Adaklu	35	Ampong and Sika
MoFA district office	Ketu South	20	Ampong
MoFA station	Mampong	67	Ampong
MoFA district office	Sege	30	Ampong and Sika
MoFA district office	Juaboso	2	Ampong
Farmer groups	Fanteakwa	20	Ampong
Farmer groups	Upper Akim	5	Ampong and Sika
Farmer groups	Upper Manya	5	Ampong and Sika
Farmer groups	Kintampo North	58	Ampong
Wenchi station	Wenchi	2	Broni and Otuhia
Josma Co. Ltd	Woraso, Mampong	1	Sika
Caltek	Hodzo	3	Sika and Ampong
Individual farmers who called at the station	Different locations	7	Ampong
Farmers	Ketu South	30	Ampong
Total		387acres (154.8ha)	

Activity 2

Development of new varieties through genetic crosses between landraces and exotic cultivars

Source of funding: WAAPP

Introduction

The new and emerging markets for cassava are changing its use as a food security crop to an industrial crop. Different stakeholders using cassava for different products will require specific qualities to meet their needs. Development of appropriate and new cassava varieties to meet the growing and changing needs of our clients have been going on at CSIR-CRI since 2007. Significant advances have been made through genetic hybridization between and among landraces and exotic cultivars from CGIAR centers (mostly IITA and CIAT). The team is currently targeting the following traits: yellow flesh (Vitamin A) cassava, poundability, high starch, HQCF, resistance to root rot, suitability for intercropping and delayed post harvest deterioration.

Objectives

- To develop suitable varieties preferred by farmers and other stakeholders
- To improve farmers' access to a diversity of high yielding, disease resistant cassava varieties appropriate to their needs and the needs of other end-users.

Materials and Methods

Forty landraces and 20 exotic cultivars were established, at Fumesua in April 2015, in crossing blocks of single rows of landraces alternating with rows of exotic cultivars in a completely randomized design. Each row measured 10m and there were four blocks of 15 different cultivars. Plants were fertilized with NPK at a rate of 20g/plant at four weeks after planting. Manual crosses (diallel crosses) were carried out from October to December and seeds were collected between December 2015 and February 2016. Seeds collected from the previous year's crosses were air-dried, nursed and planted as F_1 seedling for field evaluation. Vigorous growing plants showing no symptoms of diseases and pests were tagged and observed for other traits of interest.

The selected F_1 seedlings from 2013 and 2014 were advanced into Preliminary Yield Trial (PYT) and Advanced Yield Trials (AYT) respectively in 2015. Screening will be carried out using markers. Successful candidates will be advanced into Uniform Yield Trials (UYT) and evaluated using participatory approaches in multi-locational trials.

Results and Discussion

Over 650 crosses were made, however, seed set was less than expected due to the dry weather conditions at the flower initiation stage. Over 2000 (2150) seeds were collected in 2015. These seeds will be planted and evaluated in seedling trials in 2016. Close to 400 (397) of the seedlings established in 2015 were tagged at 3 MAP based on their tolerance for CMD. Further observation (at 6-12 MAP) indicated that 51% of the tagged plants showed improvement in terms canopy development and general vigour compared to their parents. Generally, 60% of the clones evaluated in the PYT had mean yields greater than the average and 75% of them were poundable (Table 31).

Table 31. Mean performance of PYT clones evaluated at Fumesua in 2015

Clones	Root No.	Root wt	Mealiness
13/0001	63	16	1
13/0002	40	34	1
13/0005	30	21	2
13/0006	58	13	4
13/0007	82	38	5
13/0008	18	4	1
13/0009	54	15.6	5
13/0010	24	15	4
13/0012	39	22	4
13/0013	38	26.4	1
13/0014	22	4.4	3
13/0015	48	54.8	5
13/0016	56	28	2
13/0017	24	11.6	5
13/0018	30	12.4	3
13/0019	32	12	3
13/0020	22	6.4	5
13/0021	42	19.6	4
13/0022	64	25	3
Ampong	16	10	2
Debor-1	12	43.6	5
Debor-2	34	10.4	4
Mean	38.55	20.15	3.27
SD	18.25	13.09	0.87

Activity 3

Multi-locational participatory evaluation of clones for different uses

Source of funding: WAAPP

Introduction

Elite cassava lines were evaluated as AYT and UYT as well as on-farm trials. This was to serve as final evaluation for selection of suitable cultivars for release in 2016/17. This participatory approach has served as a viable means of selecting and disseminating suitable cultivars to different stakeholders.

Objectives

- To elicit different stakeholders' needs and preferences for the different cultivars
- To sensitize stakeholders on the attributes of the different cultivars

Materials and Methods

Elite cassava lines were evaluated for the second time at six locations in the Forest, Forest-Savannah Transition and Coastal Savannah zones for different end-uses. Six each, selected for food and industrial uses were involved. At each location, the clones were planted in unreplicated blocks with three checks. Each location served a replicate. NPK fertilizer was applied at a rate of 20g per plant at four weeks after planting and weeds were controlled as and when necessary. Assessment and selection were based on their yield potentials, disease and pest tolerance and end-user preferences such as poundability, starch yield and flour quality.

Results

Mean root yields ranged from 29.3 to 48.3 t/ha with an overall mean of 30.8 t/ha across the locations (Table 32). Yields were generally very high in the Forest compared to the other agro-ecological zones. Though yields were relatively lower at the Coastal Savannah, they were higher than the national average yield of 9 to 12 t/ha. Dry matter yields across the locations were generally high, averaging 35.1%. Starch yields were relatively average and better than the previous year. They showed impressive tolerance to CMD with 85% showing no symptoms. Three best lines will be selected and established in an inspection plot for certification by the National Variety Release Committee (NVRC) for release in 2016/2017.

Table 32. Mean performance of clones evaluated at six locations for food and industrial uses

Accessions	CMD score	Yield (t/ha)	Dry matter	Starch
00/0338	1	44.3	35.5	23.8
00/0354	1	42.6	36.5	21.8
00/0388	1	37. 7	35.1	23.4
01/0034	1	46. 7	37.3	19.5
01/0090	2	44.9	35.5	23.7
01/0093	1	39.3	38.6	25.5
01/0203	1	42.9	35.5	20.4
01/0364	1	35.7	39.5	19.5
01/1369	2	48.3	31.0	21.8
01/1807	1	38.3	34.7	20.6
TME 419	2	35. 7	33.4	23.3
TME 693	1	38.3	36.3	22.5
Abasafitaa	4	33. 7	35.4	21.5
Afisiafi	3.5	32.3	29.4	18.4
Amakuma	3	29.3	33.0	19.8
Mean	1.7	30.8	35.11	21.7
SD	0.99	1.5	2.55	1.93

Activity 4

Official release and launching of six cassava varieties developed through introgression of CMD resistance into farmer preferred landraces for food and other uses in Ghana

Source of funding: AGRA

Introduction

Cassava production in Ghana is estimated at 12.5 million metric tonnes with an average yield ranging between 6 and 15 t/ha. These yields are far below the potential yields 40 - 60 t/ha of improved varieties. The low yields can be attributed to the extensive use of low yielding but farmer-preferred landraces, varieties susceptible to pest and diseases and poor agronomic practices adopted by farmers. Since 1993, 18 improved varieties have been released and disseminated to Ghanaian farmers. However, these are insufficient to meet the different needs and the growing demand for improved varieties to satisfy the needs of the emerging markets. In some cases, the varieties have started showing signs of susceptibility to the common endemic diseases, while others are rejected by farmers because they are not poundable. This has resulted in low adoption of improved varieties in the past since most farmers produce cassava for their household needs (Manu-Aduening *et al*., 2006). The purpose of the current variety release is to improve the yield, pest and disease resistance/tolerance of farmer-preferred landraces and disseminate these varieties to farmers and other end-users.

Materials and methods

- **Certification and release of new varieties**

  Inspection and certification fields of the six varieties were set up at Fumesua in April 2015. Each of the varieties had 250 plants (i.e. 10 rows x 25 meters). Field lay out, planting and post planting management practices followed the required standard for certification of varieties for inspection and release. Final inspection and certification by the NVRC took place in July 2015 and a letter of authorization from the Minister of Food and Agriculture was received in September, 2015.

- **Initial multiplication of the new varieties**

  Production of breeder materials started in August, 2015 at Fumesua after the final inspection by the NVRC. Initial multiplication fields were also established in August at Ejura and Ohawu. A total of 3-acre field was established.

Results and discussion

Fresh root yields of the six varieties ranged from 46 to 63 t/ha with dry matter content of 32 - 40%. The varieties are tolerant to ACMV and suitable for cultivation in the Forest, Forest Savannah Transition and Coastal Savannah zones (Table 33). The maturity periods for the varieties span from 10 to 15 months with most of them maturing at 12 months. They are very vigorous and early branching, reaching full branching width at 4 MAP. Two of the varieties (*CRI-Duade Kpakpa* and *CRI-Lamesese*) are poundable all year round and *CRI-Lamesese* is yellow-fleshed (contains β-carotene). They are mostly high starch (27-34%) and suitable for the brewery, pharmaceutical, textile and lumber industries.

- **Launching of the six new varieties**

  Official out-dooring of the six varieties took place at Fumesua in November, 2015. Over 120 stakeholders including farmers, processors, MoFA staff, seed producers, lecturers from Universities, chiefs and opinion leaders from communities around CSIR-CRI and representatives from AGRA office in Ghana attended.

Strategies for dissemination

Multiplication and dissemination of the released varieties will be achieved through sensitization of stakeholders on the attributes of the new varieties, use of multi-stage community-based multiplication scheme, FBO production groups, Innovation platforms, RELCs, Contract farmers for secondary and tertiary multiplication, development and use of production guides and fliers as well as linkages with other projects.

Table 33. Summary of characteristics of the six released varieties

Variety	Maturity period (mths)	Mean root yield (t/ha)	Total dry matter (%)	Uses†	Reaction to CMD	Suitable ecologies
CRI-Duade kpakpa	12	60	37	Poundable Flour, textile industry	Resistant	Forest, Transition and Savannah
CRI-Amansan bankye	12	57	38	Flour and bakery products	Resistant	Forest, Transition and Savannah
CRI-AGRA bankye	12	63	32	Hi-starch and flour	Resistant	Forest, Transition and Savannah
CRI-Dudzie	12	49	38	Starch and flour	Resistant	Forest, Transition and Savannah
CRI-Abrabopa	12	46	40	Hi- starch	Resistant	Forest, Transition and Savannah
CRI-Lamesese	12	50	39	Poundable Flour, Hi-starch	Tolerant	Forest, Transition and Savannah

† All cultivars can be processed into wet cake as an intermediary product for processing into gari and cassava dough for local foods such as banku and agbelima. The cultivars fit into the existing cropping systems of the different ecological zones of Ghana.

Conclusion

The six cassava varieties released which were developed through improvement of farmer-preferred landraces are expected to fill the niches currently created by the growing market for cassava for food and industrial uses. There is also a high demand for planting materials from private producers to go into large scale production of cassava for industrial demand. It is expected that the "home developed varieties'' will contribute to increase cassava production by at least 30%, and consequently help to create jobs in cassava production and processing and result in improved livelihoods.

Activity 5

Enhancement of availability and accessibility of quality seed for cassava growers in Ghana

Source of funding: KAFACI

Introduction

A baseline survey was carried out in six selected communities in the Coastal Savannah, Forest and Forest Savannah Transition zones to collect information on current state of cassava production, technology level, farmers' preferences and use of varieties and challenges associated with accessibility of high quality seeds (planting materials). The overall goal is to select the elite cassava varieties (seeds) suitable for the three zones and establish the dissemination strategy. Specifically efforts were made (in 2015) to analyze the current status and problems in the dissemination of high quality planting materials (seeds).

Methodology

Both primary and secondary data were collected. Primary data were collected through the use of questionnaires, focus group discussion, field observations and review of past work. Secondary data obtained from programme/project documents from research institutions, MOFA and journals were also reviewed to provide background information on the survey areas and research carried out. Two communities each were selected from the three agro-ecological zones. Farmers, processors (small and medium scale) and others (extension staff, researchers, marketers and consumers) were contacted during the survey. There were 380 respondents (Table 34). Selection of communities was based on the scale of cassava production, access to production inputs within the community, links with research and extension services, importance of cassava in the community, availability of market and market channels such as processing facilities. Data collected were analyzed using Statistical Package for Social Science (SPSS) version 20 and Microsoft Excel.

Table 34. Communities surveyed and respondents

Agro-ecology	Community	Respondents		
		Farmers	Processors	Others
Forest	Kyeremfaso	30	5	25
	Krobo	30	25	
Forest-Savannah Transition	Techiman-Akrofom	30	30	30
	Asueyi	30	20	
Coastal Savannah	Mafi-Adaklu	30	25	25
	Akatsi	30	15	
Total		180	120	80

Results and discussions

Overall, 41% of the farmers, 63% of processors and 54.5% of the other respondents were women. The age of the farmers ranged 25 - 80 years, averaging 45 years. Two-thirds of them are natives of the communities surveyed and about one-third (33.4%) of them had some formal education. Cassava is produced by small to large scale farmers with farm sizes of 0.5 - 25ha. Most of the farms were less than 1ha and owned by small scale farmers. Cassava is the main food and cash crop for 66% and 43% of the farmers, respectively. Most farmers intercropped cassava with maize at the onset of the rains; the maize is harvested earlier, leaving the cassava to mature as a sole crop. Cassava roots are used to prepare a range of traditional foods, particularly *fufu*.

Varieties planted were predominantly landraces. Overall, 64% of farmers interviewed had never planted improved varieties (in the Forest). However, seven out of 18 varieties released in Ghana were popular among the farmers. These were *Afisiafi, Nkabom, Tek bankye, Essam bankye, Bankye hemaa, Ampong* and *Sika bankye*). Most farmers planted one or two varieties and the maximum number planted by any one farmer was four. The proportion of farmers planting more than two varieties, including landraces was greatest in the Forest (69%) and least in the Forest Savannah Transition zone (11%). Farmers usually planted different varieties based on their uses and availability of market. Most farmers planted two varieties or one (Table 35).

Table 35. Number of varieties grown by farmers, their frequency and percentages.

Number of varieties	Frequency	Percentage (%)
1	35	19.4
2	69	38.3
3	34	18.9
4	14	7.8
No idea	28	15.6
Total	180	100

Most (131) farmers obtained planting materials from their own farms and only a few (10) bought planting materials (seeds). In most of the communities, there were no defined systems (such as commercial cassava seed producers) for farmers to obtain high quality seeds. A few who had access to improved varieties obtained them from external donor funded projects. About 75% of farmers had no idea of the quality of the seeds (planting materials) they planted.

Most farmers, extension workers and sellers of cassava seeds had no idea of the suitability (agronomic characteristics) of the varieties grown in their agro-ecological zones. Farmers mentioned grass cutter, rats and termites as major pests that destroy their crops. The crop is occasionally attacked by diseases; especially the landraces and those planted in water-logged areas.

Most farmers considered high yields, poundability, marketability and early maturity as the key characters they look for in selecting varieties for production (Table 36). Other important characters desired by most farmers were long shelf life (storability) of roots, good taste and suitability for processing.

Table 36. Some attributes of cassava desired by farmers across all communities

Attributes	Importance: Percentage of farmers giving that ranking			
	Very	Somewhat	Not	Can't tell
High yielding	97	2	0.3	0.7
Poundability (mealiness)	94.5	4.6	0.6	0.3
Marketable	93.7	1	5	0.7
Early maturing	92.9	4.4	1.7	0.7
Long shelf life	88.5	6.1	2.4	2.7
Good taste	87.5	8.8	1.7	1.7
Suitable for industrial processing	66.6	17.6	12.8	2.7
Suitable for food processing	82.4	6.1	8.8	2.4
Resistance to pests and diseases	52.8	12.4	28.2	6.6

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CEREALS

RICE IMPROVEMENT

Development and dissemination of high yielding, disease resistant and consumer-preferred rice varieties for the lowland and upland ecologies of Ghana

Research Team: M. Darko Asante, P.K.A. Dartey, H. Doku, R. Bam, G. Acheampong, E. Annan Afful, P. Acheampong, S. Abebrese* and J. Ofori**
(*CSIR-SARI, **UoG)

Collaborating Institutions: CSIR-SARI and UoG

Source of funding: AGRA

Introduction

Rice is the fastest growing staple food in Ghana. Per capita consumption increased from 15 kg/person/annum in 2005 to 45 kg/person/annum in 2015. Even though, domestic rice (milled) production has almost doubled (from 235,000 MT in 2009 to 417,000 MT in 2015) in the last decade, the country continues to import about 50% of its requirements. Production challenges include poor land development and incidence of rice yellow mottle virus (RYMV) and blast diseases. The current goal of the breeding programme at CRI is to develop high yielding consumer-preferred rice varieties with tolerance to blast and rice yellow mottle virus (check with goal in the introduction. Subsequently, improved rice lines with tolerance to blast and RYMV, and having the grain quality preferred by most consumers have recently been developed by CSIR-CRI. Two aromatic varieties, CRI-Amankwatia and AgraRice were also released in 2010 and 2013 respectively. The goal of this project is to promote and disseminate AgraRice and CRI-Amankwatia and evaluate new lowland and upland lines for possible commercial release.

Objective

To evaluate the newly developed lowland rice lines for yield, disease tolerance and phenotypic acceptability.

Materials and Methods

The experiment was conducted in a lowland ecology at Fumesua. Forty-four lines mostly developed by CRI were planted using an 11 x 4 alpha lattice design with three replicates. Plot size was 2x 2m^2. Data were taken on tiller number, plant height, days to 50% flowering, days to maturity and panicle number. Selection was done by the Breeder and farmers based on yield and general phenotypic acceptability.

Results

Yields ranged from 2.3 to 8.7 MT/ha. Three of the lines had significantly higher yields ($p<0.001$) than the check (AgraRice) (Table 37). Plant height ranged from 107.2 to158.7 cm. However, many of the lines including those with significantly higher yields were shorter ($p<0.001$) than the check (AgraRice). Average number of panicles ranged from 6.2 to15.3. About 68% of the lines evaluated had significantly ($p=0.03$) higher number of panicles than the check. Also, 50% of the lines had maturity period lower or similar to that of the check.

Table 37: Yield and yield components of lowland lines grown at Fumesua

Variety	Tiller number	Panicle Number	Days to 50% flowering	Days to maturity	Plant height (cm)	Yield (MT/ha)
AGRA-CRI-LOL-1-11	14.6	11.2	99.6	124.4	131.8	4.8
AGRA-CRI-LOL-1-14	12.5	10.5	107.9	133.1	141.1	5.3
AGRA-CRI-LOL-1-15	9.6	8.1	112.6	139.0	148.2	4.6
AGRA-CRI-LOL-1-17	11.7	9.3	106.2	138.0	145.7	4.2
AGRA-CRI-LOL-1-21	12.7	10.8	97.5	126.7	157.5	6.2
AGRA-CRI-LOL-1-23	9.8	8.8	113.1	135.2	146.1	4.8
AGRA-CRI-LOL-1-7	9.6	8.7	96.6	125.3	130.8	8.7
AGRA-CRI-LOL-1-9	15.3	10.8	99.0	131.6	117.7	4.5
AGRA-CRI-LOL-2-14	12.8	10.0	98.4	135.8	112.9	6.3
AGRA-CRI-LOL-2-15	7.9	7.0	106.4	140.7	131.8	6.1
AGRA-CRI-LOL-2-2	8.6	6.2	95.7	125.7	107.2	4.1
AGRA-CRI-LOL-2-27	14.6	12.6	103.1	129.2	123.5	5.9
AGRA-CRI-LOL-2-29	14.1	12.3	104.5	132.3	129.4	7.0
AGRA-CRI-LOL-2-5	15.4	10.6	100.1	135.9	110.4	4.7
AGRA-CRI-LOL-2-5 (2)	12.0	10.7	97.9	135.8	149.7	5.4
AGRA-CRI-LOL-2-6	13.2	7.4	101.0	131.1	115.8	3.7
AGRA-CRI-LOL-2-7	12.4	11.7	98.9	130.1	118.5	6.2
AGRA-CRI-LOL-2-9	8.8	7.4	100.1	134.0	117.1	4.4
Amankwatia	13.5	11.9	97.1	133.8	122.1	7.5
CRI-1-11-13-3	14.3	12.8	108.5	134.7	150.3	4.2
CRI-1-11-15-21	17.4	15.3	100.3	131.7	158.7	6.0
CRI-1-11-15-3	13.7	11.4	109.2	132.6	142.2	6.8
CRI-1-11-15-3(2)	10.1	8.7	108.3	131.7	144.8	4.8
CRI-1-11-15-5	14.0	10.5	105.2	136.0	142.4	7.1
CRI-1-11-19-12	14.4	12.7	84.0	133.3	150.5	7.4
CRI-1-11-19-4	11.6	8.8	105.2	131.2	140.9	6.9
CRI-1-14-17-11	15.9	13.7	101.5	133.7	125.8	6.4
CRI-1-14-17-14	8.5	7.6	103.4	141.0	135.0	2.6
CRI-1-14-17-18	15.2	13.0	98.4	138.0	127.6	5.2
CRI-1-15-21-23	14.1	11.4	98.0	135.3	136.5	5.3
CRI-1-15-21-23(2)	15.9	11.9	99.3	127.5	131.6	6.3
CRI-1-21-5-12	15.2	11.3	91.4	123.5	123.4	7.1
DKA-M2	11.3	8.8	108.7	133.6	138.8	2.3
FAROX 508-3-10-F43-1-1	12.7	10.1	102.6	139.8	121.6	8.0
FAROX 508-3-10-F44-2-1-1	9.0	8.0	107.9	141.2	132.0	7.0
AgraRice	9.6	7.1	98.5	130.6	143.9	6.3
J85 ex Owusu	12.3	10.4	104.8	133.5	135.6	4.5
JASMINE 85 CRI	16.4	12.9	94.9	130.2	123.4	6.4
JASMINE 85 CRI (2)	15.1	12.4	98.6	127.9	128.5	6.3
Jasmine85-SARI RED	15.1	11.9	92.7	123.1	113.3	5.7
L-22-26-WAC B-TGR4-B	12.9	11.8	99.2	135.0	147.6	5.4
Nerica-L-41	13.1	10.6	96.7	129.2	128.0	7.1
SAHEL 177	9.5	8.6	99.9	133.1	114.0	4.3
Sahel 201	14.3	12.8	114.1	133.2	121.3	5.8
P-value	0.02	0.03	<0.001	0.01	<0.001	<0.001
SED	3.5	1.8	5.2	3.1	8.2	1.0

Discussion

Most of the lines are in the same maturity range and matured earlier than the check. About 70% of the lines had more panicles than the check. The higher number of the panicles did not result in yield advantage as only three of the newly developed lines showed significantly higher ($p<0.001$) yields compared to the check. Twelve of the lines that had high yields with consumer-preferred grain quality and better disease tolerance than the check have been selected for multi-locational trials.

Conclusion

The project is likely to achieve its goal of developing lines that combine consumer-preferred grain qualities with high yield and tolerance to RYMV and blast diseases.

Enhancement of High-Yielding Rice in Ghana using Korean Germplasm

Research Team: M. D. Asante, K. Dartey, R. Bam, G. Acheampong, E. Annan Afful and H. Doku

Collaborating Institutions: KAFACI and AGRA

Source of funding: KAFACI through AGRA

Introduction

Rice has become a staple food in Ghana in the last two decades. It is now the fastest growing food source with current per capita consumption of 45 kg/ person/year which is expected to reach 63 kg/ person/year by 2018. However, local rice production in Ghana is able to satisfy about 40-50% of the current demands due to low productivity. Higher yielding varieties are therefore required to help make Ghana self-sufficient in rice production. Developing varieties from lines with diverse background could lead to new recombinants with higher yield potentials. The goal of this project is to develop new high yielding varieties from crosses between elite Korean lines and popular varieties from Ghana and other African countries.

Objectives

- Identify Korean genotypes with high yield potential
- Develop higher yielding varieties from crosses between the best Korean lines and adapted genotypes

Materials and Methods

Two sets of Korean rice genotypes comprising 100 and 106 lines were introduced into Ghana in 2014. Based on preliminary analysis (phenotypic acceptability), 32 lines were selected for yield trials at Nobewam using 3 x 12 alpha lattice design with three replications. Four locally adapted aromatic cultivars (*Jasmine 85, Jasmine, CRI-Amakwatia* and *AgraRice*) were used as checks. Plot sizes were 2 x 2 m^2. Data taken included grain yield, tiller number, days to maturity, plant height, number of grains per panicle and a thousand grains weight. Twelve crosses were made between the best looking Korean lines and the three most popular aromatic rice cultivars (*Jasmine 85, CRI-Amakwatia* and *AgraRice*) in Ghana (Table 38). The populations were advanced to the F_2 generation.

Results

There were no significant differences in tiller number, plant height, number of grains per panicle and thousand grain weight (Table 39). Yield and maturity period showed significant differences. The yields ranged from 2966 to 5161 kg/ha. Four Korean lines had significantly higher ($p=0.01$) yields than the best check (*AgraRice*). These lines had similar or earlier maturity periods than *AgraRice* (Table 39). Twenty of the Korean lines had significantly lower ($p<0.001$) maturity periods compared to *AgraRice*. The number grains per panicle and weight of thousand grains ranged 115.1-194.1 and 22.33 - 28.28 g respectively.

Discussion

In order to produce enough rice for the growing populace, there is the need to develop higher yielding varieties for domestic cultivation. Crosses between genotypes with diverse backgrounds could result in new recombinants that have higher yield potential than either parent. In this experiment, 32 lines with temperate japonica background (and recently introduced from Korea) were evaluated for yield and yield components. The Korean lines were generally earlier maturing than the local checks. Yields of the Korean lines were generally not better than the local check, *AgraRice*. Even though four of the Korean lines showed significantly higher yields, they cannot be released as varieties per se because the grain type is too short for the Ghanaian market. The Korean lines did not show susceptibility to local diseases such as blast and RYMV after two years of planting. Many of these lines have been found to have multiple resistance to Rice Yellow Mottle Virus disease, Bacterial Leaf Streak. Bacterial Leaf Blight and Rice Blast in Uganda (Jimmy et al. 2015). The Korean lines are thus used for crosses with the popular varieties from Ghana. The F_2 populations of these crosses were grown and lines that combine aroma with good agronomy grain type have been selected for fixing of the genes through anther culture. Some of the populations will also be advanced through single seed descent.

Conclusion

Even though, only a few of the lines from Korea have significantly higher yields compared to the best check, they appear to be a good source of genes for early maturity and disease resistance. Also, the diversity of the background of the parents used for the crosses made in this study is likely to generate lines have high yield potential.

Table 38: Crosses between Korean and Ghanaian rice genotypes

	Crosses	**Number of F1 seeds**
1.	AgraRice/322367-1	11
2.	AgraRice/322492	9
3.	AgraRice/322492	13
4.	AgraRice/323033	11
5.	323033/AgraRice	13
6.	AgraRice/322340	4
7.	CRI-Amankwatia/320513	5
8.	CRI-Amankwatia/322340	7
9.	CRI-Amankwatia/322441	11
10.	Jasmine 85/322222	4
11.	Jasmine 85/322240	7
12.	Jasmine 85/ 320859	9

Table 39: Yield and yield components of lowland lines grown at Fumesua

Genotypes	Yield (kg/ha)	Tiller number	Days to maturity	Plant height (cm)	Number of grains/panicles	Thousand grain wt (g)
323841(320516)	4751	9.71	121.4	103.8	171.9	23.76
323842(320515)	3299	10.84	119.7	112.5	157.5	26.88
323845(320547)	4372	10.9	121.3	105.9	162	25.24
323846(320591)	3632	11.18	126.9	102.2	157.7	26.33
323849(320852)	3309	8.71	123.3	102.9	140.9	24.56
323852(322222)	4226	10.97	120.9	106.6	175.4	23.67
323854(322226)	3631	9.71	120.7	100.1	157	24.93
323855(322231)	4162	9.77	128.6	107.4	171.2	24.36
323857(322241)	3451	8.91	133.0	113.3	158.7	25.51
323859(322255)	4344	10.18	128.1	103.6	194.1	25.4
323860(322258-1)	3998	10.31	134.7	109.6	178.9	26.44
323861(3222558-2)	4404	10.26	119.6	107.9	168.8	23.36
323862(322274-1)	4095	11.51	122.0	109	161.4	26.54
323863(322274-2)	4297	9.51	132.0	104.8	158.8	26.53
323864(322303)	5161	10.45	131.5	107.5	175.8	28.76
323865(322323)	3912	10.91	134.7	108.5	172	25.66
323866(322335)	2966	8.3	134.7	103.7	174.2	25.66
323868(322367-1)	4871	11.18	126.4	104.8	171.5	28.73
323868(322367-1b)	4175	11.9	121.0	107.8	162.6	23.8
323869(322367-2)	3344	12.82	122.7	102.9	115.1	24.04
323870(322382-1)	3248	9.11	115.8	106.7	157	23.7
323871(322382-2)	4010	11.52	126.6	107.3	167.3	22.33
323880(322441)	3768	11.43	117.1	106.6	152.9	26.77
323881(322444)	4507	11.19	121.6	105.8	154.1	23.3
323882(322446)	3871	10.64	133.6	106.4	159	25.7
323883(322458)	4943	10.3	129.6	112.5	148.2	25.66
323886(322480)	4892	8.79	124.9	103.5	185.1	24.06
323893(322518-1)	4352	11.36	129.4	105.9	177.5	26.27
323893(322518-1b)	4170	9.82	125.7	109.0	151.6	23.77
323894(322518-2)	4761	10.05	128.0	102.9	170.9	25.77
323894(322518-2b)	3563	9.93	131.3	106.7	174.8	24.63
323900(323041)	3984	9.17	122.3	105.6	146	26.37
AgraRice	4234	9.72	128.4	102.8	172.5	26.47
Amankwatia	3689	9.65	121.7	103.5	168.9	24.5
Jasmine	3555	11.37	121.4	105.7	166	22.81
Jasmine 85	3234	8.78	122.6	104.1	164.4	24.74
P-value	0.01	0.982	<0.001	0.934	0.691	0.252
SED	600.9	1.918	2.497	5.07	19.36	1.993

Reference

Jimmy, L., Gyoung-Rae, C., Ininda, J., Paul Kofi Ayirebi, D., Ekebu, J., Moses, E., Simon, A., Stephen, O., Bonny, O., Michael, O., Godfrey, A. & Kyung-Ho, K. (2015). Developing Lowland Rice Germplasm with Resistance to Multiple Biotic Stresses through Anther Culture in Uganda. *Journal of the Korean Society of International Agriculture,* 27**,** 415-420.

Participatory Advanced Trial: Evaluation of elite rice lines selected by the African Rice Breeders' Taskforce

Research Team: M.D. Asante, R. Bam, G. Acheampong, E. Annan Afful, K. Dartey and H. Doku and S. Moussa*, (*Africa Rice, St Louis, Senegal)

Collaborating Institution: Africa Rice, Cotonou, Benin

Source of funding: Africa Rice

Introduction

Rice is the fastest growing food source in sub-Saharan Africa (Nwanze et al, 2006). However, production has lagged behind consumption resulting in a heavy dependence on imports from Asia and the USA. The Africa Rice Breeding Task force has introduced a system whereby elite lines are nominated by Africa Rice, other CGAIR centers and national programs for wide testing across Africa. The experiments include Multi environment trials (MET) where 100 lines are tested at one location per country and the best 30-35 lines (including checks) are selected for Participatory Multi-Environment Trials (PET). PET is also done at one location per country and the best ten lines are selected for multi-locational trials within the country- known as Participatory Advanced Trials (PAT). During PAT, three randomly selected lines from ten lines are given to different farmers to test. This report is about the results of PAT from three locations in Ghana.

Objective

- To evaluate elite lines for yield and farmer acceptability

Materials and Methods

The experiment was planted at Nobewam, Libi and Nyankpala in the major season of 2015. The entries were eight lines from the PET plus a local check (*Agra Rice*). The design was RCB with three replications. The plots size was 5 x 2 m^2 with a planting distance of 20 x 20 cm. Data were taken on flowering dates, maturity dates, panicle number, panicle length, 1000 grain weight, number of grains per panicle and yield. Data were analyzed using ARiS (R software).

Results

Genotype x Environment interactions across the three locations was significant for yield ($p<0.001$). This indicates that the genotypes performed differently at the various locations. The check was one of the highest performing varieties especially at Libi and Nobewam (Table 40) indicated by the green colour on the heat map (Fig 21). SIK9-164-5-1-3 performed very well across all three locations. Other lines which performed well in at least two locations were SIK 350-A150 and WAB 2075.WAC5.FKR1-1-TGR1. These three lines had maturity periods (days to 50% flowering) similar to that of the check (Table 41). The high performing lines will be evaluated further for possible recommendation for varietal release.

Table 40: Yield of rice lines evaluated at three locations

Heat map code	Genotype	Libi (E1)	Nobewam (E2)	Nyankpala (E3)
G1	Agra Rice	4564	5379	5146
G2	NERICA-L 19	4460	4275	5313
G3	SIK 350-A150	3596	5100	6014
G4	SIK9-164-5-1-3	4771	5138	6415
G5	WAB 1572-10-B-B-FKR4-WAC1-1-TGR2-WAT9-1	3687	5371	3895
G6	WAB 2075.WAC5.FKR1-1-TGR1	3631	5100	6837
G7	WAB 2098.WAC1.FKR2-4-TGR1	3703	4658	5576
G8	WAB 2135-WAC B-2-TGR2-WAT3-1	1868	5167	4850
G9	WAB 2150-TGR1-WAT3-3	3790	3396	5990
	Heritability	0.84	0.90	0.77
	P-value	0.003	0.03	0.02

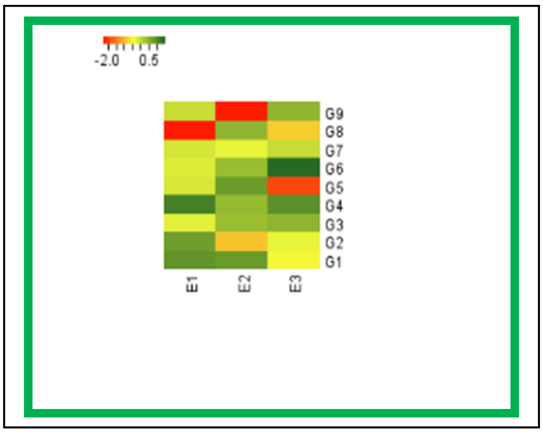

Fig. 21: Heat map showing yield across the three locations

Table 41. Days to 50% flowering for genotypes across the three locations

Genotype	Libi	Nobewam	Nyankpala
AgraRice	103.0	102.7	86.7
NERICA-L 19	97.0	95.3	78.0
SIK 350-A150	105.3	101.3	90.7
SIK9-164-5-1-3	105.0	106.0	93.0
WAB 1572-10-B-B-FKR4-WAC1-1-TGR2-WAT9-1	107.7	101.0	94.3
WAB 2075.WAC5.FKR1-1-TGR1	109.7	101.0	92.3
WAB 2098.WAC1.FKR2-4-TGR1	106.7	102.0	93.7
WAB 2135-WAC B-2-TGR2-WAT3-1	110.7	105.7	92.3
WAB 2150-TGR1-WAT3-3	103.7	99.3	87.3
Heritability	0.92	0.87	0.98
P-value	<0.001	<0.001	<0.001

Discussion

The Africa-wide regional testing of elite rice lines gives breeders the opportunity to test as many elite lines as possible from various breeding programmes across Africa and beyond, and to select the ones that best suit the local environmental conditions. Under this PAT *AgraRice* performed well across all locations. Three lines - SIK9-164-5-1-3, SIK 350-A150 and WAB 2075.WAC5.FKR1-1-TGR1 - performed better or similarly to *AgraRice*. There is however, the need for further evaluation of the best of these lines at multiple locations in Ghana for possible release as commercial varieties. Also efforts at developing superior varieties by Rice breeders on the Africa continent should continue.

Conclusion

At least three promising lines, based on yield and positive reaction to environmental stresses have been selected for further testing and possible release.

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Nitrogen-Use Efficient, Water-Use Efficient and Salt Tolerant Rice (NEWEST) for Ghana: Confined field trials of Nitrogen Use Efficient (NUE) lines

Research Team: M.D. Asante, K. Dartey, R. Bam, E. Annan Afful, G. Acheampong, H. Doku. F. Tetteh*, S.G. Boakye and K. Sanni**, (*CSIR-SRI, **AATF)

Collaborating Institutions: Arcardia Biosciences (USA), CIAT (Colombia), AATF and CSIR-SRI

Source of funding: USAID (through AATF)

Introduction

Rice is the fastest growing staple food in Ghana. The per capita consumption of rice has doubled in the last decade increasing from 20 kg/person/year to about 45 kg/person/year in urban areas. Consumption is expected to reach 63 kg/person/year by 2018. The increase in consumption is driven by population growth and rapid urbanization. Rice consumption has thus far outstripped production levels and the country imports about 50% of its requirement. There is therefore the need to rapidly increase rice production in Ghana in order to cut down on imports. Rice cultivation in Ghana is limited by poor soil fertility, drought and salinity to a lesser extent. Nerica 4, a popular African rice variety, has been genetically modified (GM) for nitrogen-use efficiency, water-use efficiency and salt tolerance (NEWEST) by Arcadia Bioscience, USA. The GM rice could help farmers to increase their crop yields and save monies spent on nitrogen fertilizers. The NEWEST lines would also help rice farmers to manage the effects of climate change and help extend cultivation to areas that could previously not support rice cultivation. The goal of this project is develop high yielding NUE and NEWEST GM rice for the Ghanaian farmer.

Objective: To identify lead NUE rice lines

Materials and Methods

The NUE trial was planted in October, 2015 at the confined trial site at Nobewam. Eighteen genotypes made up of 15 genetically modified rice lines and three controls (a bulk of the nulls, the wild type Nerica 4 used for the transformation and another Nerica 4 from Ghana) were planted on 3m x 1.4 m plots. Field design was split plot and four replicates with fertilizer as the main plot and the rice genotypes as the sub-plot. Fertilizer levels applied were 0, 30, 60 and 90 kg N/ha.

Results

Eight of the genetically modified rice lines showed yield advantage over the average of the controls at fertilizer levels 0, 30 and 60 kg N /ha. These are lower than the recommended rate of 90 kg N /ha. These eight lines have since been selected.

Discussion

In previous Confined Field Trials (CFTs) done in Ghana, all the GM lines were not available. In this trial, all 15 lines were evaluated. The eight lines selected will be further evaluated to select the best two or three lines. The proof of concept for this project is to find lines that have at least 15% yield advantage over the wild type under low nitrogen levels. NUE genes from the best lines will be introgressed into some popular varieties in Ghana. This will make the technology more beneficial to local farmers once the genes are deregulated by the National Biosafety Authority. The development of lines that use nitrogen more efficiently would help to achieve high yields and lower the costs associated with the use of nitrogen fertilizer. Local farmers who are usually unable to afford the recommended levels of fertilizer will get reasonable yields. The next set of experiments shall involve lines that have been transformed for NUE, water-use efficiency and salt tolerance.

Conclusion

Genetic modification could be a useful technology to help meet farmers' variety requirements, especially in poor countries. Eight promising lines for NUE have been identified in the on-going CFTs of GM rice. These lines will undergo further trials to identify the best two or three. The best lines will be used for crosses with popular local varieties. The next set of trials will include NEWEST lines that use nitrogen more efficiently and also be tolerant to drought and salinity.

Performance and yield of CRI-Amankwatia and AgraRice varieties under different fertilizer treatments

Research Team: E. Annan-Afful, R. K. Bam, G. K. Acheampong and M. D. Asante

Source of funding: YARA Company Limited

Introduction

Growth in rice demand in Ghana is increasing at such a rate that both intensification and area expansion must be vigorously pursued to fill the demand gap. It is therefore necessary to address the challenges in this sector to ensure the effective implementation of the various strategies and policies (GNRDS, 2009). For Ghana to achieve a sustainable agricultural sector, farmers would have to increase their productivity through the use of fertilizers that are affordable and are from sources where their quality is guaranteed. Some new fertilizer formulations introduced in Ghana by YARA Company Limited were tested on a lowland rice variety in 2014 to determine the efficacy of the products. This test was repeated in 2015 to validate the results. The fertilizers tested included: Unik 15, Amidas, Actyva, Urea, Muriate of Potash and Triple Superphosphate.

Objective

- To evaluate the effects of given rates and times of application of the different fertilizers on the growth and yield of some lowland rice varieties

Materials and Methods

The trials were set up at Afari and Sokwai (Ashanti region) in the major season of 2015. Two rice varieties, *CRI-Amankwatia* and *AgraRice*, and five different fertilizer treatments (Table 42) were used. CSIR-CRI's recommended fertilizer rate for rice (Treatment 3) was also added to the treatments. The fields were ploughed, puddled and leveled. The design was split-plot with three replications per site. Each plot size measured 3.8m x 3m with 1m alleys between and within plots. Twenty-one day old rice seedlings were transplanted at 20cm x 20cm, at two seedlings per hill. Initial weeding was done by herbicide application and subsequent weeding by manual hoeing and hand picking as and when necessary. Samples of top soil (0-20cm) were collected from the two sites and taken to CSIR-SRI for laboratory analyses. Plants were harvested when 80-90% of the panicles were matured. These were threshed, winnowed and dried. Data were collected on number of tillers/hill, plant height at maturity, number of panicles/hill, panicle length, weight of panicles, 1000 grain weight and grain yield. Data collected were analyzed using Analysis of Variance (ANOVA) by ARIS 32 software developed by AfricaRice.

Table 42. Treatments: types of fertilizer, rates and time of application

Treatments	1 week after transplanting	Beginning of tillering	At panicle initiation stage
1	Unik 15 @250kg/ha	Unik 15 @125kg/ha	Amidas @ 125kg/ha
2	Unik 15 @250kg/ha	Actyva @ 125kg/ha	Amidas @125kg/ha
3	Unik 15 @ 400 kg/ha		Urea @ 70kg/ha
4	No fertilizer	T15 @ 250kg/ha	Urea @ 125kg/ha
5	No fertilizer	No fertilizer	No fertilizer

Results and Discussion

Incidence of drought at Afari and its environs led to the failure of the trials at Afari. Hence the only the results obtained from Sokwai are being reported.

- **Soil characteristics**

  From the physico-chemical analysis of the soils (Table 43), it was observed that, the soil at Sokwai was more acidic than at Afari. The soils from both locations were comparable in terms of nutrients with Sokwai having slightly higher NPK than Afari. The soil from Afari was slightly higher in exchangeable

Ca and Mg than Sokwai, however, it was found to be sandy, compared to Sokwai and this could affect its water holding capacity and nutrients could easily leach from the soil.

- **Rice crop**

Significant differences in grain yield were observed between the treatments (Table 44) with Treatment 4 recording the highest yield in Amankwatia and the least recorded by Treatment 5, that is, the control. Significant differences were also observed between treatments for AgraRice variety with Treatment 1, recording the highest yield and the least for the control, T5. There was no significant difference between the yields for the two varieties. However, all the treatments yielded higher than the control. For 1000 grain weight, significant differences were observed between the treatments and between the varieties (Table 45). For plant height (Table 46) significant differences were observed only between the varieties. There were no significant differences between the treatments. Table 47 shows the tiller per hill for the two varieties and there were no significant differences between the treatments and varieties. Table 48 shows the panicle length of the two varieties and it was observed that significant differences existed only between the varieties and not the treatments.

The various treatments gave yields to yields from the CRI recommended rate. Performance and yields of the different varieties were similar. Unfortunately, the harsh climatic conditions that affected the trials at Afari site, had the reverse happening at Sokwai. There were series of floods at the Sokwai site and that affected tillering and the general performance of the varieties and hence the yield. Rice is a water loving crop but excess of it at some stages in the crop cycle significantly affect yield. Comparably, the yield of 2015 trials was lower than the previous years' field trials and this could be ascribed to the climatic and environmental conditions experienced during the cropping season.

Table 43: Soil characteristics of the two sites

	Sokwai	Afari
Clay (%)	11.2	9.2
Silt (%)	42.56	22.56
Sand (%)	46.24	64.24
pH (H_2O)	4.41	6.35
Organic C (%)	1.26	0.61
Total N (%)	0.12	0.07
Bray-1-P (mg/kg)	8.4	6.4
Extractable K (cmol/kg)	0.29	0.22
Extractable Ca (cmol/kg)	3.67	8.01
Extractable Mg (cmol/kg)	1.34	2.94
Extractable Na (cmol/kg)	0.17	0.12

Table 44: Grain yield (kg/ha) of CRI-Amankwatia and AgraRice varieties grown at Sokwai

	Grain yield (kg/ha)	
Treatment	CRI-Amankwatia	AgraRice
1	2287	3541
2	2322	2722
3	2656	2670
4	2724	2712
5	1458	1755
P-value =0.003 SED = 289.2	P-value=0.585	

Table 45: 1000 grain wt (g) of CRI-Amankwatia and AgraRice varieties grown at Sokwai

	1000 grain weight (g)	
Treatment	CRI-Amankwatia	AgraRice
1	26.1	27.6
2	26.67	27.7
3	26.97	27.06
4	26.63	27.5
5	24.03	26.36
P-value -0.001 SED = 0.443	P-value -0.04 SED = 0.183	

Table 46: Plant height of CRI-Amankwatia and AgraRice varieties grown at Sokwai

	Plant height (cm)	
Treament	CRI-Amankwatia	AgraRice
1	96.73	111.13
2	97.00	107.60
3	98.66	106.66
4	95.00	110.27
5	92.40	108.86
P-value = 0.615	P-value = 0.009 SED = 2.092	

Table 47: Tiller/hill of CRI-Amankwatia and AgraRice varietie grown at Sokwai

	Tiller/hill	
Treatment	CRI-Amankwatia	AgraRice
1	8.47	7.67
2	9.00	8.26
3	8.53	7.53
4	8.73	7.26
5	7.53	7.20
P-value = 0.59	P-value = 0.29	

Table 48: Panicle length of CRI-Amankwatia and AgraRice varieties grown at Sokwai

	Panicle length (cm)	
Treatment	CRI-Amankwatia	AgraRice
1	24.58	26.14
2	24.39	26.73
3	24.44	26.96
4	25.05	25.65
5	23.63	26.18
P-value = 0.62	P-value = 0.05 SED = 0.519	

Conclusions and Recommendations

Treatment differences in grain yield and other growth and yield parameters were observed at Sokwai. These findings suggest that the rate and time of fertilizer application is very important for a good crop yield. The performance and yield of the two varieties were similar and this shows that the fertilizer rates and time of application will work well for the other rice varieties. It is therefore necessary that appropriate rates and time of fertilizer application should be put in place to increase yields.

Acknowledgement

We wish to express our appreciation to YARA Company Limited for funding this research work.

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MAIZE IMPROVEMENT

Development and Promotion of Hybrid Maize Varieties in the Forest and Forest-Transition Zones of Ghana (AGRA Maize Project)

Research Team: K. Obeng-Antwi, M. Ewool, M. Tengan, K. Agyeman, A. Oppong, M. Mochia and A. Agyeman

Collaborating Institutions: CSIR-SARI and MOFA

Source of funding: AGRA

Introduction

As part of an effort to rejuvenate breeding activities in the national maize programme, and as a means of promoting the adoption and use of hybrids in the country, a hybrid maize development programme was initiated under this Project in 2012.

Objective

- To develop high and stable yielding maize hybrids (single, double, three-way and top crosses) with tolerance to the major stresses of maize in the country, from the three major maturity groups for the diverse growing conditions in Ghana.

Materials and Methods

Activity 1

- **Evaluation of diallel crosses involving extra-early yellow inbred lines**

  A total of 35 F_1 crosses selected from diallel matings carried out in 2014 were evaluated at Fumesua and Ejura during the major season of 2015. The alpha lattice design (7x5) with three replications was used. Planting distance was 75 cm between rows and 40 cm within rows on two row plots. Abontem was used as the check. Three seeds were planted and later thinned to two at establishment.

Activity 2

- **Evaluation of top crosses involving Abontem and Extra-early maturing yellow inbred lines**

  Nine varieties, including Abontem as a check, were planted at Fumesua and Ejura, in a RCB design with three replications. Planting was 75 cm between rows and 40 cm within rows with two rows per plot, five metres long. Three seeds were planted and later thinned to two at establishment. Data collected for both trials included pre- and post-harvest characteristics including: days to mid-tassel, days to mid-silk, plant and ear heights, lodging (root and stalk), husk cover, plant aspect, plants harvested, ears harvested, moisture at harvest, field weight, and diseases (streak, rust, blight). Both trials were established at Fumesua and Ejura in May 2015.

Results and Discussion

For activities 1 and 2, data were taken on several traits but only data on grain yield will be discussed in this report. Combined analyses for the two trials are presented in Tables 49 and 50, for the diallel and top cross evaluations, respectively.

- **Evaluation of diallel crosses involving extra-early yellow inbred lines**

  Highly significant differences among hybrids (P<0.0001) were obtained. Similarly, highly significant differences between locations were also obtained. However, Location x Entry interaction was not significant. This indicates that the hybrids obtained from the diallel crosses performed similarly across the two sites even though the sites were different. Even though 35 entries were evaluated, Table 49 shows data from the top 20 entries including the check - Abontem. For the top 20 entries mean grain yield across the two sites was 2372.1 kg/ha. On location basis, grain yields for the top 20 crosses for the two sites were 3492.6 kg/ha and 1251.6 kg/ha for Fumesua and Ejura respectively. The top two crosses significantly out-yielded Abontem, the open-pollinated variety used as check. In general, however, among the top 20 crosses grain yields were very similar statistically. Data on other agronomic performances of the diallel crosses are not presented, however, significant differences among entries for days to mid-silk, plant and ear heights, lodging and reaction to major diseases in Ghana were obtained indicating variations of the crosses in those traits. The data confirmed that the materials were extra-early in maturity. Disease incidence was minimal during the period of evaluation, and hence the results obtained which indicated tolerance of the crosses to the major maize diseases in the country cannot be justified, since the required environmental conditions for local diseases to manifest themselves were not attained.

- **Evaluation of top crosses involving Abontem and Extra-early maturing yellow inbred lines**

  The combined analysis of the top cross hybrids indicated highly significant differences between the two locations and among the nine entries. Location x Entry interaction was also highly significant indicating that the two sites were different, the performances of the entries differed and that they performed differently across the two sites. Grain yield of the yellow top crosses averaged 3077 kg/ha for the nine entries including the check (Table 50). Fumesua recorded significantly higher yields (4077 kg/ha) than Ejura (2077 kg/ha). At Fumesua, the top ranking top cross, Abontem x TZEEI-64 out-yielded Abontem, the check variety, by 69.9% whereas the yield advantage between the highest yielding top cross at Ejura, (ie. Abontem x TZEEI-67) and the check was 25.0%. The data on agronomic performance of the top crosses are not presented, however, significant differences among entries for days to mid-silk, plant and ear heights, lodging and reaction to major diseases in Ghana were obtained indicating variations of the top crosses in those traits. Disease incidence, was minimal during the period of evaluation, hence the results obtained cannot be interpreted to mean tolerance/resistance of the hybrids to the major maize diseases in the country.

Conclusion and Recommendations

Opportunities exist to identify and propose for release yellow single cross hybrids and top-cross hybrids from the available germplasm in the Maize programme. It is therefore recommended that further crossing and evaluation of the parents involved in the diallel be carried out under favourable conditions to confirm results from this study and to generate data for release of potentially good hybrids. This recommendation also goes for the top crosses.

Table 49. Grain yield (kg/ha) of extra-early yellow single cross hybrids evaluated at two locations during the major season of 2015.

Entry Name	Locations		
	Fumesua	Ejura	Across
TZEEI-78 x TZEEI-66	4539.0	1704.4	3121.7
TZEEI-61 X TZEEI- 64	4202.6	1998.6	3100.6
TZEEI- 94 X TZEEI- 61	4039.1	1923.0	2981.0
TZEEI-96 X TZEEI- 76	3975.2	1762.7	2868.9
TZEEI-67 X TZEEI-64	4383.0	1228.9	2805.9
TZEEI- 63 X TZEEI- 96	4177.8	1398.0	2787.9
TZEEI-94 X TZEEI- 67	3822.4	1710.6	2766.5
TZEEI-94 X TZEEI-96	3895.2	1569.7	2732.5
TZEEI-66 X TZEEI-63	3659.2	1757.7	2708.5
TZEEI-71 X TZEEI-96	4022.0	1262.9	2642.4
TZEEI-94 X TZEEI-76	3948.7	1266.2	2607.4
TZEEI- 63 X TZEEI-67	3681.5	1529.5	2605.5
TZEEI-78 X TZEEI-66	3482.4	1708.8	2595.6
TZEEI-76 X TZEEI-61	3760.6	1405.4	2583.0
TZEEI- 94 X TZEEI-66	3890.2	1146.4	2518.3
TZEEI-67 X TZEEI-63	3945.3	1044.1	2494.7
TZEEI-61 X TZEEI-96	3833.3	921.7	2377.5
TZEEI- 66 X TZEEI-61	3553.6	1177.9	2365.8
TZEEI-76 X TZEEI- 64	3841.2	852.1	2346.6
ABONTEM (Check)	2766.0	926.5	2346.2
Grand mean (35)	3492.6	1251.6	2372.1
LSD (0.05)	1327.1	795.9	769.5
CV%	23.3	39.0	28.4

Table 50: Grain yield (kg/ha) of yellow top cross hybrids evaluated at two locations in the major season of 2015.

Entry Name	Locations		
	Fumesua	Ejura	Across
Abontem x TZEEI-64	5244	1733	3488.3
Abontem x TZEEI-76	4442	2346	3393.6
Abontem x TZEEI-67	3845	2531	3188.0
Abontem x TZEEI-96	3884	2479	3181.3
Abontem x TZEEI-66	3841	2338	3089.4
Abontem x TZEEI-94	4349	1772	3060.2
Abontem x TZEEI-71	4217	1701	2959.0
Abontem x TZEEI-61	3788	1767	2777.5
Abontem	3086	2025	2555.2
Grand mean	4077	2077	3076.9
LSD (0.05)	781.8	980.3	597.4
CV%	11.1	27.3	16.5

Maize Variety Evaluation in Ghana (Advance Project)

Research Team: K. Obeng-Antwi, M. Ewool, M. Tengan, K. Agyeman and A. Agyeman

Collaborating Institutions: CSIR-SARI and MOFA

Source of funding: WIENCO and SEEDCO

Introduction

Maize varieties developed in the national programme and those obtained from other sources are evaluated for yield and other agronomic characteristics in target ecological zones, as Station Variety Trials (SVTs). Three types of variety trials are usually conducted in the programme, namely, SVT-1 involving extra-early (80-85 days) maturing varieties, SVT-2 involving early (90-95 days) maturing varieties and SVT-3 involving intermediate (105-110 days) maturing and late (120 days) maturing varieties. These trials are classified by the maturity of the materials involved. They are planted using appropriate/recommended agronomic practices. However, in the major season of 2015, only SVT-3 was conducted in the major ecological zones of southern Ghana.

Objective

- To compare the performances of introduced and local varieties on-station under growing conditions in Ghana to identify varieties which could be recommended for on-farm testing, and for eventual release for commercial production in Ghana.

Materials and Methods

Two sets of evaluation trials were conducted during the year - in the major season at Fumesua (Forest), and in the minor season at Ejura and Akomadan (Forest Transition), Kpeve (Coastal Transition) and Pokuase (Coastal Savanna). The materials involved were 14 intermediate-late maturing hybrids obtained from Pannar (5), Monsanto (2), Seedco (2), Syngenta (2), Lake Agriculture (1) including two local checks (Mamaba and Tintim) for the major season and Aseda and Opɛaburoo for the minor season. Seeds were planted 0.75m between rows and 0.45 m between hills in a row and two rows per plot, 5 m long. The design was RCB with three replications per site. Data were taken on days to mid-tassel, days to mid-silk, plant and ear heights, lodging (both root and stalk), husk cover, Plant aspect, plants harvested, ears harvested, moisture at harvest, field weight and incidence of diseases (Streak, Rust, Blight).

Results and Discussion

Useful data could not be obtained from some of the locations due to severe drought. High soil variability, resulted in high coefficients of variability (especially at Fumesua and Pokuase). The trial at Pokuase was completely lost to drought. In the major season, highly significant differences among hybrids ($P<0.0002$) were noted. However, locations and Loc x Ent interaction were not significant. This indicates that the hybrids performed similarly across the two sites. In the minor season, highly significant differences occurred among the locations ($p<0.0001$), hybrids ($p<0.0001$) and the interaction (Loc x Entry; $p<0.002$). Low rainfall, with very poor distribution characterized the seasons at some of the locations. This constraint adversely affected the productivity of the materials. Data obtained from some of the sites indicated unexpectedly low yields. Data on grain yields combined over two sites in the major season and three sites in the minor season are presented as Tables 51 and 52 respectively.

In the major season, grain yields across the two sites, averaged 2.4 t/ha, ranging from 1.3 t/ha for (Syngenta-MRI 594) to 3.8 t/ha (for Pan 7M-81), a hybrid nominated by Wienco (Table 51). The mean grain yield among the four Pioneer hybrids (excluding 30F32) was 4.6 t/ha, whereas the mean grain yields of the four Wienco hybrids, the three local hybrids and the two hybrids from Calli Ghana, were 4.5 t/ha, 2.1 t/ha and 3.5 t/ha, respectively. On the average, the yield of the five Pannar hybrids was statistically equivalent to that of Monsanto in the major season, but they out-yielded the local checks (Mamaba and Tintim) by 62.8%, Seedco hybrids by 29.8%, Syngenta hybrids by 74.8% and Lake Agric hybrid (L601) by 93%.

In the minor season grain yields of the hybrids were generally moderate, with Ejura emerging as the most favourable environment among the five environments where useable data were obtained. Grand mean yield was 4.3 t/ha across the 14 entries, and ranged from 1.7 t/ha (for Pan 12) to 6.3 t/ha (for Pan 7M-81). Grain yields were lowest at Akomadan (minor season), averaging 0.9 t/ha, and ranging from 0.4 t/ha (for Pan 12), to 1.9 t/ha (for Pannar 7M-81) (Table 52). For the minor season, the five Pannar hybrids had statistically similar yields as the two Seedco hybrids. They, however, out-yielded the two Syngenta hybrids by 29.5%, the two checks (Aseda and Opɛaburoo) by 12.2%, Monsanto hybrids by 23.4% and Lake Agric by 34.7%. Interestingly, the two check hybrids out-yielded the Syngenta, Monsanto and Lake Agric hybrids by 15.4%, 9.1% and 20.0%, respectively.

Data on the other agronomic performances of the hybrids are not presented, however, it was observed that there were significant differences among the entries for days to mid-silk, plant and ear heights, lodging and reaction to major diseases in Ghana, indicating variations among the hybrids in those traits during the two seasons of evaluation. The flowering data confirmed that the materials were, from the intermediate maturity group. Disease incidence was minimal during the evaluation, hence the results obtained cannot be interpreted to mean tolerance/resistance of the hybrids to the major maize diseases in the country.

Conclusion and Recommendation

Out of the 14 hybrids, Pan 12, Pan 53 and the four local checks, (two each per evaluation) were officially released. The remaining eight hybrids entered the evaluation process for the first time. On the basis of the harsh conditions under which the hybrids were evaluated and their initial performance we wish to recommend that all the nominated hybrids be advanced into the second year of on-station evaluation to confirm the 2015 results and, to further generate data to support proposal for commercial release in future, if appropriate.

Table 51: Grain yield (kg/ha) of intermediate to late maturing hybrids tested at two locations during the 2015 major season.

Entry name	Locations		
	Fumesua	Ejura	Across
Pannar-7M-81	4212	3298	3755
Pannar-7M-83	3738	3254	3496
Monsanto-Big 717	2696	3527	3112
Monsanto-Prabal	2631	2998	2815
Pan 12	3388	2031	2709
Pan 53	3517	1873	2695
Seedco-SC 402	2428	2282	2355
Seedco-SC 506	1872	2487	2180
Tintim (check)	2047	2141	2094
Pannar-8M-93	2202	1923	2062
Syngenta-MRI 614	2018	2087	2053
Lake Agric.-L601	1333	1717	1525
Mamaba (check)	1362	1683	1522
Syngenta-MRI 594	854	1777	1315
Grand mean	2450	2363	2406
LSD	1965	904	1050
CV%	48	23	38

Table 52: Grain yield (kg/ha) of intermediate to late maturing hybrids tested at three locations during the 2015 minor season.

	Locations			
Entry Name	Ejura	Akomadan	Kpeve	Across
Pannar-7M-81	6274	1857	4039	4057
DK 77	6054	972	3820	3615
Pannar-8M-93	5553	470	4499	3507
DK 234	5448	1135	3900	3494
Pannar-7M-83	4637	1832	3873	3448
Seedco-SC-506	4957	1526	3140	3208
Seedco-SC-402	4417	1399	3451	3089
Aseda (check)	4844	802	3596	3081
Pan 53	3571	682	4109	2787
Monsanto-Prabal	3774	570	3629	2658
Opɛaburoo (check)	3265	776	3714	2585
Syngenta-MRI 614	3848	369	3284	2500
Monsanto-Big 717	3601	646	3236	2494
Syngenta-MRI 594	3512	632	3078	2408
Lake Agric.-L601	3085	759	3237	2360
Pan 12	1704	402	4187	2097
Grand mean	4284.0	926.6	3674.5	2961.7
LSD	1702.7	575.8	1073.3	686.1
CV%	23.8	37.3	17.5	24.8

Technology testing and fine tuning (SARD-SC Sub-Project 1)

Research Team: M. L. Tengan, K. Obeng-Antwi, K. Agyeman, A. Adu-Appiah, A. Halidu* and G. Boakyewaa-Adu* (*SARI)

Collaborating Institutions: IITA, CSIR-SARI and MoFA

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Introduction

In Ghana maize is the most important cereal grain in terms of total production and utilization. It is the largest staple crop and the most widely cultivated due to its high potential grain yield. The crop is the largest commodity crop in the country second only to cocoa (MiDA, 2010). Unfortunately, its production in the country is constrained by recurrent drought, aflatoxin contamination, S*triga* and low soil nitrogen. Identifying and selecting maize varieties that can overcome these stresses will constitute an important intervention to increasing maize yield and productivity; thereby enhancing people's livelihoods, food security and economic development in Ghana.

Objectives

- To compare the performance of Early White QPM multi-stress tolerant lines, Aflatoxin 3-way hybrids and Low-N multiple stress tolerant populations in the Transition and Forest agro-ecological zones,
- To identify varieties which could be recommended for on-farm testing, and eventual release for commercial production in Ghana.

Materials and Methods

In 2014, eighteen sets of trials were obtained from IITA and established by three Innovation Platforms (IPs). Sixteen sets of the trials were repeated during the 2015 minor season (Table 53) to confirm their performances and to enable selection of superior genotypes for on-farm evaluation.

Table 53: Distribution of trials established by the IPs in 2015

S/N	Code	Name of Trial	No. of locations	IP
1	SC 2	Early White QPM multi-stress tolerant trial	3	Forest
2	SC 2	Early White QPM multi-stress tolerant trial	3	Transition
4	SC 5	Aflatoxin 3-way hybrid trial	2	Forest
5	SC 2	Aflatoxin 3-way hybrid trial	2	Transition
7	SC 7	Low-N multiple stress tolerant populations trial	3	Forest
8	SC 2	Low-N multiple stress tolerant populations trial	3	Transition
		Total number of trials =16		

Materials and Methods

The trials were established, at all locations, at the onset of the rains. Data were taken on several parameters and analysed using Genstat 9th edition.

Results and Discussions

- **Early white QPM multi-stress hybrid trial**

Significant differences (P<0.05) were observed for grain yield. Mean grain yield ranged between 3122 kg ha^{-1} (for Abontem), and 4128 kg ha^{-1} (for EWQH-2) with a grand mean of 3469 kg ha-^{1} (Table 54). The most productive environment was Location 6, (ie Sunkwa in the Nkoranza South district in the Transition IP) which recorded a mean yield of 5249 kg ha^{-1}, with a range of 4900 kg ha^{-1} (for Abontem) and 6633 kg ha^{-1} (for Omankwa), both of them being released varieties from the CSIR-CRI maize programme which were used as checks in the trial. Location 1 (ie Gulumpe in the Kintampo North district) recorded the lowest yields ranging between 1433 kg ha^{-1} and 2167 kg ha^{-1} with an average of 1723 kg ha^{-1}. Generally significant differences were observed among the genotypes as well as for locations.

Table 54: Grain yield (kg ha-^{1}) of early white QPM multi-stress tolerant hybrids evaluated in the Forest and Transition zones of Ghana: 2015 minor season

	Location*						
Entry Name	1	2	3	4	5	6	Across
EWQH-2	2167	3667	4267	4067	5500	5100	4128
EWQH-6	2100	3500	3533	3467	5133	5000	3785
EWQH-20	1567	2067	3433	2867	5367	4933	3372
Omankwa	1467	1500	2600	2533	5433	6633	3361
EWQH-9	1600	2333	3567	2867	4833	4933	3339
EWQH-13	1833	2343	3556	2300	5200	4833	3328
EWQH-7	1600	2334	3900	1800	4600	5632	3312
Abontem	1433	1934	2336	2766	5223	4900	3122
Mean	1723	2334	3400	2834	5179	5249	3469
SED	153.7	246.7	431.6	269.6	826.3	404.2	247.8
CV (%)	16.7	19.2	15.3	12.8	14.1	13.4	13.9

*Location 1 = Gulumpe, 2 = Kobeda, 3 = Njaya, 4 = Woraso, 5 = Badukrom, 6 = Sunkwa

- **Aflatoxin Resistant 3-way cross hybrid trial**

Grain yield across locations and within locations were significantly different (P <0.05). The mean yield across locations was 3180 kg ha^{-1} and ranged from 2016 kg ha^{-1} to 3501 kg ha^{-1} (Table 55). Location 3, (Bonsu in the Nkoranza South district) was the most productive environment with an average yield of 3414 kg ha^{-1}. Grain yields were lowest at Location 1 (Gulumpe) in the Kintampo North District, averaging 2945 kg ha-1, and ranging from 2781 kg ha-1 for AR1307-1, to 3365 for AR1316-13.

Table 55: Grain yield (kg ha^{-1}) of Aflatoxin Resistant 3-way cross hybrids evaluated in the Forest and Transition zones of Ghana: 2015 minor season

	Locations*				
Entry Name	1	2	3	4	Across
AR1316-15	2852	3203	3459	3498	3501
AR1316-13	3365	2144	4356	3136	3500
AR1316-22	2941	2151	3646	3061	3200
Check 1	3176	2499	3090	2977	3186
AR1307-8	2808	2458	3116	3255	3159
AR1316-17	2415	2390	3093	3088	2996
Check 2	3224	1944	3308	3228	2981
AR1307-1	2781	1682	3238	2962	2916
Mean	2945	3309	3414	3053	3180
SED	204.4	191.3	326.4	212.1	198.3
CV %	14.4	17.3	10.5	14.4	16.1

*Location 1 = Gulumpe, 2 = Adidwan, 3 = Bonsu, 4 = Njaya

- **Low Nitrogen Multiple stress populations trial**

Out of the six sites where this trial was established only three sites produced usable data. Combined analyses of yield data (after applying 30 kg N ha^{-1}) from the three sites (Woraso, Nkoranza, Badukrom) where useable data were obtained, are presented as Table 56. Significant differences among locations (P<0.05) and among entries within locations (P<0.05) were noted, indicating the variable nature of the sites and differences in the performances of the entries. Location 1 (Nkoransa) recorded the highest mean grain yield of 2913 kg ha^{-1} under 30 kg N ha^{-1}. Mean grain yield across the three locations was 2491kg ha^{-1}, ranging between 2329kg ha^{-1} for Check 1 (Omankwa) and 2696 kg ha^{-1} for LNE DMRSR-W-SynC3.

Table 56: Grain yield (kg ha^{-1}) of Low Nitrogen multiple stress tolerant populations evaluated in the Forest and Transition zones of Ghana: 2015 minor season

	Locations*			
Entry Name	1	2	3	Across
LNE DMRSR-W-Syn C3	3637	2047	2397	2696
LNE DMRSR-Y-Syn C3	3365	1938	2514	2606
TZE3 DTC2 LN Syn	2993	2076	2645	2571
CHECK 2 (Abontem)	2610	3413	2650	2558
EARLY LN-W	2659	2235	2414	2436
EW LN Pop	3015	1903	2249	2388
TZE31 DMRSR LN Syn	3193	2511	1336	2347
CHECK 1 (Omankwa)	1828	2464	2694	2329
Mean	2913	2323	2362	2491
SED	188.7	114.9	123.6	98.1
CV (%)	15.5	20.4	19.2	25.4

*Location 1=Sunkwa (Nkoransa), 2= Badukrom (Kintampo), 3=Woraso (Mampong Municipal)

Conclusions and Recommendations

Six promising varieties (EWQH-2 and EWQH-6 from the Early white QPM hybrid trial, AR1316-15 and AR1316-13 from the Aflatoxin Resistant trial and LNE DMRSR W SynC3 and LNE DMR SR Y SynC3 from the Low N Multiple stress populations trial) were identified for on-farm evaluation and eventual release for commercial production.

Production and Promotion of Breeder and Foundation Seeds of Improved Stress Tolerant Varieties and Hybrids (Sub-Project 4)

Introduction

Maize is a cross pollinated crop, therefore, varieties released usually get contaminated within a couple of years after their release. For this reason, poor plant stand and segregating plant materials are very common on farmers' fields, contributing to low yields. In general, improving smallholder farmers' access to high quality seeds of improved high yielding varieties may be considered as one major approach to achieving increased productivity and production of maize, leading to poverty alleviation and food security enhancement in the country. The lack of improved seeds has very often been cited by farmers and other stakeholders as a major constraint affecting maize productivity and production in Ghana. To meet the demands of maize farmers for certified seeds of improved maize varieties, there is the need to up-scale breeders' and pre-basic seed production of these improved varieties in the country. The aim of the project is to bridge the gap of the shortfall in certified seed availability in Ghana by increasing and maintaining the physical and genetic purity of breeder and foundation seeds of improved varieties of maize in the country.

Specific Objectives

- To maintain the genetic purity of open-pollinated varieties and parental lines of released hybrids.
- To multiply and produce breeder and pre-basic seeds of released varieties and hybrids.
- To make available to seed companies and seed producers breeder seed of parental lines of released hybrids and open-pollinated varieties.

Materials and methods

- **Production of breeder and foundation seed of Open pollinated varieties (OPV)**

  Fields were established at Fumesua, Wenchi and Akumadan to produce breeder and foundation seeds of Aburohemaa and Omankwa (Table 57). The isolated half-sib ear-to-row crossing block procedure for maintaining and producing breeder seed of an open-pollinated variety was used while the foundation seed was produced through open-pollination in isolated fields, away from any source of pollen contamination. An isolation distance of between 350 and 400 metres was maintained.

Table 57. Breeder and Foundation seed fields established in 2015.

Variety (Seed type)	Location	No. of Acres
Aburohemaa (Breeder seed)	Fumesua	1
Aburohemaa (Foundation seed)	Wenchi	10
Omankwa (Foundation seed)	Akumadan	20

Results

Planting in the minor season was delayed as a result of delayed rainfall. The generally unfavorable weather during the critical growth stages of the crop resulted in barren plants, smaller ear sizes and eventually low seed yields. The quantities of seed produced are presented as Table 58.

Table 58. Quantities of seed produced

Variety	Class of seed	Quantity (kg)
Aburohemaa	Breeder	75
Aburohemaa	Foundation	4,000
Omankwa	Foundation	4,050
Total		8,125

LEGUMES AND OIL SEED

GROUNDNUT IMPROVEMENT

Research Team: J.Y. Asibuo, S. Amoah, H. K. Adu-Dapaah, K. Osei, Maxwell Lamptey, A. G. Gyima, F. W. K. Gaplezi, H. K. Mireku, A. Adu-Appiah, M. B. Mochiah, Z. Appiah-Kubi, A. Agyeman, K. Osei and P. Osei Bonsu

Source of funding: AGRA

Introduction

Groundnut is a major annual oilseed crop. It is estimated that about two-thirds of the total groundnut production was crushed for oil and the remaining one-third utilized in confectionery products during the 1990s (Dwivedi *et al*., 1993). There has been a gradual shift from using groundnut for oil and meal towards confectionery products (Freeman *et al*., 1999). The global demand for groundnut oil increased from 2.8 million tons to 4.3 million tons between 1979-81 and 1994-96, even though international groundnut prices were increasing (Freeman *et al*., 1999). Despite the recognition of Ghana as one of the leading producers of groundnut in the world, yield on farmers' field continue to be less than the attainable yield of 2-3 mt/ha due to unstable rainfall patterns, diseases and pests, lack of quality seeds and favourable agronomic practices. Groundnut rosette virus disease (GRD) contributes to annual losses of US$156 million across Africa (Nigam *et al*., 2012). Aflatoxins are highly toxic mycotoxins produced as secondary metabolites by the fungi *Aspergillus flavus* and *A. parasiticus*. Aflatoxicosis is poisoning that result from ingestion of aflatoxins in contaminated food or feed. Screening of groundnut varieties for resistance to aflatoxin contamination has going on at CSIR-CRI for about three years. The groundnut breeding programme at CSIR-CRI is addressing climate change and other issues such as drought, pests, diseases, aflatoxin, nutrition, high oil content and high oleic acid content which offer better product stability.

Objective 1

- To evaluate improved groundnut lines developed at CSIR-CRI and select adapted lines for further on-farm evaluation.

Materials and methods

ICRISAT rosette resistant trial and two station variety trials (SVT 1 and SVT 2) - developed at CSIR-CRI with materials tolerant to rosette disease - were conducted at Fumesua, Akomadan, Kwadaso, Ohawu and Ejura, using Lattice design with three replications. The CSIR-CRI lines were grouped into early (85 to 90 days) and medium (90 to 100 days) maturity groups. SVT 1 consisted of 15 new lines and a check while SVT 2 and ICRISAT trial consisted of eight new lines each, with a released variety as a check. Seeds were sown in four-row plots, five metres long at a spacing of 40 cm between rows and 20 cm within rows. Data collected included days to 50% flowering, days to maturity, 100 seed weight, shelling percentage and pod yield. Lines with superior attributes will be further tested on farmers' fields.

Results and Discussion

Mean pod yield of SVT 1 across the five locations ranged from 1317 to 1793 kg/ha (Table 59). Seven of the improved lines out yielded the check (*Yenyawoso*). SH-AZ-1-13 produced the highest pod yield across locations.

Based on pod yield and their reaction to diseases, some of the lines will selected for further testing on farmers' fields before release.

Mean pod yield of SVT 2 across the five locations ranged from 1518 to 2983 kg/ha (Table 60). One of the test lines out yielded the check (Otuhia). Some of the lines will be further tested on farmers' fields.

Mean pod yield of the rosette resistant lines from ICRISAT ranged from 1780 to 2401 kg/ha (Table 61). Otuhia, a released variety gave the highest pod yield across the locations Based on pod yield and their reaction to diseases some of the lines will be further tested on farmers' fields before release. Data on rosette incidence are yet to be analysed.

Table 59. Pod yield (kg ha^{-1}) of Groundnut Station Variety Trial 1

Entry	Fumesua	Akomadan	Kwadaso	Ohawu	Ejura	Mean across locations
AP-AZ-10-13	2427	1322	672	2052	1330	1561
AP-AZ-11-13	2537	1618	626	2165	1739	1737
AP-AZ-12-13	2816	1793	532	2582	887	1722
AP-AZ-13-13	1431	1496	612	2025	1362	1385
AP-AZ-14-13	1166	1562	1481	1995	2212	1683
AP-AZ-15-13	1268	1520	553	2111	1136	1317
AP-AZ-2-13	1260	1071	438	2865	1765	1480
AP-AZ-3-13	2935	1050	653	2591	1328	1711
AP-AZ-6-13	2413	1353	667	2485	1740	1732
AP-NK-2-13	2306	1342	799	1973	1435	1571
AP-NK-3-13	2198	1575	435	2179	1677	1613
SH-AZ-3-13	2114	1572	585	2344	1955	1714
SH-AZ-5-13	1647	1644	462	2340	1165	1452
SH-AZ-6-13	1794	1660	400	3023	2088	1793
SH-NK-1-13	2108	1300	383	2393	1678	1572
YENYAWOSO	1803	1069	678	2575	2044	1634
MEAN	1993	1434	624	2356	1596	1601
SED	448	166.3	242*	395.5	386.8	
CV(%)	27.5	14.2	7.3	20.6	29.7	

Table 60. Pod yield (kg ha^{-1}) of Groundnut Station Variety Trial 2

Entry	Fumesua	Akomadan	Kwadaso	Ohawu	Ejura	Mean across locations
AP-AZ-1-13	2303	1150	782	2285	1124	1518
AP-AZ-16-13	1754	1510	1010	2750	1782	1761
AP-NK-11-13	2438	1438	974	2310	1523	1696
AP-NK-8-13	2174	1205	1507	1880	1145	1582
AP-NK-9-13	2677	1332	1361	2979	1720	2005
NP-NK-2-13	2523	1152	1765	2985	1801	2045
NP-NK-7-13	2295	1554	934	2386	1095	1653
OTUHIA	4118	926	1868	2461	2165	2308
SH-AZ-7-13	3259	1284	972	2218	1982	2983
MEAN	2616	1283	1241	2473	1593	1841
SED	518*	274.8	375.4	333	365.7	
CV(%)	24.2	26.2	29.4	16.5	28.1	

Table 61. Pod yield (kg ha^{-1}) of Rosette resistant trial (ICRISAT)

Entry	Fumesua	Akomadan	Ohawu	Ejura	Mean across locations
ICGV-15-96801	3446	1594	2035	1792	2217
ICGV-I5-96805	2944	2002	2975	1414	2334
ICGV-SM-93518	2380	1286	2357	1700	1931
ICIAR 6AT	2546	1407	2383	1507	1961
ICIAR 7B	2381	1903	2523	1244	2013
ICIAR-12AR	1802	1550.	2900	1881	2033
ICIAR-18AR	1808	2269	2174	1770	1780
ICIAR-19BT	2381	1896.	2467	1355	2025
OTUHIA	3804	1607	2518	1674	2401
MEAN	2610	1724	2481	1593	2102
SED	419.5	272.8*	247.7	490.9	
CV (%)	19.7	19.4	12.2	25.7	

Objective 2

- To evaluate improved aflatoxin resistant groundnut lines and select adapted lines for further evaluation.

Materials and Methods

Eight aflatoxin resistant groundnut lines received from ICRISAT, Mali, and a check variety were evaluated at Fumesua Akomadan and Ohawu, using a 3 x 3 lattice design with three replications. Seeds were sown in four-row plots, five metres long at spacing of 40 cm between rows and 20 cm within rows. Data collected included days to 50% flowering, days to maturity, 100 seed weight, shelling percentage and pod yield.

Results and Discussion

Mean pod yield across the locations ranged from 1438 to 2075 kg/ha (Table 62). Two of the test lines out yielded the check (*Yenyawoso*). Based on pod yield, their reaction to diseases and their aflatoxin tolerance some of the lines will be further tested on farmers' fields before release. Data on aflatoxin incidence and scores are yet to be analysed

Table 62. Pod Yield (kg ha-1) of Aflatoxin resistant trial- Ohawu

Entry	Fumesua	Akomadan	Ohawu	Mean across locations
ICGV 01094	2808	1289	1880	1992
ICGV 02171	3373	1330	1505	2069
ICGV 02184	2812	670	1972	1818
ICGV 02206	2505	1355	1595	1818
ICGV 02207	2392	328	1595	1438
ICGV 03331	3163	1070	752	1662
ICGV 03398	2462	1130	1278	1623
ICGV 03401	2946	1050	2229	2075
YENYAWOSO	2946	1278	1932	2052
MEAN	2829	1056	1637	1841
SED	416**	230.3**	338.6	
CV (%)	18.0	26.7	25.3	

Objective 3

- To evaluate improved high oil content groundnut lines and select adapted lines for further testing on-farm evaluation.

Materials and methods

Eight high oil content groundnut lines (with oil content of 50% or more of total seed dry mass) received from ICRISAT, Mali, and a check variety were evaluated at Fumesua, Akomadan, Kwadaso, Ohawu and Ejura using a 3 x 3 lattice design with three replications. Seeds were sown in four-row plots, five metres long at spacing of 40 cm between rows and 20 cm within rows. Data collected included days to 50% flowering, days to maturity, 100 seed weight, shelling percentage and pod yield. Lines with superior attributes will be further tested on farmers' fields

Results and Discussion

Mean pod yield across locations ranged from 1734 to 2137 kg/ha (Table 63). *Otuhia*, a released variety that served as a check gave the highest pod yield across the locations. Data on disease incidence and severity and their oil contents were being compiled for analysis. Based on their pod yield, reaction to diseases, oil contents and their oleic/linoleic acid ratio (mark of stability) some of the lines will be further tested on farmers' fields before release.

Table 63. Pod Yield (kg ha^{-1}) of High oil content groundnut trial

Entry	Fumesua	Akomadan	Kwadaso	Ohawu	Ejura	Mean Across locations
ICGV 00171	2847	1295	1330	1777	1419	1734
ICGV00351	2895	1621	2110	1762	1857	2049
ICGV01273	2825	2383	1946	2168	1335	2131
ICGV01274	2675	1551	1419	2417	1817	1976
ICGV99017	3711	1210	1132	1957	1088	1820
ICGV99033	2945	1472	1242	1806	1410	1775
ICGV99050	3328	898	1570	1918	1831	1909
ICGV99053	3550	1946	1284	1599	1526	1981
OTUHIA	3445	1497	1838	1853	2054	2137
Mean	3136	1541	1541	1917	1593	1946
SED	509**	387	462	439.8	438.7	
CV (%)	19.9	18.7	18.9	28.1	25.7	

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CANNING BEAN IMPROVEMENT

Research Team: J.Y. Asibuo, S. Amoah, H. K. Adu-Dapaah, K. Osei, M. L., A. G. Gyima, F. W. K. Gaplezi, H.K Mireku, A. Adu-Appiah, M. B. Mochiah, Z. Appiah- Kubi, A. Agyeman, K. Osei and P. Osei Bonsu.

Source of funding: PABRA

Introduction

The PABRA breeding strategy has generated improved bean germplasm to address climate change related stresses such as drought, pests and diseases; as well as to respond to nutritional issues ie Fe and Zn contents and Niche Market needs for dry bean, snap and canning beans. Common beans are one of the best sources of iron and zinc. Islam *et al*. (2002) observed that common bean cultivars contain iron concentrations ranging from 30 to 120 ppm in the seed; and Hacisalihoglu *et al*. (2004) found zinc concentration ranging from 20 to 60 ppm. The goal of the bean project is to improve food security, health and income of resource-poor farmers in gender equitable manner through research on micro nutrient-rich beans while maintaining the natural resource base.

Objective 1

- To evaluate improved multiple constraint resistant bean lines and select adapted lines for multi-locational testing.

Materials and Methods

Two multiple constraint resistant bean trials were established at Fumesua and Wenchi using RCB design with three replications. Each trial had 12 entries. Seeds were sown at a spacing of 40cm between rows and 20 cm within rows on four row plots. The plots measured five meters long. Data were collected on days to 50% flowering, days to maturity, 100 seed weight, pod weight, seed yield and shelling percentage.

Results and Discussion

Mean grain yield was higher at Akomadan (404 kg/ha) than at Fumesua (319 kg/ha). DOR 500 recorded the highest mean grain yield of 485 kg/ha across locations (Table 64).

Table 64. Grain yield (kg/ha) of Multiple Constraint Resistant Bean Trial

Entry	Akomadan	Fumesua	Mean
BILFA FEB 200	384	165	275
DOR 500	411	558	485
MCR-ISD-672	310	527	419
NUA 566	292	266	279
ROBA 1	378	187	283
SMB 17	431	263	347
SMB 27	484	165	325
SMC 13	430	210	320
SMR 46	571	321	446
SMR 47	299	402	351
SMR 48	420	366	393
SMR 53	442	404	423
Mean	404	319	362
SED	128	113*	
Cv ((%)	11.7	18.6	

Objective 2

- To evaluate improved canning bean lines and select adapted lines for multi-locational testing.

Materials and methods

Three canning beans trials were established at Fumesua and Akomadan using RCB design with three replications. The trials were made up of 16 lines each. Seeds were sown at a spacing of 40 cm between rows and 20 cm within rows on four row plots. The plots measured five meters long. Data were collected on days to 50% flowering, days to maturity, 100 seed weight, pod weight, seed yield and shelling percentage. Agronomic practices such as refilling, weeding, application of insecticides were done at the right time.

Results and Discussion

Mean grain yield across locations ranged from 289 to 501 kg/ha (Table 65). Bean lines will be selected for further testing based on their grain yield, grain quality and reaction to diseases.

Table 65. Grain yield (kg/ha) of Canning Bean Trial

Entries	Akomadan	Fumesua	Mean
G 14	391	348	370
G 21	532	370	451
G 27	472	312	392
G 31	548	454	501
G 32	537	226	382
G 37	354	295	325
G 40	340	268	304
G 53	572	398	485
G 6	498	425	462
G 60	424	315	370
G 72	447	130	289
G 78	420	403	412
G 80	424	296	360
G 87	512	219	366
G 90	516	249	383
G 96	535	442	489
Mean	470	322	
SED	121	84.6	
CV (%)	5.5	19.9	

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COWPEA IMPROVEMENT

Research Team:	S. Amoah, H. Adu-Dapaah, J.Y. Asibuo, J.N.L Lamptey, A. Agyeman, A. Bediako, E. Asamoah, J. K. Addo, A Adama
Collaborating Institutions:	MoFA and IITA
Source of funding:	AGRA

Introduction

Cowpea (*Vigna unguiculata* (L.) Walp) is one of the most important grain legumes in Ghana. It is a cheap source of vegetable protein, minerals and vitamins and it constitutes an integral part of Ghana's agriculture. It is currently considered a food security crop (METASIP) with a huge potential for sustainable agriculture. Despite these numerous benefits, cowpea production is faced with many constraints including inherent low yields, low adoption of improved varieties, field pests and diseases, storage pests and erratic rainfall. As a result of these constraints cowpea yields on farmers' field are low, averaging 0.7 - 1.5t/ha as compared with a potential yield of 3.5t/ha from improved varieties. Some farmers, in an attempt to control field pests, resort to indiscriminate use of insecticides with its attendant health hazards on consumers and negative impact on the environment. Thus, the cowpea improvement programme at CSIR-CRI is focused on developing varieties that are high yielding with host resistance to most cowpea pests and diseases, and have consumer-preferred characteristics.

Objective

- To develop improved cowpea varieties that are high-yielding, resistant to pests and diseases and have consumer-preferred characteristics.

Activity 1

Cowpea International Trials (CITs)

The CITs are part of preliminary field trials organized by IITA in which Ghana (CSIR-CRI) participates. In 2015, two trials - CIT 2 (medium maturity group) and CIT 3 (dual purpose cowpea) were established.

Objectives

- To evaluate the lines for yield performance, adaptation to local environment and reaction to diseases and pests
- To select best performing lines to constitute station variety trials.

Materials and Methods

The two trials (CIT 2 and CIT 3) were established at Fumesua and Ejura in a lattice design in serpentine planting order with 16 entries each including a local check in each trial. Seeds were sowed at a spacing of 60cm x 20cm on 5m long plots. There were four rows for each plot. Data were recorded from the two central rows. Data were recorded on days to emergence, days to 50% flowering, days to maturity, plant height at harvest, number of pods per plant, seed and haulm yields.

Results and Discussion

Mean data from CIT 2 and CIT 3 are presented as Tables 66 and 67. For CIT 2 days to emergence ranged from 4.0 to 5.7 with IT08K-150-24 emerging as the line that emerged latest. The line IT07K-188-49 flowered earliest at 35 days after planting, while Iron Clay flowered latest. IT07K-211-1-8 had the highest yield of 3.03t/ha while IT97K-499-35 had the lowest yield of 1.89t/ha. Best performing lines will be selected by index selection to constitute Station Variety Trial 2.

Table 66. Mean agronomic performance of 16 cowpea lines evaluated in CIT 2

Entry	Days to emergence	Days to 5% flowering	Days to maturity	Plant height (cm)	Yield (kg/ha)
GH-7875	4	38.33	61	50.7	1941
HEWALE	4	39.00	61	60	2679
IRON CLAY	4	46.33	62	60	2644
IT07K-187-24	4.3	37.67	61	51.3	2083
IT07K-188-49	4.3	35.00	61	46.3	2072
IT07K-211-1-8	4	36.67	63	53.3	3036
IT07K-291-92	4	40.00	62	57	2330
IT07K-292-10	4	36.33	62	53.7	3105
IT07K-304-9	4.3	36.67	62	47	1936
IT07K-318-2	4	37.33	62	59	2758
IT08K-149-3	4.3	38.67	62	50	3347
IT08K-150-12	4.3	37.00	62	55	2783
IT08K-150-24	5.7	37.33	63	49.7	2578
IT08K-180-7	4.3	38.33	62	46	2132
IT97K-499-35	4	35.33	62	48.3	1893
TVU-90037	4.3	39.00	62	54	2372
Mean	4.25	38.06	61.88	52.62	2481
s.e.d	0.3	4.05	0.78	4.7	529
CV (%)	8.8	13	1.6	11	16.1

Table 67. Mean performance 16 cowpea genotypes evaluated in CIT 3

Entries	Days to 50% emergence	Days 50% flowering	Days to maturity	Plant height (cm)	No. of pods per plant	Yield (kg/ha)
AMOAH	8	43.33	61.67	31.33	6.33	1177.92
ASIBUO	8	43.33	61.33	38.67	8.67	1277.64
HANS	7.67	42.33	61	36.67	10.67	1508.40
IT04K-332-1	5	38	60	43.67	10.67	1672.78
IT04K-339-1	5.33	39.33	59.33	44.67	8	1441.66
IT07K-274-2-9	5.67	36	60	48	12.33	1764.71
IT07K-297-13	11.67	36.33	61.67	36.33	10.33	1623.66
IT08K-126-19	7.33	39.33	60.67	40	8.33	1311.13
IT08K-180-11	10	39.67	61	41.33	9	1108.94
IT08K-180-5	8	38.67	60.67	45.67	10.67	1793.29
IT08K-193-15	8.67	36.33	62	44.33	14	2023.15
IT09K-269-1	5.33	36.67	60.67	46.67	10.33	1630.33
IT09K-321-1	5	36	59.67	45.67	15.67	1816.70
IT09K-456	8	38.67	60.33	42.33	13.33	1775
KV X 403	5.67	38.33	59	43.67	7.67	1404.91
VIDEZA	5.33	38.33	59.67	48.67	9.33	1812.48
Mean	7.17	38.79	60.54	42.35	10.33	1571.46
S.E.D.	2.270	2.151	0.658	4.320	1.761	299.955
CV (%)	18	6.8	1.3	12.5	13.9	15.4

Activity 2

Cowpea Station Variety Trials (CSVT-1 and CSVT-3)

Objective

- To evaluate early maturing cowpea lines on-station (CSVT-1) and dual purpose cowpea lines (CSVT-3) for their yield performance, reaction to diseases and pests and seed characteristics.

Materials and Methods

Cowpea Station Variety Trials 1 and 3 which were constituted in the major season were repeated during the minor season. Early maturing advanced breeding lines obtained through hybridization and successive screening of several populations (during phase 1 of the project) were used to constitute CSVT-1. The trial consisted of 16 entries including two check varieties (*Nhyira* and *Asetenapa*) and a farmer's variety called *Uganda*. The experimental design was RCB with three replications. Each entry was established on a five metre long plot at a spacing of 60 x 20cm, and a total of four rows per plot. Data collected included days to 50% flowering, nodule score, days to maturity, plant height at harvest, seed weight, yield per hectare, haulm weight and reaction to pests and diseases.

Results and Discussion

Data from CSVT-1 and CSVT-3 are presented as Tables 68 and 69. For CSVT -1, days to flowering ranged between 35 and 46, after planting, with Zamzam maturing earliest. Days to maturity ranged between 51 and 62. The line 11(1)-2 produced the highest yield of 2805kg/ha. The lowest yield of (922kg/ha) was produced by UCR-1432. The yields were generally low and might be due to the prolong drought experienced during the minor season. Four superior lines would be selected to constitute a new on-farm trial.

Table 68. Performance of 16 early maturing cowpea genotypes evaluated in CSVT

Entry	Days to emergence	Days to 5% flowering	Days to maturity	Number of pods per plant	Plant height	Yield (kg/ha)
1(11)-2	6	38	52	9	36	1689
11(1)-2	6	42	54	11	40	2805
21(1)-2	5	36	51	6	41	1603
25(1)-2	6	36	52	6	30	1504
Asomdwee	6	46	62	9	50	2235
BRA 01	5	36	53	10	42	2040
ITY06K-111	6	39	54	10	41	2693
IT0K- 147-2	6	39	54	9	40	2090
IT06K-242-3	6	37	54	8	43	1994
IT07K-243-1-2	6	36	52	5	37	1638
IT07K-273-2-1	6	37	52	7	47	1226
IT07K-2-98-15	6	37	54	7	44	1888
IT97K-819-132	5	36	52	5	46	1838
UCR-1432	5	36	52	6	37	922
UCR-779	5	38	52	7	42	1751
Zamzam	6	35	53	9	35	1295
MEAN	5.60	37.8	53.3	7.4	41.3	188.9
SED	0.315	0.835	0.366	2.686	3.510	619.346
CV	3.9	0.5	0.4	13.9	6.3	21.1

Table 69. Mean performance of 16 cowpea lines evaluated in CSVT 3

Entries	Days to 50% emergence	Days to 50% flowering	Days to maturity	No. of pods per plant	Plant height (cm)	Grain yield (kg/ha)
IT04K-227-4	5	35	62	16.33	44.67	2734.23
IT06K-108	5	36.33	62	12	53	2700.46
IT06K-123-1	4.67	38.67	62	11.33	50.67	3065
IT06K-135	4.67	36.33	62	18	50	2686.37
IT06K-147-1	6.67	38.33	61	15.67	47	3728.90
IT06K-147-2	5.33	40	62	16.33	44	3049.95
IT06K-270	4.33	41	61	11.33	50	2884.42
IT06K-91-1	5	36.67	62	11.67	50	2289.38
IT06K-91-11-1	5.67	36.67	62	10.33	47	2127.08
IT07K-187-55	4.67	39	61	9.33	45.33	2650.86
IT07K-249-1-1	5	36	61	12.33	51	2908.68
IT07K-300-12	5	37	61	11.67	46.33	2382.89
IT07K-309-44	5	37	61	13.67	48.67	2617.58
SORONKO	4.33	41.33	64	15	49	2778.20
TONA	4.67	40.67	62	13.67	62	3118.65
VIDEZA	5	38.33	62	19.67	50.67	2915.53
MEAN	5	38.02	61.75	13.65	49.33	2789.89
S.E.D	0.51	1.143	5.1	2.842	4.785	404.610
CV	12.4	3.7	10.3	15.5	11.9	17.8

Activity 3

Variety Release

Four improved varieties named as *Crops Hans Adua, Crops Agyenkwa, Crops Nketewadɛ and Crops Zamzam* (Plates 12-15) were approved for release by the National Varietal Release Committee. Some characteristics of the varieties are presented as Table 70.

Table 70. Characteristics of four released cowpea varieties

Variety	Maturity (days)	Pot. yield (t/ha)	Attributes	Suitable Ecologies
Crops Hans Adua	65 - 67	3.5	White seed coat, Tan brown eye colour, Tolerant to Cercospora Leaf Spot and Anthracnose	Transition, Deciduous Forest
Crops Agyenkwa	62 - 64	3.3	White seed coat, black eye, Tolerant to Cercospora Leaf Spot, Thrips, Aphids, Maruca	Transition, Guinea Savanna
Crops Nketewadɛ	62 - 65	3.2	White seed coat, black eye, Tolerant to Cercospora Leaf Spot and Anthracnose	Guinea Savanna
Crops Zamzam	64 - 67	3.0	White seed coat, Tan brown eye	Transition, Deciduous Forest

Plate 13. *Crops Hans Adua*

Plate 14. *Crops Agyenkwa*

Plate 15. *Crops Nketewa dɛ*

Plate 16. *Crops Zamzam*

SOYBEAN IMPROVEMENT

Research Team: S. Amoah, H. Adu-Dapaah, J.Y. Asibuo, J.N.L Lamptey, A. Agyeman, A. Bediako, E. Asamoah, J. K. Addo, and A Adama

Collaborating institutions: MoFA and IITA

Source of funding: WIENCO Ghana Ltd.

Introduction

Soybean is one of the most important grain legumes in Ghana. It is currently considered as one of the major cash crops in Ghana. It is a very good source of vegetable protein with well-balanced essential amino acids. Soybean is used in fortification of many traditional foods including weaning foods for children. However, there are a number of production constraints that beset soybean production in Ghana. These include inherently low yields, pests and diseases, erratic rainfall, drought. The focus of the soybean improvement programme is, therefore, to develop improved soybean varieties with resistance to pests and diseases and with consumer acceptable characteristics.

Objectives

- To evaluate introduced soybean germplasm within the soybean international observation trials - (SIT-E and SIT-M) - for their adaptation to the local environment, yield performance, reaction to diseases and to select promising lines for further testing

- To evaluate advanced soybean breeding lines within the soybean station variety trials (SSVT 1 and SSVT 2) and select lines that are high-yielding, disease and pest resistant/tolerant, for on-farm testing

- To produce breeder seed of released varieties for the seed industry, farmers and other stakeholders

Materials and Methods

- **Soybean International Trials**

  Two Soybean International Trials (SIT-E and SIT-M), were received from IITA. SIT-E comprised early maturity group with 16 entries including a local check, while SIT-M comprised medium maturity group with 16 entries including a local check. The trials were set out in a lattice design with three replications. Planting distance was 60cm x 10cm for SIT-E and 75cm x 10cm for SIT-M. Data collected included number of days to flowering, days to maturity, plant height and seed yield.

- **Soybean Station Variety Trials**

Soybean Station Variety Trials (SSVT-1 and SSVT-2) comprised early and medium maturity groups respectively. The SSVTs had previously been constituted from introductions and local checks. SSVT-1and SSVT-2 were established at Fumesua (Forest zone) and Ejura (Forest-Savannah Transition zone).

Both trials were set out using lattice design with three replications. Planting distance was 60cm x 10cm for SSVT-1 and 75cm x 10cm for SSVT-2.

Results and Discussion

The trials were lost to a severe drought experienced during the growing season. The flowers did not bear any pods and those that were produced could not develop properly. The trial was therefore abandoned.
Data obtained from the Soybean International Trials are being analyzed.

HORTICULTURE

VEGETABLES

On-farm and on-station evaluation of promising technologies and dissemination of best bet technologies via community field days.

Research Team: K.O. Bonsu S.O. Ekyem, J. Osei-Adu, Z. Appiah -Kubi and K. Osei

Collaborating Institution: MOFA

Source of funding: AVRDC

Introduction

The cocoa industry in Ghana is vital to the strength of the formal economy and it employs 1.5 million people in production and transport (GIPC, 2016). In Ghana's cocoa belt, cocoa is considered the main cash crop, all other crops are secondary. The long gestation period of the cocoa coupled with the two bearing seasons in a year, usually leaves farmers with long periods without any source of income. This at times does not make cocoa industry attractive to the youth. Vegetable production, on the other hand, is a source of fast income generation, because of the short gestation period of the crops. For some leafy vegetables the period could be as low six to eight weeks. (Oloyede, 2013). Vegetables are important protective food components highly beneficial for the maintenance of health and prevention of diseases. They are valued mainly for their high vitamin and mineral contents (McDowell, 2009). The farmer who integrates vegetable production with cocoa production shall get financial benefits in addition to satisfying the nutritional requirement of his/her household. The project therefore intends to encourage more farmers to integrate vegetables such as tomato (*Lycopersicon esculentum*), hot pepper (*Capsicum annum)*, garden eggs (*Solanum aethiopicum, S. anguivi* and *S. macrocarpon*), and okra (*Abelmoschus esculentus*) into their cocoa business.

Objective

To identify varietal preferences and suitable technologies for increasing vegetable productivity in homestead and commercial systems within cocoa based farming systems at the Offinso Action Sites of the Humid tropics in the Ashanti Region of Ghana.

Methodology

On September 15, 2015, Research Scientists from CSIR-CRI and Extension workers of MOFA met with a farmer group from Adankwame, in a cocoa growing area close to the Offinso district, to discuss the objectives of the programme. Adankwame is a community noted for leafy vegetable production. Improved indigenous leafy vegetable varieties (Jute Mallow/ *Corchorus* and Amaranths) were introduced to the farmers for evaluation. The farmer field school approach was adopted and the farmers were taken through nursery practices, land preparation, weed management, pest management and selection of appropriate fertilizers for the crops. The farmers were supported with funds, herbicides and technical backstopping. Land preparation began in October 2015. Harvesting was done once for all the varieties.

Results

Data from the evaluation are presented as Tables 71 to 74.

Table 71: Characteristics of five Jute Mallow varieties evaluated at Adankwame in the Ashanti region

Variety	Plant height (cm)	Root depth (cm)	Leaf length (cm)	Leaf width (cm)	Yield /10m^2 (kg)
Aziga	38.68	8.98	12.18	7.80	3.80
Local Big leaf	47.20	9.03	11.88	6.57	6.50
SUD 2	59.14	9.35	10.08	4.99	5.43
ES	66.17	8.08	10.06	5.54	6.50
Farmer material	45.17	7.94	6.85	3.09	3.67
% CV	1.42	1.91	5.91	4.97	10.37
LSD (0.05)	1.37	0.31	1.14	0.52	1.01

Plant height was greatest in ES (66.17 cm) Differences observed were significant at p=0.5. They were separated into five groups. Root depth was separated into four groups with SUD 2 having the deepest. Leaf size was measured by leaf length and width. For leaf length Aziga topped with a mean value of 12.18 cm, followed by Local Big Leaf. The differences between the two were not significant at p=0.05. The difference observed between ES and SUD 2 was also not significant at p=0.05.The famer material had the least value and was significantly different from all the others. Aziga had the widest leaf with a value 7.8 cm and was different from the rest. The farmer material had the least and the difference was also significant from all the rest. Local Big Leaf and ES had the highest mean yield of 6.50 kg/10m^2 each. The Farmer material had the lowest yield of 3.67 kg/10m^2 but this was not different from that of Aziga with the value of 3.80 kg/10m^2. Table 72 shows farmers' preferences for the varieties in terms of earliness and taste. A score of 1 means the most preferred and 5 the least preferred. In terms of the earliness Farmer Material was the best and ES was the worst. SUD 2 was the best, in terms of taste while Local Big Leaf was the worst.

Table 72: Farmers' preferences for the Jute Mallow varieties

Variety	Earliness	Taste
Farmer Material	1	2
SUD 2	2	1
Aziga	3	4
Local Big Leaf	4	5
ES	5	3

Tables 73 and 74 show plant characteristics and farmer preferences in terms of their earliness and taste for the Amaranth varieties evaluated at Adankwame. Here there was no local check as they were not growing it.

Table 73: Characteristics of Amaranth varieties evaluated at Adankwame in the Ashanti region

Variety	Stem height (cm)	Root depth (cm)	Leaf length (cm)	Leaf width (cm)	Yield /10m^2 (kg)
AHTL	92.84	11.58	17.95	10.26	22.20
Mandiira 1	56.64	15.91	12.19	2.85	16.87
Mandiira 2	61.48	12.22	15.15	7.69	18.33
SAME	95.96	14.34	15.08	10.29	21.87
% CV	1.01	2.33	1.54	2.63	5.36
LSD (0.05)	1.540	0.63	0.4635	0.41	2.12

The stem height of the varieties were statistically separated into four groups at p=0.5. SAME had the highest value with Mandiira 1 having the least. Root depth also was separated into four groups and differences were significant p=0.05. Leaf length and width were each separated into three groups. For leaf length AHTL had the highest of 17.95cm and was followed by Mandiira 2 (15.15cm) and SAME (15.08 cm). Mandiira 1 had the least value of 12.19 cm. For leaf width, AHTL and SAME had the largest widths. Their differences were not significant. Mandiira 1 had the least width and was significantly different from the rest. Yield figures were taken for a single harvest with AHTL and SAME producing the highest yields. The differences between the two were however not significant. Mandiira 2 and 1 also fell into another class with yield values of 18.33 and 16.87 kg/10 m^2 respectively.

Table 74: Farmers' preferences for four Amaranth varieties evaluated at Adankwame.

Variety	Earliness	Taste
SAME	1	1
Mandiira 2	2	4
Mandiira1	3	2
AHTL	4	3

Discussions

The farmers were initially hesitant to participate in the trial. They explained that there had been too many of such programmes which had not benefitted them in any way. This time around they realized that they could use SUD 2 (Jute mallow) which was early maturing (second after the farmer material), yielded far better than the farmer variety and had the best taste according to their evaluation (Tables 71 and 72). During the dry periods their variety usually got stunted in growth and they found that they could replace it with ES, which though matured late, grew tall and produced good yields. The deeper roots of ES will also enabled it to draw water from the ground better than the farmer variety. The farmers were initially not planting the amaranths in their locality but after the trials it was observed (during a field visit) that they had harvested the seeds at one location - an evidence of their acceptance of the crop. SAME was best in taste and yield was also not significantly different AHTL which had the best yield. Farmers were a bit skeptical about how SAME which tasted best and produced good yields (Tables 73 and 74) will sell on the market and they decided to eat it themselves. The other varieties were very well accepted and the farmers had started multiplying seeds for themselves, however they were not using proper seed production practices.

Conclusion

Since the farmers were not using proper seed production practices, the varieties will in no time get mixed up. The next phase of the programme will therefore look at good agronomic practices and good seed production practices for higher yields and quality produce.

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On-farm and on-station evaluation of promising technologies and dissemination of best bet technologies via community field days.

Research Team: K.O. Bonsu, S. O. Ekyem, J. Osei-Adu, Z. Appiah -Kubi and K. Osei

Collaborating Institutions: MOFA and Farmers

Source of funding: AVRDC

Introduction

Vegetables are increasingly becoming important produce for the domestic and export markets. They have a great potential to improve nutrition and thereby the health of consumers as most are good sources of vitamins, minerals and proteins needed for the proper functioning and development of the human body (Wills *et al.,* 1998). Despite the importance of vegetables, their production is faced with a number of challenges. Among these is the weak and inefficient seed system. The vegetable seed industry in Ghana is still at its formative and access to improved seed is a challenge. Osei *et. al.* (2001) reported that the genesis of any agricultural production is seed. Without a good seed source, the venture is bound to fail. Very few improved vegetables lines have been tested in the country for dissemination to farmers. Seed companies are also few in number and sometimes far from producers. Information on the seed industry is also limited discouraging investment in the industry. These are the basis for this study as a response to the challenges highlighted and an attempt to provide some information to develop a vibrant vegetable seed industry.

Objectives

- Identify socio economic drives affecting farmer access to quality seed
- Analyze constraints to access to seed and their effects on production
- Investigate gender diversity in access to seed, production and marketing

Methodology

This study took place in the Offinso South municipal in the Ashanti region of Ghana. The total land area is about 741 km^2. Using multi stage sampling approach, 137 producers of cabbage, okra, tomatoes, garden eggs and leafy vegetables were randomly sampled. The farmers were interviewed with a standard questionnaire developed by scientists from CSIR-CRI. Data were analysed using descriptive statistics and graphs.

Results and Discussions

Respondents were made up males (71%) and females (29%) and their average age was 47 years, ranging from 20 years to 75 years - confirming the assertion that our farmers are ageing. About 45.3% of respondents indicated they acquired seed from seed growers who are either in the community or elsewhere (Fig 22). Bonsu *et.al.* (2009) has reported that the local vegetable seed industry has very poor standards and this could account for the poor products on the market. Farmer saved seed was also another important source (37.2%) and sourcing of seed from other farmers constituted 32.1%. Developing a seed system will require that the channels of distribution are strengthened and used to distribute improved seed to farmers. The role of seed companies was minimal since only 10.2% of respondents' sourced seed from them.

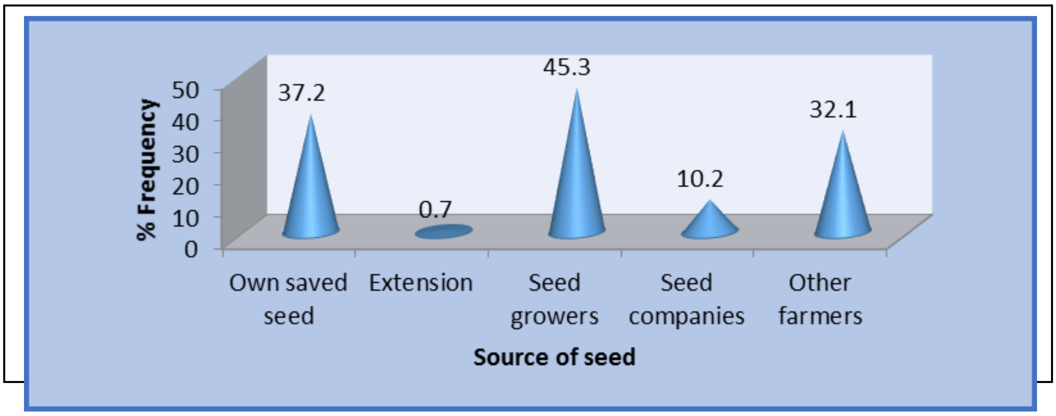

Fig 22: Sources of vegetable seed

Seed quality is important in determining the rate of germination. Most farmers got seed from sources for which it is difficult to guarantee quality. About 49% of respondents claim they are able to determine seed quality. The method of determination was however not clear and had no scientific basis. Building capacity of farmers in seed testing will be important in strengthening the seed system.

Many (53.3%) respondents had a strong association with other farmers. About 40.1% and 38.7% also indicated they interacted with extension services and land onwers respectively. Only 10.9% treated their seeds before storage and 38.7% before planting. This led to 23% of seed loss in stoarge with some farmers losing 100%. Lack of seed growers in the community was ranked as the number one constraint to accessing quality seed. Pest and disease together with high cost of chemicals were ranked as the number one production constraint. The major marketing problem was fluctuation in prices. To develop a vibrant vegetable seed system will require strong linkages of actors in the seed supply chain and finding solutions to the identified constraints. Government support for seed companies to operate in farming communities. Provision of storage structures will also be needed to ensure producers get good prices for their commodities.

Conclusion

The vegetable seed industry was found to be weak, therefore any effort to integrate vegetable production into the cocoa industry must take into consideration the vegetable seed industry.

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Evaluation of four elite tomato lines from Burkina Faso.

Research Team: KO Bonsu, M.K. Osei, S.O. Ekyem, M.B. Mochiah and M.K. Boateng

Collaborating Institutions: MoFA and Farmers

Source of funding: WAAPP

Introduction

Tomato (*Lycopersicon esculentum*) is the world's second most important vegetable crop next to potato. Present world production is about 100 million tonnes produced on 3.7 million hectares of land. Tomato production has been reported for 144 countries, Ghana inclusive (FAOSTAT Database, 2013). In Ghana, tomato is one of the most important vegetables in terms of area of production, generation of income and consumption. Ghana consumes approximately 800,000 mt of fresh and processed tomato per year. Local production is around 300,000 - 400,000 mt of fresh tomatoes per annum. Ghana is, therefore a net importer of tomato - both fresh (from Burkina Faso) and processed products. The government of Ghana, in order to cut down on importation of tomatoes, made it a key vegetable crop in its agricultural development agenda (METASIP, 2010). Under the auspices of WAAPP, a team of scientists paid a working visit to Burkina Faso to interact with scientists there and study their systems of tomato production and collect some of their improved genetic materials for evaluation and adoption in Ghana. During the visit some commercial cultivars were collected to be evaluated in Ghana.

Objective

- Evaluate tomato varieties obtained from Burkina Faso for adaptability and possible integration into the Ghanaian agricultural system.

Materials and methods

Three week old tomato seedlings were transplanted onto ridges at Kwadaso and Bewadze/Winneba in July 2015. Planting was done at the two sites only due to limited quantity of seedlings. They were planted on ridges. The ridges were 1m apart and distance between plants on the ridges was 0.50 m. The field was laid out in a RCB design with four replications. All agronomic practices (weed control, fertilizer application, irrigation, staking and pest control) were carried out as required. The crop was evaluated for earliness, tolerance to virus attack, yield characters and fruit firmness (ability to withstand transportation pressure).

Results and Discussion

An intense drought adversely affected the field at Bewadze/Winneba so no data were not collected. Nevertheless the fruit quality of the varieties made the farmers adopt the crop and have established dams and are growing some of the varieties. As at January 2016, two acres of tomato had been planted and seedlings to plant over 30 acres are in nurseries.

Data on the tolerance of the tomato varieties to the Tomato Yellow Leaf Curl (TYLC) disease and some major fruiting characteristics, collected from the Kwadaso fields are presented as Table 75.

Table 75: Tolerance of tomato varieties to TYLC and some major fruiting characteristics.

Varieties	Days to first harvest	Viral Severity* score (0-5)	No. of fruits / plant	Fruit firmness	Fruit weight (grams)	Yield /plant (grams)
Jaguar	69.0	3.350	9.00	68.750	54.75	518.3
Kiara F1	70.5	4.225	6.00	74.250	48.50	291.0
Mongal F1	72.0	2.45	13.25	67.500	124.5	1653.0
Tropimech	68.5	2.225	15.25	67.500	91.00	1387.0
UC8 2B	68.0	4.4	7.5	64.143	59.50	446.8
CV (%)	0.95	7.0	4.6	0.85	9.87	11.07
LSD (0.5)	1.0142	0.1743	0.6445	0.9003	11.502	146.50

* Viral incidence score was 100% in all cases

Days to first harvest (after transplanting) ranged between 68.0 and 72 days for UC8 2B and Mongal F1. The mean separations placed them into three groups. UC8 2B, Tropimech and Jaguar being the earliest, Kiara F1 intermediate and Mongal F1 late (p=05). All the five lines succumbed to the TYLC virus disease. Incidence of the disease was 100% for all the varieties. However the ability to tolerate the disease was different among the varieties. Tropimech and Mongal F1 tolerated the TYLC virus better than the others with UC8 2B and Kiara F1 having the least tolerance. This reflected in the number of fruits, fruit size and overall yield of the varieties. Osei, (2011) has described TYLC as one major disease killing the tomato industry in the country. Any variety which shows some tolerance to the virus could be is a boon to the industry. Tropimech and Mongal F1 produced the highest number of fruits while Kiara F1 produced the least. The differences observed were significant (P=0.5). Fruit firmness ie ability to tolerate shock due to packing and transportation, were acceptable for all the varieties with Kiara F1 being the best.

Mongal F1 and Tropimech came up as the top varieties. Besides producing the highest yields per plant (1653 gm and 1387gm respectively), their tolerance levels to the TYLC virus were also the best. Their ability to contain the virus, probably enabled them to express their fruit yield potentials.

Way forward

These results shall be confirmed in 2016. These materials would be tested on-farm in 2016 to confirm the results obtained so far and if they maintain their attributes, they will be recommended to farmers.

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Evaluation of four elite African eggplant *(Solanum aethiopicum* L*)* lines from CSIR- CRI for adaptability and possible release for cultivation in Ghana.

Research Team: K.O Bonsu, I. Osei-Bonsu, S.O. Ekyem, M.B. Mochiah and M.K. Boateng

Collaborating Institutions: MoFA and Farmers

Source of funding: WAAPP

Introduction

Solanum aethiopicum (gilo group) according to Lester and Seck (2004) belongs to the group of garden eggs known as the African eggplants (Schippers 2000). They are mostly found in the sub Saharan African countries though they are now being cultivated in most tropical and sub-tropical environments (Schippers 2000). It is ranked as the number three vegetable on most of the African markets and in Ghana according to Schippers (2000) it is the number three vegetable after tomato and pepper. However in Ghana, varieties that breed true-to-type are not available and farmers are still planting landraces. CSIR-CRI has developed some new lines to be released as varieties in Ghana. Different varieties of a particular crop may have different plant architectures and thus have different spacing requirements for optimum growth and yield. It is therefore imperative that the improved lines developed at CSIR-CRI must be accompanied by the appropriate agronomic practices including the optimum spacing required for higher yields before they are released.

Objective

- To determine the appropriate spacing for optimum growth and yield of some garden eggs varieties being evaluated for release.

Materials and Methods

- Sensitization meeting was held with farmers and MoFA staff.

  Five varieties of garden eggs (African eggplant) namely: CRI 02, Dwomo, Kpando and Oforiwa, developed at CSIR-CRI were evaluated against a local check (Aworoworo) with respect to yield under five different plant spacing configurations in a split-plot experiment having a RCB design with three replications. The location was Kwadaso. Five week old seedlings of the varieties were transplanted in early March 2015 onto a field already prepared by slashing and harrowing with a tractor. The spacing (treatments) were T1: 80 x 70 cm, T2: 80 x 80 cm, T3: 90 x 80 cm, T4: 90 x 90 cm, T5: 100 x 90 cm. Plot sizes ranged from 2.4 x 4.2 m to 3 x 4.5 m, depending on the spacing treatment with each plot having four rows. 15:15:15 NPK fertilizer was applied at a rate of 250 kg/ha two weeks after transplanting and followed with 125kg/ha Ammonia fertilizer six weeks after transplanting. Other cultural practices such as weeding and spraying with insecticide were carried out as and when necessary. Matured fruits were harvested once a week from late June to middle of August 2015 for eight weeks. The fruits were weighed after every harvest and the weights bulked together at the end of the last harvest. Data on yield per plant were collected from five plants selected from the two middle rows. Only data from the two middle rows were used to calculate the total yield. The data were analyzed using SPSS software version 16.0. The means of the various parameters were compared in a multivariate analysis of variance (MANOVA) and differences between treatments and blocks compared using LSD at $p < 0.05$.

Results and Discussion

- **Growth parameters of five garden eggs lines under different spacing**

The growth parameters of the varieties in response to the different spacings are presented as Table 76. CRI 02 and Dwomo were the earliest to flower and mature followed by Kpando and Oforiwa. The local check (Aworoworo) was the last to mature. The differences in number of days to 50% flowering and 50% maturity between varieties were highly significant ($P < 0.001$) but between the different spacing they were not statistically significant ($p < 0.05$). Aworoworo and Oforiwa had the tallest plants both at 50% flowering and 50% maturity, whereas CRI 02 and Dwomo were the shortest ($p < 0.001$). Significant differences were observed for height at 50% flowering and 50% maturity. Dwomo had the widest canopy followed by CRI 02 at 50% maturity.

Table 76: Growth parameters of six garden eggs varieties and five different spacing

Treatment / Block	Days (after transplanting) to		Height (cm) at		Canopy spread (cm) at	
	50% Flowering	50% Maturity	50% flowering	50% Maturity	50% flowering	50% Maturity
Variety						
Aworoworo	46.3^{a*}	68.5^{a}	55.6^{a}	87.6^{a}	77.5^{a}	99.5^{bc}
CRI 02	33.7^{c}	50.3^{c}	37.4^{b}	67.1^{c}	73.8^{a}	104.2^{ab}
Dwomo	33.9^{c}	49.5^{c}	40.5^{b}	67.0^{c}	79.6^{a}	110.1^{a}
Kpando	44.1^{b}	64.8^{b}	52.3^{a}	74.6^{b}	80.7^{a}	99.1^{bc}
Oforiwa	44.2^{b}	60.3^{d}	56.0^{a}	86.6^{a}	75.9^{a}	94.9^{bc}
Treatment / Spacing						
80 x 70	40.7	59.6	50.3	76.6	78.4	99.5
80 x 80	40.9	59.9	48.5	78.3	77.3	100.9
90 x 80	42.1	60.6	49.8	75.8	78.5	100.8
90 x 90	41.8	59.9	48.0	77.2	76.3	100.1
100 x 90	42.6	60.5	47.4	75.9	75.5	100.5

Though plants spaced at 80 x 70 cm were the tallest at 50% flowering, while those spaced at 80 x 80 were tallest at 50% maturity, the differences observed for height and canopy spread at both stages were non-significant ($p<0.05$). The interaction between variety and spacing was not statistically significant.

- **Yield and yield parameters of five garden egg lines under different spacing**

Differences between the five varieties were highly significant ($p < 0.001$) for total yield, number of fruits per plant and total weight of fruits per plant but not for the mean weight of fruits. Only Dwomo yielded significantly higher than the local check (Aworoworo) (Table 77). Furthermore, Dwomo had significantly higher number of fruits per plant as well as total weight of fruits per plant than all the other varieties including the check. This was followed closely by CRI 02 with 39.1 and 1.86 kg/plant respectively. No significant difference was observed in the mean weight of fruits.

Differences in the yield parameters for the different spacing were not statistically significant ($p < 0.05$) except for total yield per hectare which was highly significant ($p<0.001$). Planting at 80 x 70 cm (T1) produced the highest yield (25.3 ton/ha) followed by 80 x 80 cm (T2) with 23.1 ton/ha. This implies that the higher yield observed for T1 and T2 may be due to the higher planting density.

Table 77. Yield parameters of garden egg varieties under five different spacing

Treatment Block	Total yield (ton/ha)	Mean fruit weight (g)	Yield per plant	
			Number of fruits	Total fruit weight (kg/plant)
Block: Variety				
Aworoworo (check)	18.8^{bcd}	53.3	34.0^{bc}	1.45^{d}
CRI 02	23.9^{ab}	52.5	39.1^{ab}	1.86^{ab}
Dwomo	24.7^{ab}	54.4	42.2^{a}	2.04^{a}
Kpando	20.3^{bcd}	48.4	33.5^{bc}	1.47^{d}
Oforiwa	22.1^{bc}	48.2	38.7^{b}	1.74^{bc}
Treatment / Spacing				
80 x 70	25.3^{a}	52.5	34.7	1.61
80 x 80	23.1^{ab}	51.0	36.5	1.68
90 x 90	19.0^{bcd}	51.5	36.2	1.67
90 x 80	22.0^{bc}	51.4	36.8	1.72
100 x 90	17.4^{cd}	55.9	35.9	1.69

Conclusion

Among the varieties, Dwomo and CRI 02 produced the highest yields and they were the earliest to mature thus they would be economically advantageous for farmers, in markets where early season garden eggs command higher prices. Economic analysis is however yet to be carried out for this study.

Plant spacing of 80 cm x 70 cm and 80 cm x 80 cm produced the highest yields due to the higher planting density. Farmers may opt for the widely recommended spacing of 80 x 80 cm or use 80 x 70 cm for an even higher yield. This study was conducted on station and must be repeated on-farm to see how the varieties will perform on farmers' fields. There would be the need to determine the nutrient and water requirements of these varieties, as higher yields of 57mt/ha have been recorded by Oluoch *et. al* (2007), with similar varieties.

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Upscaling of Tomato Integrated Pest Management Technology

Research Team: M. K. Osei, M.B. Mochiah, J.N.L. Lamptey and J. Gyau

Collaborating Institutions: Agri Commercial Services Limited and MOFA

Source of funding: TDTC/COTVET

Introduction

Tomatoes are a critical source of nutrients and an important cash crop in Ghana. However, production in Ghana is beset by numerous constraints, including incidence of pests and diseases; lack of improved production technologies including varieties, abuse and lack of unavailability of suitable pesticides and abuse of available ones. Previous tomato integrated pest management (IPM) research made some progress in addressing a number of these constraints in three (Ashanti, Brong Ahafo, Upper East) regions of Ghana.
IPM stresses a combination of chemical, biological and other control methods for insect pest management.

It is intended to build upon and extend these results to the coastal savannah ecology (covering Greater Accra and Volta regions).

Objectives

- To implement a comprehensive IPM package technology for tomato growers in the Greater Accra and Volta regions of Ghana.
- To build the capacities of tomato farmers in tomato production and reduce the use of pesticides.

Materials and Methods

Activity 1

- **Surveys**

  Reconnaissance surveys were conducted in March 2015 at Ada (Ada district, Greater Accra region) and Adidome (South Tong district, Volta region) where there is intensive small-holder production of tomato and high incidence of tomato pests and diseases. Data were collected by administering questionnaires to some farmers. Information collected included background of farmers, common tomato pests and diseases encountered and farmers' control methods, time of incidence and severity of the diseases.

Activity 2

- **Field selection and establishment of trials**

  Fields that had not been cropped with tomatoes in the previousyear were selected for the IPM demonstration. This was done in collaboration with farmers and extension officers in those areas. Seeds of early maturing tomato varieties namely Shasta, Heinz, CRI-PO34 and OPB-155 were nursed in April 2015. Farmers' local (open pollinated) varieties were included in the trials for comparison. in terms of the varieties and the IPM technology was also included in the trials. At each location, Farmers were taught on how to prepare nursery beds including sterilization and sowing. On one bed, farmers were allowed to prepare the nursery beds and sow their seeds in their own way (farmers' practice). On another bed the farmers were taught how to prepare nursery beds including sterilization and sowing in lines (instead of broadcasting the seeds). The tomato seedlings were transplanted to the fields three to four weeks later. The fields were divided into two: researcher field (for the demonstration of the IPM package) and farmers' field (where the farmers carried out their usual practices). On the researcher field, a spacing of 60cm x 50 cm was used whereas on the farmers' field they used 100 cm x 30 cm. Manual irrigation was used to supplement rain water on the field. Data were collected on plant establishment, days to flowering, mean plant height at flowering, fruit set and fruit abortion/drop, insect damage, especially fruit borers per plot and fruit yield. Yields from the researcher field were compared with yields from the farmers' field. The old crops were destroyed and burnt after harvesting to prevent the spread of diseases.

Results and Discussion

- **Survey**

Forty-two tomato farmers (67% males and 33% females) were sampled for the study (Table 78). Majority of the farmers (73.8%) were married and with about six dependants - this implies availability of household labour for farm work. Respondents' age ranged from 23 to 70 years, with a mean age of 42.61 years (Table 78). This indicates an active age group higher than youthful age of thirty-five (35) years in Ghana. The statistical significance of the age was tested and it was realized that, the mean age was statistically significant at 1% level of significance (Table 79) meaning as age increases production will decrease. This is similar to an observation made by Islam *et al*., (2010). Majority of the respondents were educated. With their level of education, it is believed that the farmers can easily grasp new practices, try them and adopt them. More than half of the sample had more than five years' experience in farming. About 57% had farm sizes more than two acres (about 0.8ha). Majority of respondents cropped their fields once annually, even though some could plant twice and even thrice annually. About 57.1% preferred planting tomato just once per season because of inadequate rains during the year and lack of irrigation facilities. These were two major constraints to tomato production in the areas.

Table 78: Characteristics of respondents (Qualitative variables)

Variables	Frequency: N= 42	Percent
Demographic characteristics		
Sex		
Male	28	66.70
Female	14	33.30
Marital status		
Single	8	19.00
Married	31	73.80
Divorced	3	7.10
Educational level		
None	11	26.20
Primary	7	16.70
JHS/Middle	18	42.90
Secondary	3	7.10
Tertiary	3	7.10
Farm level characteristics		
Experience in tomato production (years)		
Beginner	7	16.7
1-2	6	14.3
Up to 5	5	11.9
>5	24	57.1
Length of cultivation per season (months)		
3	25	59.5
3.5	4	9.5
4	11	26.2
5	2	4.8

Number of times tomato is cultivated per year		
Once	24	57.1
Twice	13	31.0
Thrice	5	11.9
Preference for cultivation in any season		
Yes	30	71.4
No	12	28.6

Table 79. Summary statistics of quantitative variables

Variable	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Age	23	70	42.61	12.10
Number of dependents	1	18	5.55	3.44
Age of seedlings before transplanting	3	6	3.74	0.86
Length of tomato of the field	3	5	3.40	0.57

Table 80. Test of significance of quantitative variables

Variable	**N**	**Mean**	**SD**	**T- value**
Age	42	42.61	12.10	22.83
Number of dependents	42	5.55	3.44	10.46
Age of seedlings before transplanting	42	3.74	0.86	28.27
Note: *** significant at 1% level of significance				

- **Frequency of tomato cultivation and land tenure systems**

The factors that determine the number of times farmers cultivate tomato within a year are presented as Fig. 3. The major reasons given were the availability of water followed by the demand of the product by consumers and the distribution of the rainfall. This confirms why 28.6% would prefer cultivating tomato in only one season. The land tenure systems reported are presented as Fig. 4. Majority depended on leasehold followed by those who cultivate their own lands and the rest hiring lands. The tenure system affects the investments made in improving the productivity of the land in terms of input application and use of improved technologies, therefore with the leasehold (which are are long term in nature), it is hoped that farmers will invest more in the land to achieve the needed benefits.

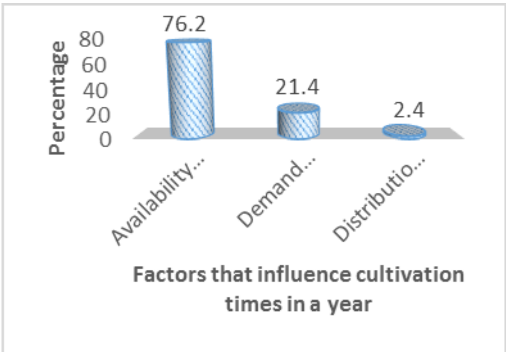

Fig. 23. Factors accounting for the number of times farmers produce tomato in a year

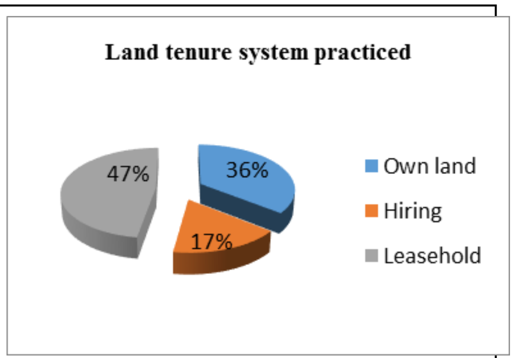

Fig. 24. Distribution of land tenure systems

- **Production practices**

The study investigated the different practices employed by producers from land preparation through management practices after crop establishment. Majority of the farmers used slash, burn, plough and harrow while others slash, burn and dig with a mattock or hoe. Only 7% of the producers practiced zero tillage (Table 81). The low adoption of zero tillage may be lack of knowledge or the costs associated with the technology. A study by Turi (2009) on wheat grain showed that zero tillage which is a form of farm technology in Conservation Agriculture (CA) could increase the productivity by 20 - 50% however, this requires an important investments and farm organizational changes. Zero-tillage is known to enhance optimal soil biological, chemical, and physical features (including moisture retention). Majority of the respondents prepared their nursery beds either by slashing weeds, preparing bed and planting or slashing weeds, digging up soil and planting on flat. The most common method of planting in the two districts was broadcasting followed by drilling.

Table 81: Production practices

Variable	Frequency	Percentage
Land preparation		
Slash, burn, plough and harrow (Mechanical Flat)	24	57.1
Slash, burn and dig up with a mattaock or hoe	11	26.2
Raised bed manual	4	9.5
Zero tillage	3	7.1
Nursery bed preparation methods		
Slash weeds, prepare bed and plant	20	47.6
Slash weeds, dig up soil and plant on flat	17	40.5
Reshape old bed and plant	3	7.1
Other	2	4.8
Planting methods used in nursery		
Broadcasting	27	64.3
Dibbling	3	4.8
Drilling	14	31.0
Awareness of sterilization		
Yes	27	64.3
No	15	35.7
Adoption of sterilization		
Yes	22	52.4
No	5	11.9

- **Management practices**

Tomato like any other vegetable crop requires basic inputs and mangement practices to achieve optimal yields. Mangement practices adopted by the farmers are presented as Table 82. Thining out was not a common practice among the respondents. Fertilizer was applied by 81% of the producers. This is a good indication of the knowledge level of farmers about the effect of fertilizer on productivity. For those who did not apply fertilizer, no reasons were given. The common types of fertilizer applied were the inorganic, organic and a combination of both. About 67% apply fertilizer once per season. Irrigation is very critical in this era of climate change. About 69% of the respondents applied watered to their fields using watering can or buckets. This can be labour intensive and costly if labour is hired.

Table 82: Management practices

Variable	Frequency	Percentage
Frequency of watering plants in nursery		
Once a day	19	45.2
Twice a day	6	14.3
As and when necessary	7	16.7
Other (thrice and rainfed)	10	23.8
Post emergence practices		
Raise a shed over seedlings	18	42.9
Handpick weeds	22	52.4
Cover with net to protect from pests	7	16.7
Thin	1	2.4
All the above	5	11.9
Ferlizer application		
Yes	34	81.0
No	8	19.0

Types of fertilizer used		
Organic	9	21.4
Inorganic	16	38.1
Both	9	21.4
Frequency of fertilizer application per season		
Once	28	66.7
Twice	6	14.3
Irrigation system		
Watering can/ bucket	29	69.0
Furrow	2	4.8
Milk tin	1	2.4
Rainfed	8	19.0

- **Fruit yield from Researchers' plot**

Significant differences were found for all the parameters taken at the research field at Ada. Data collected from Ada are presented as Table 83. At Ada Shasta produced the tallest plants (84.13cm), the highest number of marketable fruits (508.33) and highest fruit weight (45.47kg). OPB155 produced the lowest number of non-marketable fruits harvested. It also produced fruits with less number of holes, less damage and least number of borers. At Adidome Heinz produced the highest number of marketable fruits. The highest number of fruits with damage was also recorded on Heinz (Table 84). The overall performance of the varieties was better at Ada than Adidome. This could be due to genotype environment interaction. Variations in the climatic conditions across the locations may account for the variations in the performance of the varieties across locations. Shasta and Heinz were outstanding in terms of number of marketable fruits and fruit weight at Ada and Adidome respectively from the researchers' field. The different varieties varied in plant heights across the locations. This agrees with Messian (1992) who indicated tomato plant height varied up to 2m.

Table 83. Fruit yields of five tomato varieties from Researchers' field at Ada

Treatment	Plant height (cm)	No. of Marketable fruits	No. of Non-marketable fruits	Fruit weight (kg)	Fruits with holes	Damaged fruits	Fruits with borers
SHASTA	84.13	508.33	62.33	45.47	26.33	22.67	26.33
HEINZ	58.93	198.00	68.33	20.00	19.00	30.00	19.00
CRI-P034	65.87	159.00	92.33	36.17	28.33	19.33	28.33
OPB155	61.60	95.33	52.00	12.63	10.67	17.67	10.67
LOCAL	83.07	196.00	141.33	18.73	43.33	83.67	43.33
P Value	0.0001	0.0014	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CV	7.32	65.94	32.93	29.29	27.89	28.84	27.49

Table 84. Plant height and fruit yields of five tomato varieties from Researchers' field at Adidome

Treatment	Plant height (cm)	No. of Marketable fruits	No. of Non-marketable fruits	Fruit weight (kg)	Fruits with holes	Damaged fruits	Fruits with borers
SHASTA	59	165.00	26.33	5.77	4.33	22.00	1.67
HEINZ	52	199.00	52.67	9.37	4.00	45.67	0.67
CRI-P034	69	183.67	22.67	8.18	10.00	12.67	1.00
OPB155	55	142.33	38.33	6.26	4.00	34.00	0.00
LOCAL	66	187.33	17.67	10.91	5.33	10.67	0.67
P Value	0.155	0.019	0.013	0.01	0.045	<0.001	0.57
CV	12.34	32.89	49.20	38.95	47.63	40.44	149.79

- **Fruit yield from on Farmers' plot**

At Ada Shasta and OB155 had the tallest and shortest plants respectively (Table 85). Shasta and Heinz produced the highest number of marketable fruit and fruit weight. Less number of fruits with holes, damage and borers were recorded on OPB155. Significant differences were found on all the parameters measured. At Adidome, Heinz produced the highest number of marketable fruits (Table 86). The local variety however, produced the highest fruit weight which was not significantly different from Heinz. Apart from plant height and fruits with borers, significant differences were seen in all the parameters.

Comparing the researchers' field and farmers' field at both locations, the former field – produced the tallest plants, highest number of marketable fruits and highest fruit weight. Fruit with fewer holes, less damage and fewer borers were also produced by plants established on the researchers' field. The percentages of non-marketable fruits per variety on farmers' fields were higher than on the researchers' fields at both locations. It is obvious that implementation of IPM strategies on the research fields resulted in higher yields and fewer numbers of non-marketable fruits and damaged fruits.

Table 85. Plant height and fruit yield from farmers' field on five tomato varieties at Ada

Treatment	**Plant height (cm)**	**No. of Marketable fruits**	**No. of Non-marketable fruits**	**Fruit weight (kg)**	**Fruits with holes**	**Damaged fruits**	**Fruits with borers**
SHASTA	81.80	144.33	43.33	14.40	15.33	11.33	15.33
HEINZ	56.93	144.33	39.33	14.87	14.67	15.00	14.67
CRI-P034	63.53	47.33	34.33	7.63	10.00	15.67	10.00
OPB155	61.23	48.00	24.00	4.57	8.33	6.00	8.33
LOCAL	79.40	54.33	57.33	4.00	15.33	48.00	15.33
P Value	<0.0001	0.0014	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
CV	7.32	65.94	32.93	29.29	27.89	28.84	27.49

Table 86. Plant height and fruit yield from farmers' field on five tomato varieties at Adidome

Treatment	Plant height (cm)	No. of Marketable fruits	No. of Non-marketable fruits	Fruit weight (kg)	Fruits with holes	Damaged fruits	Fruits with borers
SHASTA	59	165.00	26.33	5.77	4.33	22.00	1.67
HEINZ	52	199.00	52.67	9.37	4.00	45.67	0.67
CRI-P034	69	183.67	22.67	8.18	10.00	12.67	1.00
OPB155	55	142.33	38.33	6.26	4.00	34.00	0.00
LOCAL	66	187.33	17.67	10.91	5.33	10.67	0.67
P Value	0.155	0.019	0.013	0.01	0.045	< 0.001	0.57
CV	12.34	32.89	49.20	38.95	47.63	40.44	149.79

Conclusion

Significant differences were observed among the varieties at Ada and Adidome. The yields obtained and the quality of fruits suggest that farmers could increase their crop yields, reduce pesticide usage and obtain high profit when they adopt the IPM technology.

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TREE CROPS

Establishment of clonal citrus museum for in-depth study on characteristics and qualities of citrus germplasm in Ghana.

Research Team: P. Mintah, I.N. Boakye Mensah, J. Gyau, and J. Afriyie

Source of funding: Government of Ghana

Collaborating Institutions: CSIR-PGRRI, Agricultural Research Centre (UoG),Kade

Introduction

Citrus was first introduced into Ghana by the colonial masters in 1900 to solve the vitamin C deficiency problem of its sailors. Mexican Lime (Citrus aurantifoliaswingle) is one of the earliest introduced varieties to be cultivated commercially in Ghana. The lime was however wiped away by tristeza viral disease (Adansi, 1972, Godfrey Sam-Aggrey, 1973). Attempts to salvage the situation led to studies to identify suitable varieties and the development of improved technologies for cultivation which resulted in the introduction of a number of citrus varieties including Late Valencia, Rough lemon, Grapes, Tangerines. Rough lemon was identified as a compatible and suitable root stock for most citrus varieties including the Mexican lime (Opoku 1972). Besides the early introductions many more citrus cultivars of commercial importance are frequently introduced into the country by institutions and individuals. These new plant varieties need to be conserved, evaluated and suitable ones recommended to farmers and scientists to be used in their crop improvement programs. CSIR-Crops Research Institute used to have a virus –free clonal museum about forty varieties but lost it to encroachers. Work therefore began to establish a new museum to replace the lost one.

Materials and Methods

Scions of about thirt citrus varieties were collected from the old museum and budded onto rough lemon rootstocks. The budgrafts were planted at a spacing of 6m x 6m on a two-acre field at Kwadaso.

The field has been demarcated into blocks of:

- The tangerine/mandarine varieties (Satsuma mandarin, Ponkan, Imperial mandarin, King de'semis, local tangerine and Robinson.
- Tangor (Ortanique) and tangelos (Orlando tangelo and Lake tangelo).
- Sweet orange varieties - Late Valencia, Pineapple, Natal Valencia, Nigerian green, Rhode Red Valencia, Mrs. Wright, Portuguese sweet, Ovaleto, Hamilin, Mediterranean sweet, Subi, Asuansi,Kumaning, Obuasi, Abofour, Washington navel, Baninhia navel, Red blood round and Red blood spherical.
- Duncan Grape fruit, Pumelo, Ruby grape fruit, Mayer lime, sweet lime, Mexican lime and kumquat. Between 5 and 12 budgrafts per variety were planted out in single rows within the block marked for the particular species. The following data are collected periodically - Plant height, stem girth, canopy spread, canopy volume, flowering, fruit yield, pest and disease tolerance.

Results and Discussion

Data are collected periodically on the state and performance of the various citrus varieties.

- **Plant height**

  The heights of some of the citrus plants, at 900 days after planting, are presented as Fig. 25. The heights of the Duncan grape (210 cm) and Pumelo were similar and both were taller than another grape variety Ruby grape (151cm). The heights of the tangerine, tangor and tangelo group ranged between 150.5cm and 202cm. The shortest in the group was the Satsuma mandarin and the tallest was King de semis. The heights of most of the remaining varieties in this group were between 202cm and 228cm. The varieties have shown differences in height and if these persist at maturity, they could be classified into short, medium and tall varieties within the group. The heights of sweet orange varieties ranged between 168cm and 310cm. Washington navel was the shortest (168 cm) while Late Valencia was the tallest (310cm) followed by Nigerian green (285cm). The heights of six of the sweet orange varieties (Aboffour, Subi, Hamilin, Ovaleto, Baninhia navel and Pineapple) were between 180cm and 198cm. Heights of the other eight in the group ranged between 200 and 260cm. If the observed height differences among the sweet orange varieties persist at maturity, they could also be classified as short, medium and tall.

- **Stem girth**

  Stem girth (measured at five centimetres above the bud union) showed differences among the varieties. It ranged between 33cm and 64.2cm. Satsuma mandarine had the least girth whilst Kumaning had the biggest girth of 64.2cm. Some sweet orange varieties also had small girth whilst some tangerine and tangor varieties also had bigger stems (Fig. 26).

- **Canopy spread**

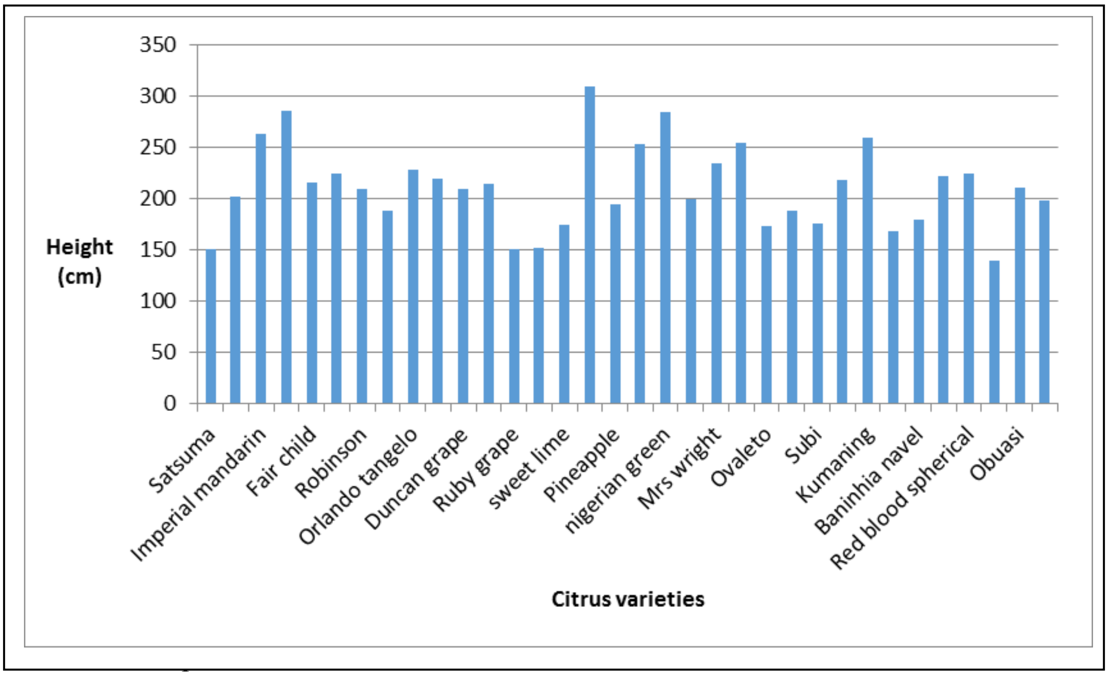
  This is an indication of how wide the canopies extend. It is important because it determines the planting distance to be adopted for the particular variety. It also affects the potential yield. The canopies of seven out of the 35 varieties were about 1.5m wide while 13 varieties had canopies wider than 2m (Fig. 28).

- **Canopy volume**

  Some differences were observed (Fig 29). Fair child had the biggest canopy volume among the mandarin group. King de semis, Satsuma mandarin, Ponkan, Robinson and ortanique had between $1.19m^3$ and $2.27m^3$. Late Valencia developed the biggest canopy volume, followed by Nigerian green and Portuguese sweet among the sweet orange varieties. Kumquat (naturally known to have a diminutive structure) had the smallest canopy volume ($0.44m^3$).

- **Fruit bearing**

Twenty two of the citrus varieties had started producing fruits as at 900 days after planting. These include some tangerines and sweet oranges (Fig 30). It is not strange for citrus budgrafts to produce fruits. It is also normal for fruit bearing to delay in some varieties. Some citrus varieties are said to be shy bearing and would therefore delay bearing fruits for many years. The number of fruits borne per tree ranged between 0 and 105 among the varieties. The highest fruit numbers (100 and 105) were produced by Late Valencia and Hamilin. It is too early to talk about yield now, since some varieties may shed some fruits pre-maturely whilst others may retain fruits better than others. Moreover, fruit sizes and fruit weight would also vary among the varieties.



i
g. 25. Plant height of 34 citrus varieties at 900 days after planting

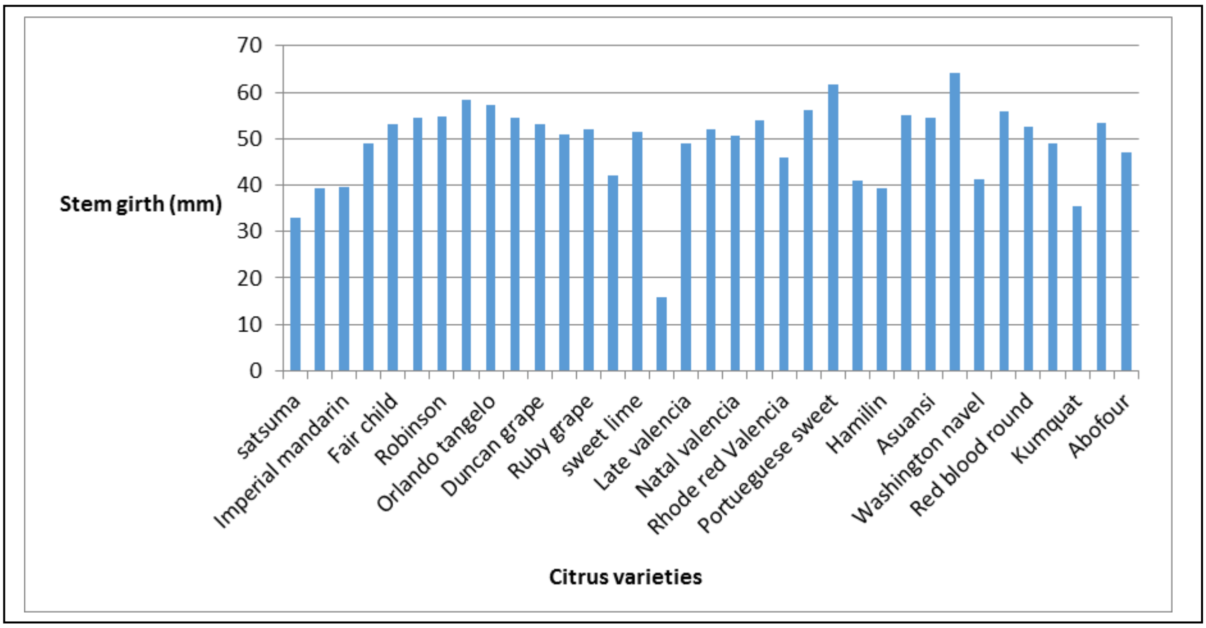
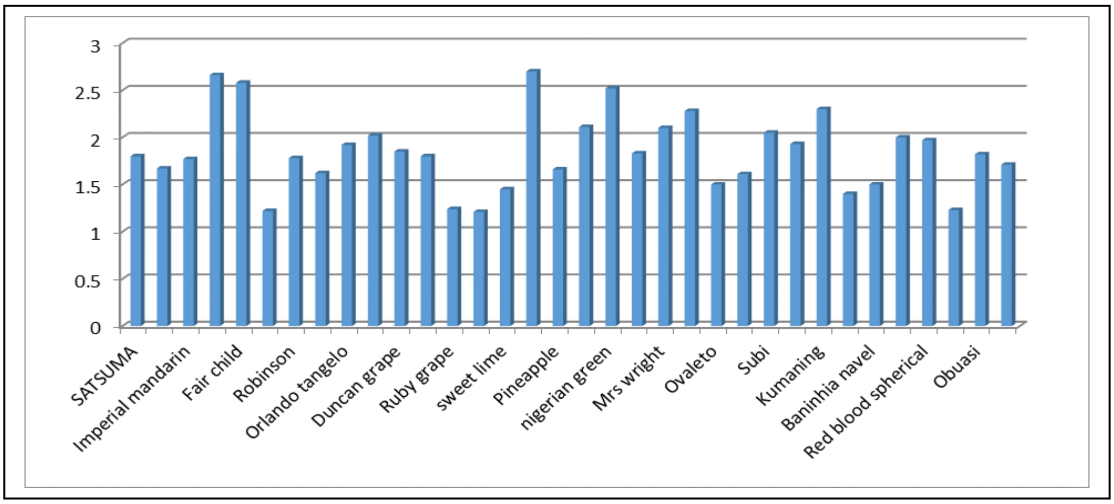


Fig. 26. Stem girth of citrus varieties at 900 days after planting

Fig. 27.



Canopy height of citrus varieties at 900 days after planting

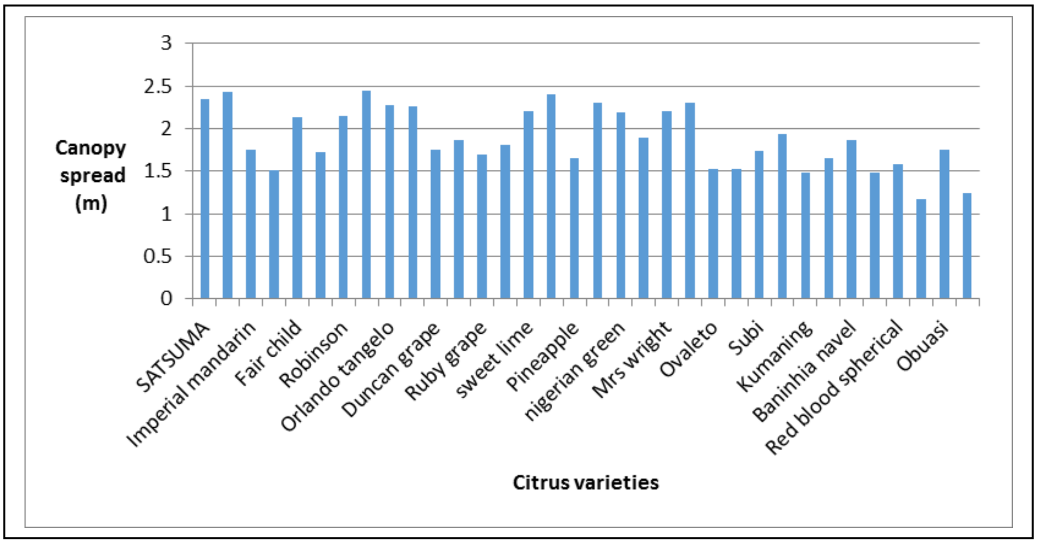


Fig. 28. Canopy spread (width) of citrus varieties at 900 days after planting

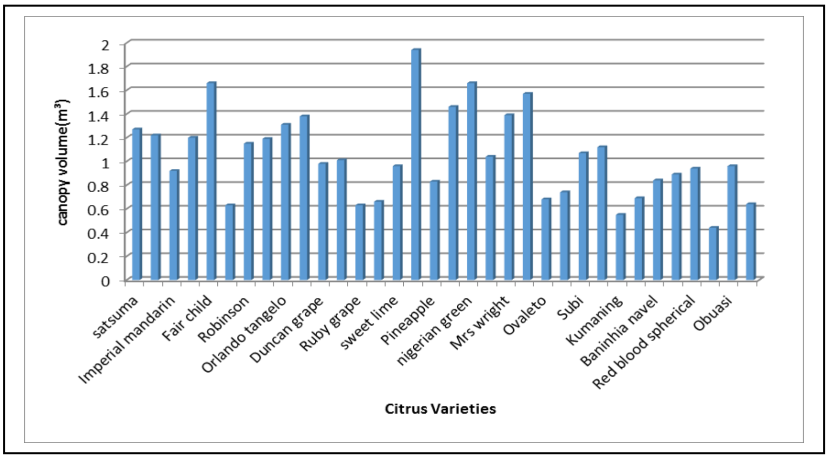


Fig. 29. Canopy volume of citrus varieties at 900 days after planting

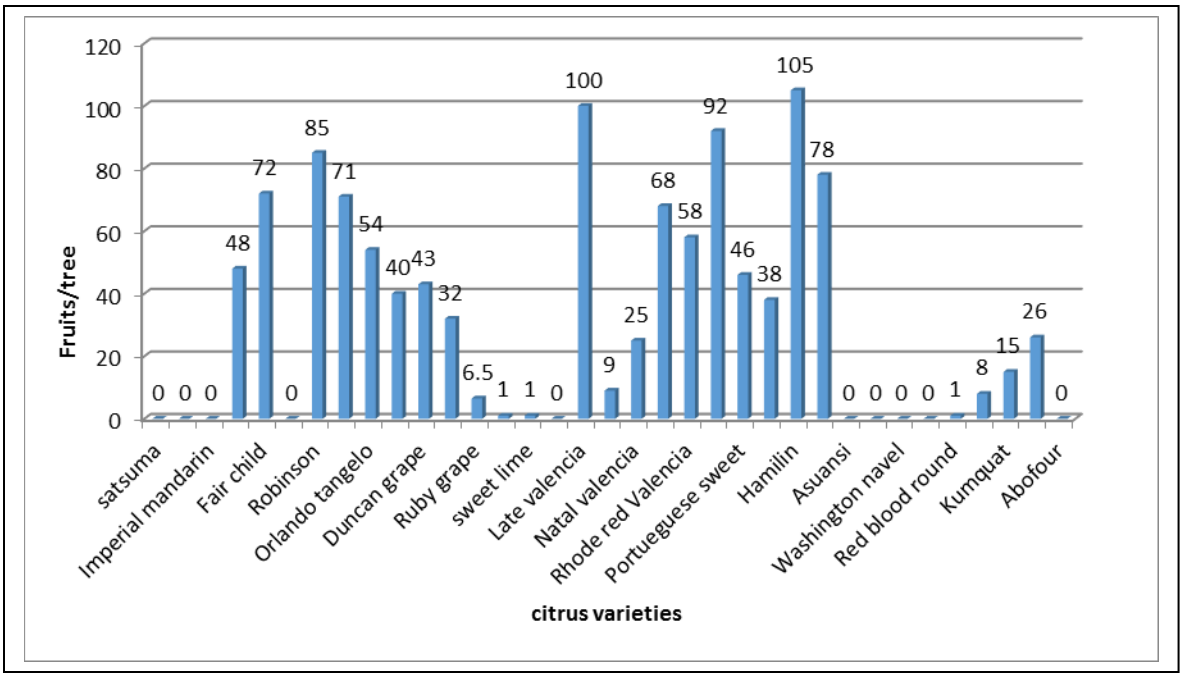


Fig. 30. Fruiting of citrus varieties at 900 days after planting.

Conclusion and Recommendation

Data collected so far have shown some differences among the varieties as indicated above. It is however too early to draw any conclusion as the plants are still developing. More data would be collected to support any future conclusions and recommendation.

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Effects seeding depth on germination and subsequent growth of rough lemon seedlings.

Research Team: P. Mintah, E. Adjei Asamoah and E. Osei-Bonsu

Collaborating Institution: CSIR-PGRRI

Source of funding: Government of Ghana

Objectives

- To assess the effects of depth of seed placement on germination of rough lemon seeds
- To determine the optimum depth of seed placement for good germination and faster growth of seedlings
- To compare the growth of seedlings emerging from different soil depths.

Introduction

Commercial and modern methods of raising planting materials of tree crops including citrus is by vegetative propagation such as budding and grafting that assures faster growth, productivity and inherent qualities of the parent plants. These methods involve a root-stock and a scion. The variety whose fruits are desired forms the scion component of the budgraft (planting material) usually derived from a shoot/budwood of a parent variety. The rootstock component on the other hand is usually derived from seeds of a suitable variety that confers certain qualities.

A number of citrus varieties including Rough lemon, Cleopatra mandarin, Swingle citrumelo, Rangpur lime and Volkameriana, are proven sources of rootstock and Rough lemon has been widely adopted in Ghana. Rough lemon seeds are either sown on seedbeds to be transplanted later or sown directly into soil-filled polybags. Germination of rough lemon seeds is sometimes sporadic resulting in a number of empty polybags within the rows. Re-seeding of such empty bags at a later date results in non-uniform seedling growth and the late ones become over-shadowed, stunted and often fail to reach budding stage or are unduly delayed. Seeds must be planted at the proper depth to achieve a uniform stand of the intended population. It has been observed that depth of sowing of the lemon seeds is often taken for granted and may be sown either too deep or shallowly. It is perceived that, variation in depth of sowing could affect germination and growth of seedlings. It can also affect the number of seedlings per seed emerging. Sowing seeds at the appropriate depth can enhance seed germination and uniform seedling growth. It is anticipated that a standard dibbler can be developed to enhance accuracy of seed positioning.

Methodology

Topsoil was obtained and mixed thoroughly to form a uniform medium. Polybags of size 12cm in diameter and 15cm long were filled to a depth of 14cm high. The potted soil (bags) were watered for three days to allow the soil to settle. Freshly extracted rough lemon seeds were air-dried for a day and sorted into uniform sized seeds (100mg). The average diameter of the 100mg seeds were 5.1mm. Six levels of soil depth: (1 cm, 2 cm, 3cm, 4cm, 5cm and 6cm) were created using a calibrated dibbler and the seeds sown at those depths accordingly. The experimental unit consisted of 30 soil-filled polybags arranged in three rows. The sown seeds were watered regularly and observed for germination.

Results and Discussion

- Germination and growth of seedlings sown at different soil depth

Rough lemon seeds sown at soil depth of 1cm to 3cm germinated earlier compared to those sown deeper: 4cm to 6cm, (Fig. 31). Seeds placed one centimeter deep had 24.5% germination at 15days after sowing (DAS) and reached 76% at 19 DAS. Seeds sown at 2cm and 3cm deep recorded 11.65 and 8.3% germination respectively at 15 DAS and reached 73% and 58% at 19 DAS. The germination of seeds sown 4cm, 5cm and 6cm was zero (0%) at 15 DAS and came up to 3.3%, 10% and 36% respectively at 19 DAS. The highest germination (81.7%) was obtained for the 1cm deep sown seeds at 27 DAS. while the values for the 2cm and 3cm deep sown seeds were 80% and 75% respectively were obtained at 30 DAS. Seeds sown at the depth of 6cm recorded the least value of 23%, whiles the 4cm and 5cm depth sown seeds recorded 58% and 40% respectively at 30 DAS. The optimum depth of sowing lemon seeds to obtain maximum and early germination is therefore between 1cm and 3cm.
The poor germination associated with deep sowing is an economic loss, in terms of cost of non-germinated seeds and labour cost used in sowing, as more labour hours would be required to drill and sow the same quantity of seeds at greater depth compared to sowing ay shallower depths. High percentage of non-germinated seeds as observed with the deep sowing may require removal of the empty polybags and re-seeding which would result in non-uniform seedlings within the rows and complicate their management. Seeds sown too deep may not obtain adequate moisture to germinate. In this trial, however, efforts were made to ensure water availability at all depths. The low rate of germination may therefore be attributed to loss of energy used by the seedling to thrust out of the soil.

The average number of seedlings per seed recorded was more than one (Fig. 32) because Rough lemon seed is poly-embryonic with the tendency of producing more than one seedling per seed (Ofosu Budu et. al 2013). The number of seedlings emerging from each seed reduced from an average of 1.78 to 1.14 with increasing depth of seed placement. This reduction can be attributed to exhaustion (energy depletion) by the seed embryo. Energy for germination and emergence of seedling from the soil is derived from the carbohydrate stored in the cotyledons and endosperms, which gets depleted leading to loss of seedling vigor, hence the reduced ability to emerge from the soil.

Measurements for the rate of growth of seedlings began at 36 DAS. The heights of the seedlings at 36 DAS for the depths 1cm, 2cm, 3cm, 4cm, 5cm, and 6cm were 5.4cm, 5.3cm, 4.3cm, 3.9cm, 3.7cm and 2.5cm respectively (Fig. 33) The seedlings that germinated early grew faster and remained tallest at 86 days after sowing. This has implications on subsequent activities such as budding and transplanting of the resulting budgrafts which can also be done early.

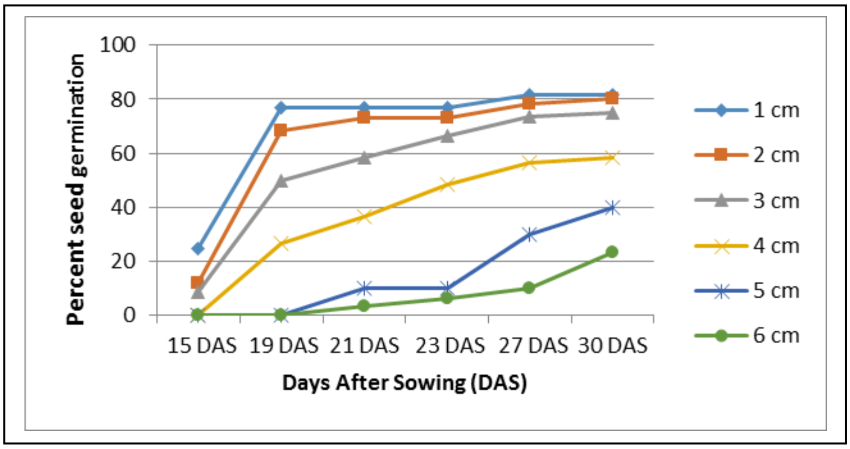

Fig. 31. Germination percentage of Rough lemon seeds sown at different soil depths

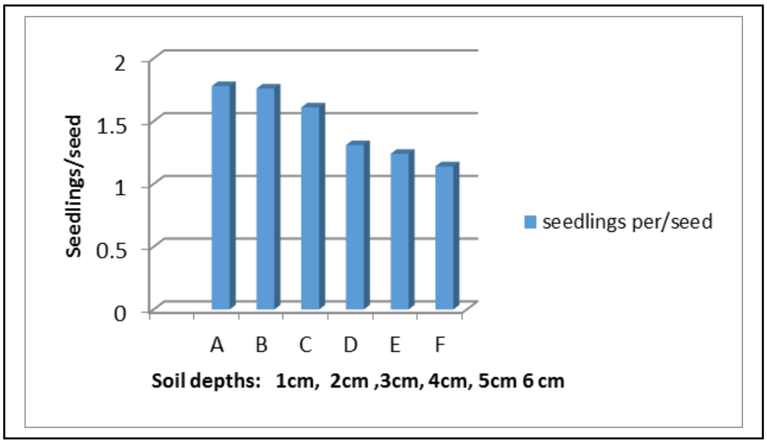

Fig. 32. Seedlings per rough lemon seed sown at different soil depths

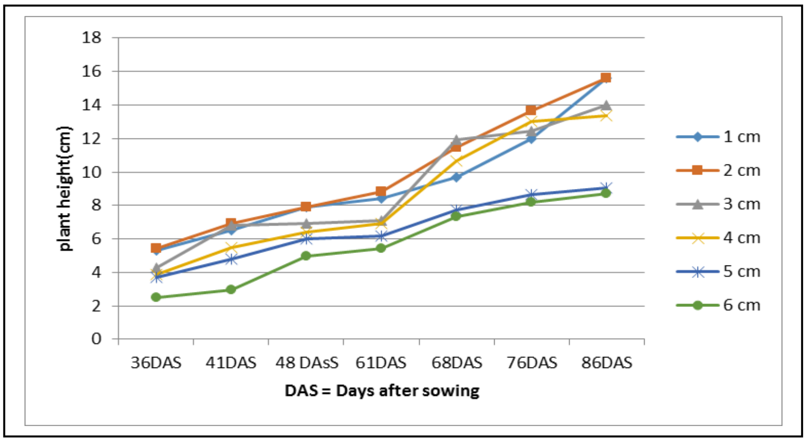

Fig. 33. Growth of seedlings from seeds sown at different soil depths

Conclusion

Uniform plant stands are important for management of the crop because growth requirements of the crop vary at different stages in the crop's life cycle. Plant stands that are uneven become difficult to manage. The optimum seeding depth of rough lemon seeds for good germination (75-81%), better expression of poly-embryony (1.78) and faster growth of seedlings is between 1cm and 3cm. Sowing rough lemon seeds beyond these depths resulted in a loss of 60 - 77% of viable seeds.

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Morphological responses of False Horn Plantain to water stress

Research Team: B.M. Dzomeku, S.K. Darkey, R.K. Bam, C. Staver*, J. Wuensche** and J. Sarkodie Addo***
(*Biodiversity International, ** University of Hohenheim, ***KNUST)

Collaborating Institutions: Biodiversity International (France), University of Hohenheim, (Germany) and KNUST

Source of funding: Bioversity International (France)

Introduction

Water deficit adversely affects morphological features in plantains. The physiological responses of plants to abiotic factors limit and constrain plant photosynthesis and productivity. Consequently, plant responses to drought have been extensively investigated from molecular, physiological, and whole plant to ecosystem levels (Chaves et al., 2003). Water stress may reduce leaf net photosynthetic assimilation (A_n) by both stomatal and metabolic limitations (Farquhar and Sharkey, 1982; Chaves et al., 2003; Ghannoum et al., 2003; Ripley et al., 2007). In addition, many studies have reported that stomatal effects are significant under moderate stresses, but biochemical limitations are quantitatively important during leaf ageing or during severe drought (Grassi and Magnani, 2005; Galle et al., 2007). An early response to water deficit in a plant is a reduction in leaf area and plant growth, which allows plants to reduce their transpiration, thus increasing water use efficiencies (*WUE*) (Xu and Zhou, 2005; Monclus et al., 2006; Aguirrezabal et al, 2006), and promoting interspecies competition capacity under drought (Xu et al., 2007).

Materials and Methods

Planting materials of Apantu (False Horn plantain AAB subgroup) were generated using macro-propagation technique (Dzomeku et al., 2014). Healthy seedlings of uniform sizes with six leaves were selected and used for the study. The plants were grown in 120kg sterile soil in large plastic bowls. The bases of the bowls were perforated to avoid water logging. The surfaces of the bowls were covered with black polyethylene sheets to prevent rain water from entering. The soils were initially soaked to field capacity at planting. The bowls were then subjected to various water regimes - 10ml, 15ml, 20ml, 25ml, 30ml per week. The plantain plants were thus subjected to different water regimes for three months. The surfaces of the bowls with control plants were uncovered to receive natural rain. Irrigation was done with a large syringe through a pore at the base of the pseudostem. Fertilizer (NPK) was applied weekly at 15g per plant. Fertilizer was applied at the time of watering. Each treatment had 15 plants replicated four times in a RCB design and repeated. Data were taken weekly from the first week to the 12th week on leaf emergence, leaf length, leaf width petiole length of fully opened new leaf. Plants were "released" from the stress condition after the 12th week. The plants were subjected to one month water stress again from the 37th to the 42nd (flowering) leaf stage of growth. Data were collected on leaf length and leaf width. Data were analysed using Analysis of Variance (ANOVA) (P= 0.05).

Results and Discussion

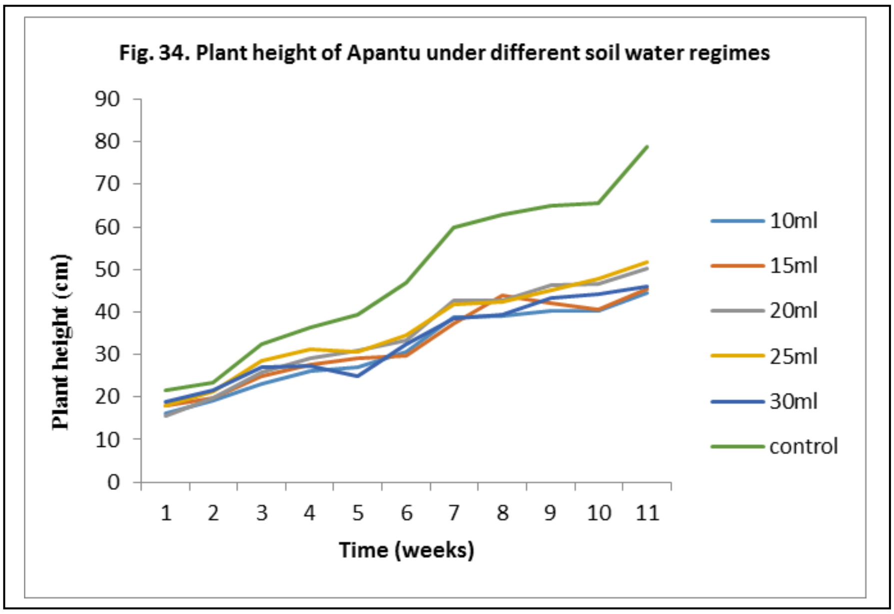
The study area experiences bimodal rainy season with the major rainy season starting from March to July and the minor reason season from September to November. The average temperature of the study area was 26 ^{O}C and the relative humidity was 82% (Table 87). The minimum and maximum annual temperatures recorded during the study period were 24^{0}C and 28^{0}C respectively. The minimum temperatures occurred between the major and the minor rainy seasons whereas the maximum was observed during the peak (February) of the dry season. This deviates widely from the notion that April is the hottest month in the middle belt of Ghana.
In April, the relative humidity is often high and coupled with the high temperature, the weather becomes humid and warm; unlike in February when the weather is dry and hazy with the north-west westerly winds. The lowest relative humidity was recorded in January (the dry season). This is not surprising as the weather is often dry and hazy in January with the north-west westerly winds bringing in a lot of dust from the Sahara desert. It is interesting to observe that the strongest winds were experienced in September and October. However, the heaviest lodging in plantain is experienced between March and April at the onset of the rains after a long drought.

The beginning of the rains comes along with strong winds and because the plants are dehydrated, as a result of the long drought, there is severe lodging. Strong winds are known to cause stem and root lodging in plantain but not at the tender ages. However, strong wind coupled with low relative humidity could influence water loss from the leaves; as these could influence stomatal opening and closure to conserve water in the tissues.

Table 87. Weather conditions at the experimental location (2012-2014)

Month	Temperature (^{O}C)	Rainfall (mm)	RH (%)	Wind speed (m/s)	Solar Radiation (W/m^2)
January	26.5	8.0	56.6	0.7	155.8
February	28.1	17.8	65.8	0.9	165.3
March	27.2	82.4	81.5	1.0	172.5
April	27.0	152.6	80.9	0.9	185.9
May	26.4	169.4	82.7	0.7	162.1
June	25.7	199.2	89.1	0.9	147.5
July	24.6	43.6	89.1	1.0	117.8
August	23.9	7.4	90.1	1.1	101.5
September	23.7	255.4	90.1	128.9	121.4
October	24.7	215.2	90.0	139.4	154.9
November	26.2	41.4	85.2	0.6	156.0
December	25.9	40.8	80.1	0.6	149.1

Subjecting *Apantu* plants to water stress affected physiological, morphological and biochemical processes and therefore adversely affected plantain growth and development. Leaf emergence was highly influenced by water stress. Under 25ml and 30ml of water per week regimes, *Apantu* produced one leaf in every seven days; however as the watering reduced, leaf emergence was delayed to a leaf in 12 days. Whole *Apantu* plant sensitivity to soil moisture stress is reflected in reduced growth evidenced by reduced plant height (Fig. 34). The performance of the "control" showed that water stress adversely affected the height of the plantain plant. The pattern of growth showed similar trends in all treatments with the control treatment showing outstanding growth. In their study, (Kallarackal, et al., 1990; Turner and Thomas 1998) reported that, plantains are sensitive to soil water deficits; expanding tissues such as emerging leaves and growing fruits are among the first to be affected. They also observed that as the soil begins to dry, stomates close; however, leaves remain highly hydrated. Turner, (2005) observed that stomatal closure under soil water deficit conditions may likely be linked to a signal from the roots rather than water deficit in the leaves. The concept that plantains use large amounts of water could not have a strong physiological basis as the plants remain hydrated under severe soil moisture deficit.



The study showed a systematic growth of the leaf with time (Table 88). The leaf length showed moderately undulating patterns and the growth pattern remained similar under the different watering regimes. The undulating pattern, however, showed that other factors could influence the leaf length growth. There was a significant difference between the control and the varying amounts of water application. The large leaf area used for transpiration in *Apantu* is likely to be affected by soil water deficit; the plant must therefore develop an appropriate mechanism for withstand soil water deficit. There was no correlation between watering regimes and the leaf length: leaf width ratio. This could be linked to the study by Turner and Thomas (1998) in which they stated that plants remain hydrated under severe soil moisture deficit. Thus water-use efficiency in plantain could come from a closer match between plant water use and the amount of water applied.

Table 88. Leaf length-width ratio of Apantu (False Horn plantain) under varying water regimes

Watering regimes (ml)	Mean Leaf length (cm)	Mean Leaf width (cm)	Leaf length: width ratio
10	51.9 ±4	30.2 ±6	1.7
15	42.2 ±5	21.9 ±7	1.9
20	55.8 ±7	32.1 ±4	1.7
25	63.4 ±5	35.1 ±6	1.8
30	53.5 ±4	31.4 ±3	1.7
Control	71.7 ±10	38.2 ±8	1.9

Apantu produces on the average 42 leaves before flowering. It was observed, in this study, that leaf length and width in *Apantu* increases with growth, however, these features start to reduce when the plant approaches the flower primordial stage of growth (Table 89). Leaf length and width reduction starts from 39th leaf to the 42nd (flag leaf). The leaf length: width ratio did not change much with growth (Table 89) when the plants were subjected to water stress for one month before flowering.

Table 89. Flower primordial growth stage leaf length-width ratio of Apantu (False Horn plantain) under water stress

Leaf number	Mean leaf length (cm)	Mean leaf width (cm)	Leaf length: width ratio
37th	189 ±14	82 ±12	2.3
38th	171 ±11	70 ±13	2.4
39th	153 ±14	61 ±11	2.5
40th	142 ±11	57 ±16	2.4
41st	118 ±12	49 ±10	2.4

Under the control experiment, the leaf length and width also reduced as the plant approached the flower primordial stage of growth (Table 90). However, there was no difference between the leaf length: width ratio during growth and development. The reduction in leaf length and width proportionately could be an innate characteristic of the crop. It showed that ripeness to flower primordial initiation results in energy storage hence reduction in vegetative growth.

Table 90. Flower primordial growth stage leaf length: width ratio of Apantu (False Horn plantain) under well watering regime

Leaf number	Mean Leaf length (cm)	Mean Leaf width (cm)	Leaf length: width ratio
37th	194 ±12	86 ±19	2.3
38th	187 ±14	77 ±13	2.4
39th	163 ±18	68 ±16	2.4
40th	142±16	60 ±14	2.4
41st	120±19	51 ±11	2.4

Conclusion

The *Apantu* plant was sensitive to soil moisture stress. This was reflected in reduced growth through reduced plant height. Response to water stress reflects equally on the leaf length and width hence the leaf length: leaf width ratio. The study has shown that *Apantu* and for that matter plantain genotypes have different inbuilt mechanisms for resistance to drought stress. Physiological responses of plantain to stress require that each parameter be studied under control environment without other factors having influence.

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Assessing mycorrhization of plantain roots (cv. Apantu and cv. Apem)

Research Team: B.M. Dzomeku, S.K. Darkey, R.K. Bam and J. Wunsche*
(*University of Hohenheim)

Collaborating Institution: University of Hohenheim, Germany

Source of funding: Personal Source

Introduction

Mycorrhizal association is a beneficial relationship between some soil fungi with plant roots (Smith and Read, 2008). In this mutual association, the plant can benefit from these fungi by a better transfer of inorganic nutrients like P, N, K, Ca, S, Fe, Mn, Cu and Zn, as well as water. In turn, the fungi receive plant carbohydrates (Habte and Osorio, 2001; Parniske, 2008), but some exceptions exist (Brundrett, 2004). There are different types of mycorrhizal associations with arbuscular mycorrhizas (AM) being widespread in the plant kingdom. It is estimated that around 74 % of all plant species are able to establish a symbiosis with arbuscular mycorrhizal fungi (AMF) (van der Heijden *et al.*, 2015), a group of fungi belonging to the phylum *Glomeromycota* (Berruti *et al.*, 2014). AMF are obligate biotrophs, which implies that they cannot complete their life cycle without a host plant (Berruti *et al.*, 2014). AMF can increase nutrient content and growth parameters of banana plants (Jaizme-Vega and Azcón, 1995), and improve soil structure by secreting glomalin, which improves soil stability and increases water retention (Gianinazzi *et al.*, 2010).
Many studies on banana and plantain (*Musa* sp.) showed the beneficial effects of AM on plant tolerance against abiotic and biotic stresses. It was shown that AMF can increase banana tolerance to salt stress, generally related to increased plant growth (Yano-Melo *et al.*, 2003) and to aluminium toxicity, also with positive growth effects on inoculated plants but without significant difference in water and nutrient uptake of inoculated and non-inoculated plants if no Al was applied (Rufyikiri *et al.*, 2000). Furthermore, the disease *Cylindrocladium spathiphylli,* causing root rot in banana plants, was negatively affected by AMF (Declerck *et al.*, 2002). Experimental set-up and plant genotype – AMF species – environment interaction is reported to play an important role in the functioning of this symbiosis.

Objective

- This study was to explore the natural mycorrhization potential and likeliness of dauciform rooting of plantain cultivars.

Materials and Methods

Root samples of plantain (*Musa* sp., Group AAB) cultivars cv. *Apantu* and cv. *Apem* were obtained from macro-propagated seedlings planted in polybags at Fumesua. Root samples were washed under running tap and stored in tissue. Samples were sent to INOQ GmbH, Solkau, Germany for analysis. At arrival the root samples were quite dry, so they were soaked in tap water and cleaned by covering them with KOH 10 % (100 g KOH dissolved in 1 L of tap water) in a beaker and heating the sample in a microwave until boiling. The roots were rinsed with tap water to remove the KOH. The roots were stained by soaking in China black ink solution (China black ink 5 %, Acetic acid 5 % in tap water) in a beaker and heated in a microwave until boiling, (Vierheilig *et al.*, 1998) and rinsed with tap water for distaining. Thirty pieces of root were put on a microscope slide and covered with glycerol for conservation. The mycorrhizal colonisation was estimated according to Trouvelot et al., 1986, using a microscope for observation of mycorrhizal structures.

Frequency (F%) of mycorrhiza in the root system was estimated by the number of root pieces which contain mycorrhizal structures divided by the total number of root pieces. Soil samples collected from the root rhizosphere of plantain growing on nursery soil were also analysed.

Results and Discussion

Roots of *Apantu* (False horn plantain), expressed a higher frequency and intensity of mycorrhizal colonisation than *Apem* (French plantain) in all root samples (Table 91). The abundance of arbuscules in the root system of *Apantu* was μ=30.89 % ± 6.40 % with some root pieces being completely mycorrhized and a dense arbuscule development. Different structures of arbuscules were observed, as well as few vesicles and spores. There were unidentified microbiota in the roots of *Apantu* but their incidence was low. Arbuscule abundance in the root system of *Apem* was very low with μ=1.15 % ± 1.13 %. AMF frequency and intensity were low, while the incidence of unidentified microbiota was high and diverse. The presence of non-mycorrhizal fungal structures (not analysed), was higher for *Apem* than *Apantu*.

Table 91. Frequency and intensity of mycorrhizal colonisation of *Apantu* and *Apem*

Cultivar	Sample	F%	M%	m%	A%	a%	$\bar{x}$ (F%) ± SD	$\bar{x}$ (M%) ± SD
Apantu	1	80.00	37.70	47.13	25.37	67.29	89.17 ± 7.39	50.33 ± 8.77
	2	93.33	53.70	57.54	33.43	62.26		
	3	86.67	57.87	66.77	38.77	66.99		
	4	96.67	52.03	53.83	26.00	49.97		
Apem	1	6.67	4.67	70.00	1.17	25.00	10.08 ± 5.71	3.88 ± 1.24
	2	16.67	4.53	27.20	2.27	50.00		
	3	6.90	2.45	35.50	0.02	0.70		

F% = Frequency of mycorrhizal structures in root pieces,
M% = Intensity of mycorrhizal colonisation in the root system,
m% = Intensity of mycorrhizal colonisation in the mycorrhized root pieces
A% = Abundance of arbuscules in the root system,
a% = Abundance of arbuscules in the mycorrhizal parts of the roots
The mean $(\bar{x})$ and standard deviation (SD) for each cultivar.

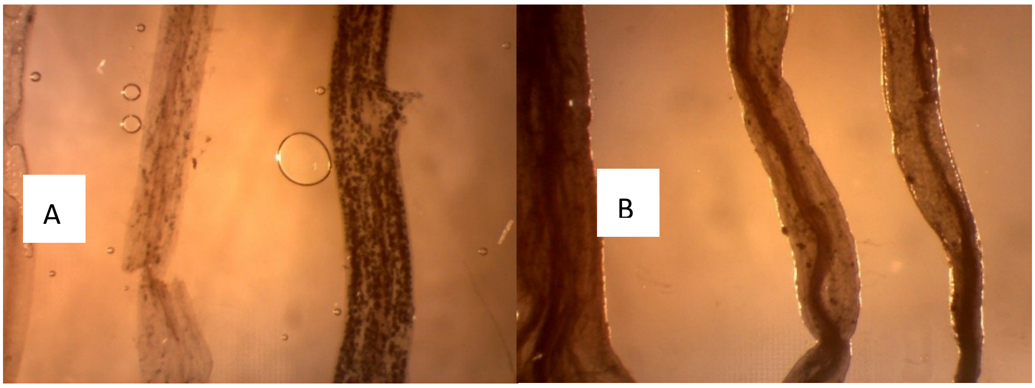

Plate. 17: Stained root fragments of: (A) Apantu, containing arbuscular mycorrhizal structures and (B) Apem, containing non-mycorrhizal fungal structures (unidentified)

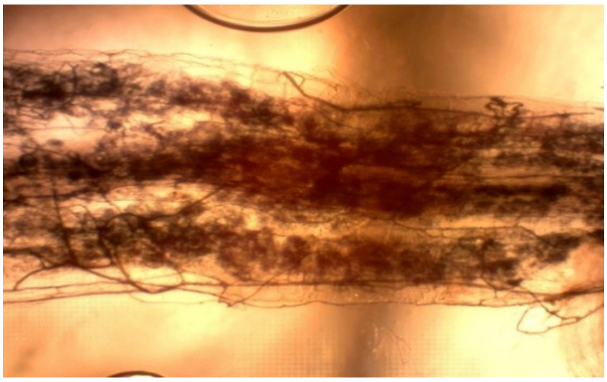

Plate. 18: Mycorrhizal structures in root fragments of Apantu – dense colonisation with arbuscules and hyphae.

Roots of *Apem* appeared a bit thicker and less branched, with shorter secondary roots, than roots of *Apantu*. Eight spores were counted in 5 g of soil. Six spores between 40-75 µm and two spores between 76-125 µm were counted. No nematodes were observed. *Apantu* roots were well-colonised by AMF and did not show high incidence of other microbiota. The *Apem* roots were poorly colonised by AMF with a high incidence and diversity of other microbiota, may be pathogens also. It is believed in some cases that AMF can reduce root infection by pathogens, which might lead to increased fresh weight and yield of plants, compared to infected non-mycorrhizal plants (Gianinazzi *et al.*, 2010). The *Apem* roots had more non- mycorrhizal fungal structures. Compared to other studies estimating F% and M% for bananas, these values were high and in a similar range for *Apantu*, but very low for *Apem*. Literature values found for the mycorrhizal colonization rate are higher than the values obtained from the analysis of the *Apem* root samples, but those studies were conducted under controlled growth conditions with sterilized substrate (Declerck *et al.*, 2002, Elsen, Beeterens, *et al.*, 2003; Elsen, Baimey, *et al.*, 2003, Rufyikiri *et al.*, 2000). As the *Apantu* and the *Apem* plants were growing in the same substrate and were of equal age it seemed that *Apantu* was more receptive to indigenous AMF species than *Apem*, pointing perhaps to AMF - plantain genotype interaction.

Despite only few spores counted in the soil sample, the mycorrhizal colonisation of *Apantu* roots was very good and high in comparison with most literature values, while the *Apem* roots were poorly colonised.

Conclusions and Recommendations

This preliminary result showed that the local mycorrhizas exist in our soils and these could be exploited for plant –nutrient study. *Apantu* has the potential to use symbiosis for plant growth and development. In this era of sustainable production it is imperative to exploit this potential for ecosystem services. The study also reveals the possible dauciform rooting in Apantu, a characteristic associated with plants growing in nutrient deficient soils. Further research is needed to explore the potential of this biological resource for sustainable nutrient management in plantain production.

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Responses of leaf stomatal parameters to induced water stress and its relationship with stomata conductance in False Horn plantain

Research Team: B.M. Dzomeku, S.K. Darkey, R.K. Bam, C. Staver*, and J. Wuensche** (*Biodiversity International, ** University of Hohenheim)

Collaborating Institutions: Biodiversity International (France) and University of Hohenheim, (Germany)

Source of funding: Bioversity International

Introduction

Water deficit is one of the most important environmental factors affecting plantain production especially under rain-fed cropping systems. Physiological responses to soil water deficit are the features that are most likely to determine the response of a crop to irrigation. Water stress may reduce leaf net photosynthetic assimilation (A_n) by both stomatal and metabolic limitations (Farquhar and Sharkey, 1982; Chaves et al., 2003; Ghannoum et al., 2003; Ripley et al., 2007). Many studies have reported that stomatal effects are significant under moderate stresses, but biochemical limitations are quantitatively important during leaf ageing or during severe drought (Grassi and Magnani, 2005; Galle et al., 2007). An early response to water deficit in a plants is a reduction in leaf area and plant growth, which allows plants to reduce their transpiration, thus increasing water use efficiencies (*WUE*) (Xu and Zhou, 2005; Monclus et al., 2006; Aguirrezabal et al, 2006), and promoting interspecies competition capacity under drought (Xu et al., 2007).

Plantain as a giant monocot poses a challenge to physiologists' efforts to measure indicators of water deficits, due to the presence of large air pockets within the leaves, and laticifers containing latex within the leaves, fruit, and corm that hinder the use of standard methods of measuring water relations (Turner and Thomas, 1998). Several methods have been used to measure physiological indicators of response (Milburn et al.,1990, Kallarackal et al.,1990, Turner and Thomas, 1998). However, none of these methods have been accepted as the only standard to be used, though Thomas and Turner (2001) confirmed the reliability of a method by Milburn et al. (1990) that is dependent on the refractive index of exuded latex. Although some authors used leaf folding as an indicator of response to water deficit, in plantain under hot, arid conditions, leaf folding is not considered to be a reliable plant-based indicator of when to irrigate (Thomas and Turner, 1998).
While physiological mechanisms of stomatal responses are complex and are not yet fully understood, it is even worse with *Apantu* as studies describing how stomatal parameters respond to different water stresses, and their relationships with physiological processes are limited.

Objectives

- To determine the stomatal response patterns to different water status
- To develop the relationship of stomatal parameters and photosynthetic processes.

Materials and methods

Healthy seedlings of *Apantu* (False Horn plantain AAB subgroup) of uniform sizes, with six leaves were selected and used for the study. The plants were grown in 120kg sterile soil in large plastic bowls. The bases of the bowls were perforated to avoid water logging. The surfaces of the bowls were covered with black polyethylene sheets to prevent rain water from entering. The soils were initially soaked to field capacity at planting. The bowls were then subjected to various water regimes - 10ml, 15ml, 20ml, 25ml, 30ml per week. The surfaces of the bowls with control plants were uncovered to receive natural rain. Irrigation was done with a large syringe through a pore at the base of the pseudostem.

Fertilizer (NPK) was applied weekly at 15g per plant at the time of watering. Each treatment had 15 plants replicated four times in RCB design. Data were taken weekly (from the first to the 12^{th} week) on leaf emergence, leaf length, leaf width petiole length of fully opened new leaf. Plants were released from the stress condition after the 12^{th} week. The plants were subjected to one month of water stress again from the 37^{th} to the 42^{nd} (flowering) leaf stage of growth. Data were collected on leaf length and leaf width. Data were analysed using Analysis of Variance (ANOVA) (P= 0.05).

The impression approach was used to determine leaf stomatal density, which was expressed as the number of stomata per unit leaf area **(Radoglou and Jarvis, 1990).** The leaves selected were those for which chlorophyll content was also measured. Micro-morphological observations were carried out 12 weeks after planting using a digital microscope (Amscope, USA). The stomatal density (SD) stomatal length (SL) and stomatal width (SW) were determined from the underside (abaxial surface) of each leaf using prints made with nail varnish.

<u>Results and Discussion</u>

The study area experiences bimodal rainy season with the major rainy season starting from March to July and the minor reason season from September to November. The average temperature of the study area was 26 ^{O}C and the relative humidity was 82%. The study revealed a homogeneous closure of stomata in response soil water deficit in *Apantu*. The water regime influenced stomatal opening and closure. Under the 10ml of water per week regime, the stomata closes, compared to 20ml and the control (Plates 19, 20 and 92). Soil water deficit is known to reduce stomatal conductance and leaf size (Kallarackal et al., 1990) and increase leaf senescence (Turner, 1998).

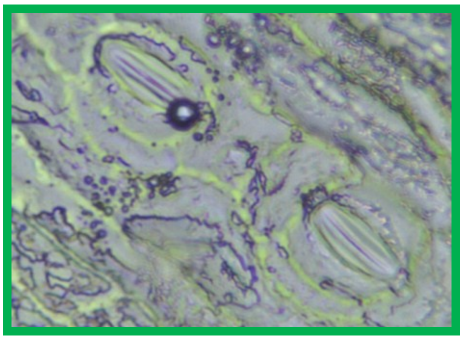


Plate 19. Stomatal shape under 10ml water regime

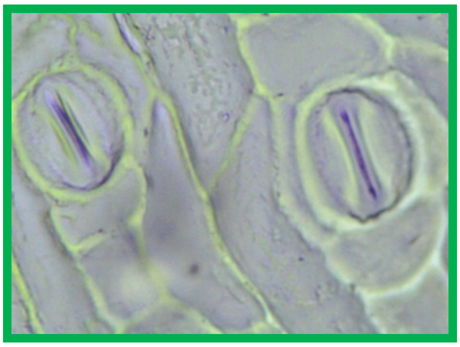


Plate 20. Stomatal shape under 20ml water regime

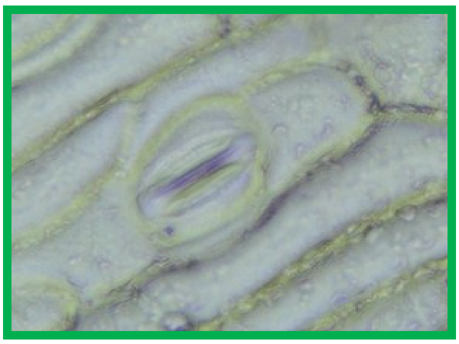


Plate 21. Stomatal shape under 30ml water regime

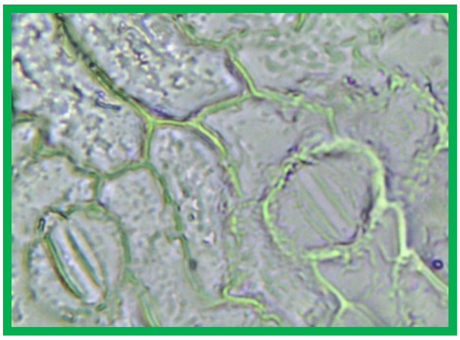


Plate 22. Stomatal shape under the control

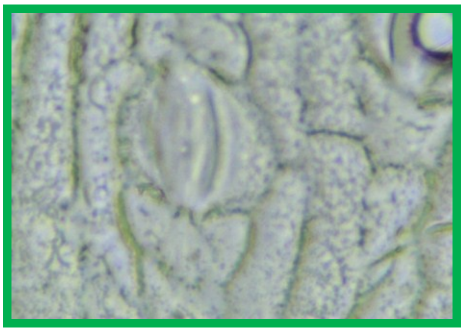


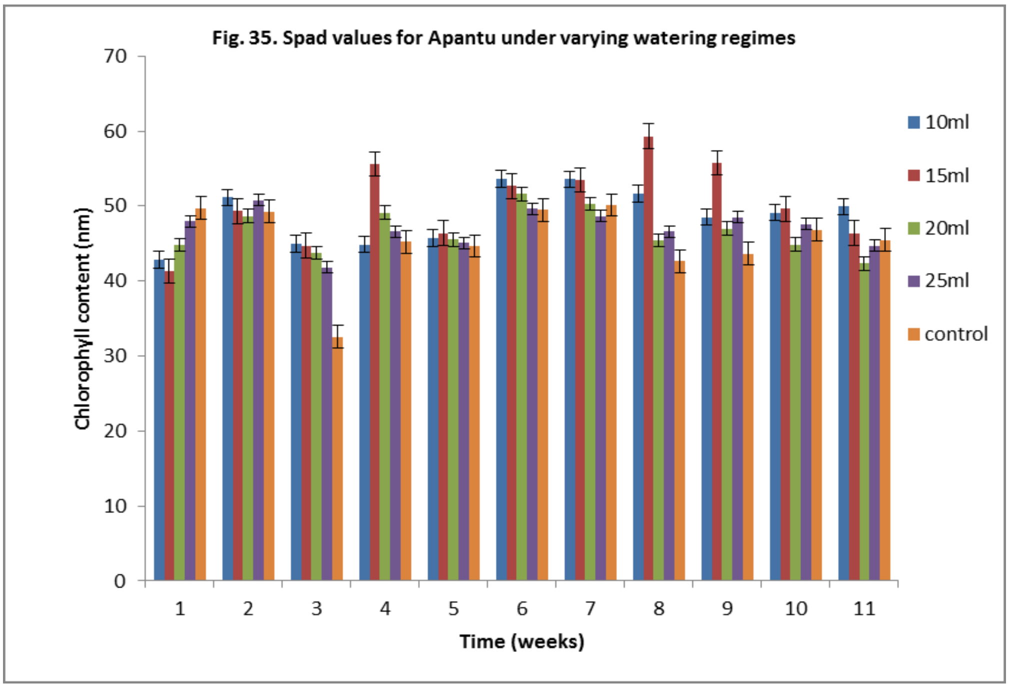
Plate 23. Stomatal shape under 15ml water regime

Table 92. Changes in guard cell length, stomatal density and potential conductance index of Apantu with varying water regimes

Watering regimes	Guard cell length (μm)	Stomatal density (count/mm^2)	Potential Conductance Index (PCI)
10ml	151.4 ± 0.6	464 ± 0.8	106.4 ± 0.5
15ml	225.0 ± 0.4	352 ± 0.5	178.2 ± 0.3
20ml	167.3 ± 0.6	304 ± 0.3	85.1 ± 0.4
25ml	178.2± 0.3	320 ± 0.6	85.1 ± 0.6
30ml	209.7 ± 0.4	304 ± 0.2	63.5 ± 0.5
Control	155.2 ± 0.3	304 ± 0.8	85.1 ± 0.4

Plantains are reported to be particularly sensitive to changes in the environment (Bhattacharya and Madhava Rao, 1988).This thus affect the productivity of the crop because there is often early closure of stomata to conserve water and hence affect photosynthetic activities.

In their study, (Turner and Thomas, 1998) reported that there was a link between leaf folding and water deficit while (Lu et al., 2002) did not find any link between leaf folding and soil water deficit as they compared sap flow system with gravimetric system to measure drought resistance in banana.



The chlorophyll content did not show any significant trend in response to watering regime (Fig. 1). The chlorophyll content showed undulating characteristics indicating that there was no relationship between soil moisture stress and chlorophyll content. Studies showed that the presence of large air pockets within the leaves and laticifers containing latex within the leaves, fruit and corm hinder the use of standard methods of measuring water relations (Turner and Thomas, 1998). This peculiar characteristic of plantains and bananas make them adjust quickly to water stress without showing significant physiological changes. In a study (Orcen et al., 2013) two tobacco species were subjected to chromium stress; and it was observed there was a significant relationship between stomatal parameters and the heavy metal dosage except stomatal width.

Stomatal conductance is linked to stomatal density and guard cell length. The study has not shown any straight forward link between water deficit and physiological responses with growth in Apantu (Table 93).

There was no correlation between stomatal density, length and stomatal conductance index (PCI) in Apantu, though it is known that stomatal densities and stomatal lengths have a correlation with stomatal conductance index (Holland and Richardson, 2009). These parameters are also influenced by water stress; however, in some plants like plantain the presence of large air pockets within the leaves, and laticifers containing latex within the leaves, fruit, and corm influence physiological responses. The worldwide water shortage and uneven distribution of rainfall as a result of climate variability makes drought resistance an important factor to consider in physiological studies. Physiological changes within leaves such as changes in stomatal aperture or leaf folding or leaf elongation in response to soil water deficit did not correspond with changes in leaf water status measured. *Apantu* crop productivity is greatly affected by environmental stresses such as drought, however, the crop responds and adaption to these stresses to survive could be at the molecular and cellular levels as well as at the physiological and biochemical levels.

Table 93. Stomatal conductance index (PCI) of Apantu under varying watering regimes

Watering regime (ml)	Stomatal density	Stomatal length (um)	PCI
10	464 ± 8	151.4 ± 6	106.4
15	352 ± 7	225.0 ± 8	178.4
20	304 ± 8	167.3 ± 5	85.1
25	304 ± 6	178.3 ± 7	85.1
30	320 ± 5	209.7 ± 6	63.5
Control	304 ±7	141. 0 ± 9	85.1

Conclusion

The Apantu plant was sensitive to soil moisture stress. The study has shown that Apantu for that matter plantain genotypes have different inbuilt mechanisms for resistance to drought stress. Physiological responses of plantain to stress require that each parameter be studied under control environment without others having influence.

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RESOURCE AND CROP MANAGEMENT

Effect of fertilizer types, and rate and time of application on growth, development and yield of maize variety Obatanpa.

Research Team: J. N. Berchie, K. Agyemang, I. Gaisie*, S. Obeng-Antwi, J. K. Fordjour, M. Offei, E. Nasarah**, A. Karim and A. Buckman (*CSIR-SRI, **MOFA)

Collaborating Institutions: CSIR-SRI and MOFA.

Source of funding: YARA, Ghana.

Introduction

Sustainable agricultural practices that lead to increase in productivity are central to the acceleration of economic growth which will aid in poverty alleviation and consequently help overcome recurrent food shortages. The potential for expanding agricultural lands is very limited, however, recent trends indicate that productivity and soil fertility are globally declining due to intensive use of soil with very little soil management practices (Cakmak, 2002). Maize (*Zea maize* L.) is an important cereal crop ranking third after wheat and rice in the world (David and Adam, 1985). The crop is one of the most important cereal crops in Ghana. New fertilizer formulations introduced in Ghana have been tested on targeted crops to confirm their efficacy before they are recommended to farmers. The importance of conducting a cost-benefit analysis of new technologies before any meaningful recommendation can be made to farmers is very paramount hence the need for this study

Objectives

- To determine the effect of Yara fertilizer types, and their time and rate of application on the growth, development and yield of maize variety Obatanpa at Fumesua and Kwadaso in the major growing season of Ghana.

Materials and Methods

The trial was arranged in RCB design with three replications per site. Maize variety *Obatanpa* was used. Seven fertilizer treatments including a control (as listed below) were used.

T_1 - Actyva (4 g/hill ie 125 kg/ha) at 2 WAP + Actyva (8 g/hill ie 250 kg/ha) at 4 WAP
T_2 - Actyva (8 g/hill ie 250 kg/ha) at 2 WAP + Actyva (4 g/hill ie 125 kg/ha) at 4 WAP
T_3 - Unik $_{15}$ (8 g/hill ie 250 kg/ha) at 2 WAP + Sulphate of Ammonia (4 g/hill ie 125 kg/ha) at 4 WAP
T_1 - Unik $_{15}$ (8 g/hill ie 250 kg/ha) at 2 WAP + Amidas (4 g/hill ie 125 kg/ha) at 4 WAP
T_5 - Control (No fertilizer) Unik $_{15}$ is equivalent to 15:15:15, N:P:K

Seeds were sown in May, 2015, at 80 cm x 40 cm with three seeds per hill and thinned to two seedlings per hill at two weeks after planting (2 WAP). The first fertilizer dose was applied at 2 WAP, after thinning, and the second dose was applied at 4 WAP (T_1- T_5). Weeds were controlled at 3 and 6 WAP and as and when necessary. The plots at Fumesua were irrigated when there was a spell of drought while those at Kwadaso were solely under rainfed conditions because there no irrigation facilities at Kwadaso. Soil samples were taken from the plots at both locations for analysis. Data on plant height, lodging, days to 50% silking, days to 50% tasseling, stover yield and grain yield were taken from the two central rows. Analysis of Variance using GENSTAT Discovery (4th Edition) was used to analyze the data. Means separation was done using SED at $p \leq 0.05$

Results

Table 94. Physical and chemical properties of soils at horizons 0-15 cm and 16-30 cm at Kwadaso.

					Bray's Available		Exchangeable Cations m.e. 100^{-1}g								Particle Size Analysis			
Depth	P^H	O. C	O.M	N	ppmK	ppmP	Ca	M g	K	Na	TEB	Ex. Acid ity	ECE C	% B.S	% Sand	% Silt	% Clay	Texture
0 - 15cm	5.2	1.8	3.3	0.2	100.4	106.8	3. 49	0. 8	0.1 2	0. 03	4.5	0.45	4.87	90.8	65.8	28	6	sandy loam
15-30cm	5.4	1.4	2.6	0.1	56.6	3.75	2. 94	0. 8	0.0 5	0. 03	3.9	0.4	4.22	90.5	62.7	28	8	sandy loam

Results of analysis of soil samples from Kwadaso are presented at Table 94.

Analysis of the soil samples from the plots at Fumesua is being done at CSIR-SRI. The results would be compared with those of Kwadaso. Grain yield, across the two locations, ranged from 2980 Kg/ha (Control) to 4555 kg/ha (Actyva 125kg/ha + Actyva 250kg/ha) with a grand mean of 4016 kg/ha (Table 95). Actyva 125kg/ha + Actyva 250kg/ha emerged as the best nutrient management combination for *Obatanpa*, outyieling the control by 65% under the same growing conditions and significantly outyielding the other nutrient management combinations except Unik$_{15}$ 250kg/ha+ Sulphate of Ammonia 125kg/ha. Grain yield at Fumesua was relatively higher than at Kwadaso. Yield ranged from 3439kg/ha (for the control) to 5657 kg/ha for Unik$_{15}$ 250kg/ha + 125kg/ha. This could be due to the supplementary irrigation applied at Fumesua when there was a dry spell. No significant difference in yield was observed between the control plot and the Actyva 250 kg/ha +Actyva 125kg/ha treatment at Fumesua. This could be due to the fact that one replication of Actyva 250 kg/ha + Actyva 125 kg/ha was severely attacked by crows. Across locations however, all the fertilizer treated plots out-yielded the control plot.
At Kwadaso, yields ranged from 2520 kg/ha to 4619 kg/ha. Significant differences were observed among the fertilizer treated plots, with Actyva 125kg/ha + Actyva 250kg/ha producing the highest grain yield. Yields of the fertilizer-treated plots were 28% - 83% greater than the control at Kwadaso.

Table 95: Grain yield of Obatanpa maize as affected by Yara fertilizer combinations at Kwadaso and Fumesua in 2015

Treatment	Grain Yield (kg/ha)		
	Kwadaso	Fumesua	Across locations
Actyva 250kg/ha + Actyva 125kg/ha	4044	3932	3988
Actyva 125kg/ha + Actyva 250kg/ha	4619	4491	4555
$Unik_{15}$ 250kg/ha + Amidas125kg/ha	3216	4838	4027
$Unik_{15}$ 250kg/ha + SOA 125kg/ha	3432	5626	4528
No Fertilizer (Control)	2520	3439	2980
CV	15.8	16.9	12.8
SED	461	616	420
Grand Mean	3566	4465	4016

Conclusion/Recommendation

Generally, *Obatanpa* showed good response to the Yara inorganic fertilizer combinations. Results of the trial showed the effectiveness of Yara fertilizers as nutrient management options for maize production in Ghana. With recommended good management, the fertilizer combinations produced 83 % and 64% more grain yields than the control plots in Kwadaso and Fumesua respectively. Socio-economic studies are being undertaken. For sustainable production of maize to meet the demand of the populace, livestock and industry, it is recommended that inorganic fertilizer should be applied to improve on the soil's nutrient status.

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Growth, Development and Yield of Cassava progeny as affected by Nutrient Status of Mother Plant

Research Team: J. N. Berchie, K. Agyeman, E. Tetteh, I. Osei-Bonsu, I. Gaisie*, H. Braimah and J.N. Lamptey (*CSIR-SRI)

Collaborating Institutions: CSIR-SRI and MOFA

Source of funding:

Introduction

Cassava is a very important staple crop in Ghana, contributing about 22% to the country's Agricultural GDP. It is estimated that about 90% of farmers in eight out of the ten regions in Ghana cultivate the crop due to the crop's resilience and its ability to grow on marginal land (IFPRI, 2007). The importance of cassava to the Ghanaian economy can, therefore, not be over-emphasized. However, the crop has, until recently, seen very little improvement in their husbandry practices. It has been marginalized in food policy debates and stigmatized as an inferior food, ill-suited and uncompetitive with the glamorous crops such as imported rice and wheat because of several long-standing myths as a poor man's crop full of nothing but carbohydrates. Cock (1985) however, reported that in most developing countries calories are in fact the paramount nutritional shortage. Cassava should therefore be regarded as a cheap energy source with other foods providing the necessary protein, vitamin, mineral and fats required. Cassava yields on farmers' fields are low (8-10 t/ha) compared with potential yields of 30 to 40 t/ha. A major factor contributing to this low yield is the low soil fertility and the poor quality of the planting material. Keating *et al.* (1982a) reported that in infertile soils, the effects of mineral nutrition are cumulative in that cuttings from plants in these soils emerge more slowly and have a lower yield potential than those from plants grown in more fertile soils. The results of this study will give a good indication to cassava planting material producers, on the need to apply a certain level of fertilizer to the plants, or for farmers to apply fertilizer on a small portion of their cassava farms before cuttings are taken to plant. This is justified because most cassava farmers do not apply fertilizer for their cassava plants (because of lack of financial resources).

Objectives

- Investigate the effect of fertilizer application to mother plants, on the growth, development and yield of the progeny from these plants.

Materials and Methods

Cassava cultivar *Dabo* was planted on-station at Kwadaso in June 2013, at a spacing of 1 m x 1 m. Four fertilizer treatments (listed below) were applied. NPK was applied at one month after planting and followed with Muriate of potash (MOP) at three months after planting (MAP). The experimental design was RCB with three replicates. These plants were harvested in June, 2014.

Planting materials (progenies) from the (mother) plants harvested June, 2014, were planted in July, 2014 (second year), at a spacing of 1m x 1m (10,000 plants/ha). No fertilizer was applied to the plants (since the effect, of the residual nutrient from the mother plants, on the performance of the progenies was to be determined). The fields were weeded as and when necessary. Harvesting was done in September, 2015. Data collected were analysed using GENSTAT Discovery 4th Edition. Mean separation was done using the SED at $p \leq 0.05$.

Treatment 1: 20g NPK (30:30:45) @ 1 MAP + 3 g MOP @ 3 MAP
Treatment 2: 20g NPK (60:30:45) and 13g of Urea @ 1MAP + 3g of MOP @ 3 MAP
Treatment 3: 20g NPK (45:30:45) and 6.5g of Urea @ 1 MAP + 3g of MOP @ 3 MAP
Treatment 4: Control (No fertilizer)

Results and Discussion

Cassava yields for all the fertilizer treated plots of mother plants were significantly ($p \leq 0.05$) higher than the control plot with yield differences ranging between 68% and 278 % in the first year of the experiment (2013) (Table 96). Cuttings from the treatment that gave the highest yield in Year 1 (45-30-45, N:P:K) gave the greatest yield - 233 % higher than the control. Results from this study justifies the need for commercial cassava planting material producers to boost the quality of the planting materials through fertilizing the mother plant. Farmers in cassava production can also fertilize a small portion of their cassava farm and use cuttings from the fertilized plot as planting materials.

Conclusion and recommendation

The results of this study showed that cuttings from mother plants grown on a nutrient rich soil develop faster and produce greater root yield compared to that which is grown in a nutrient poor soil. It is recommended that cassava planting material producers should apply fertilizer to the plants before cuttings are harvested for sale to farmers. Farmers should reserve a portion of their cassava fields and apply fertilizer to the plants so that they can be used as planting materials for subsequent planting.

Table 96: Root yield, root length and above ground biomass of mother plants and progenies of cassava cultivar *Dabo* as affected by fertilizer application.

	Root yield (t/ha)		Root length (cm)		Above ground biomass (t/ha)
Treatments	Year One (2014) Mother plant with fertilizer applied	Year Two (2015) daughter Plant No fertilizer applied	Year One (2014) Mother plant	Year Two (2015) daughter plant	Year Two (2015) daughter plant
NPK 45-30-45	33.7	24.0	34.3	33.7	12.7
NPK 60-30-45	27.2	14.4	25.4	37.5	10.1
NPK 30-30-45	20.3	10.6	26.8	28.6	9.7
Control	12.1	10.3	36.2	33.5	7.6
CV	16.1	15.7	11.5	23.4	24.5
SED	3.8	5.5	2.8	6.3	2.6
Mean	23.3	14.8	30.6	33.3	10.2

Plate 24: Root yield of two plants (progenies) from non-fertilized (control) mother plant

Plate 25: Root yield of two plants (progenies) from fertilizer treated mother plant

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Evaluation of 12 bambara groundnut landraces.

Research Team: J.N. Berchie, R. Kanton*, P. Marnor, K. Agyemang (*CSIR-SARI)

Collaborating Institutions: CSIR-SARI and MOFA

Sources of funding: AGRA and CSIR-SARI Bambara Project

Introduction

Bambara groundnut (*Vigna subterannea*) is an indigenous African legume consumed by 100 million people in Sub-saharan Africa, with additional consumers in Indonesia (Lost Crops of Africa Vol II, 2006). A key advantage of bambara groundnut is its ability to survive extended droughts and withstand over 40˚C temperature (Lost Crops of Africa, Vol. II, 2006). The crop has been described as the most drought resistant pulse crop worldwide (Doku and Karikari, 1971). Nutritionally, bambara groundnut forms a complete meal, with 42-60% carbohydrates, 16-25% protein and high in the rare sulfur-based amino acid, methionine (Brough and Azam-Ali, 1992). Bambara seeds and leaves are rich protein sources for chicken and livestock, respectively (Brink and Belay, 2006). Until lately, funding for bambara groundnut research has been negligible because the crop is not considered as a commercial oil seed crop with its low lipid content of 5 – 7 %. With the threat of climate change the need for crops that are resilient to drought cannot be overemphasized. Genotypic differences exist among bambara groundnut landraces in terms of yield, days to maturity and drought tolerance, among other traits.

Objective

- The objective of the study was to evaluate 12 bambara groundnut landraces for yield and earliness to maturity.

Materials and Methods

Twelve bambara groundnut landraces - Mottled cream, Cream with black eye, Mottled red, Zebra coloured, Tom, Burkina, NAV red, Bolga red, Black eye, Mottled brown, Techiman brown and NAV 4 - were sown at three seeds per hill on October 1, 2015, at Fumesua. Spacing was 50 cm x 20 cm. Seedlings were thinned to two per hill 21 days after sowing. Treatments were arranged in RCB Design with three replications. Data were collected on days to emergence, days to 50% flowering, days to maturity, number of pods/plant, pod weight, seed weight, haulm weight and shelling percentage, among others.

Results

The field was harvested on January, 14, 2016. The data are yet to be analysed.

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Effect of compost mound from mucuna cover crop residues on yield of yam

Research Team: P. Osei-Bonsu, G. Bolfrey-Arku and K. Asubonteng* (*CSIR-SRI)

Collaborating Institution: MOFA

Source of funding: WAAPP

Introduction

Low soil fertility is a major factor limiting crop yields in Ghana and most developing countries. Chemical fertilizer usage in developing countries is very low partly because of low income levels of farmers and high costs of fertilizers (Tian et al., 1993; Buckles et al., 1998). Yam farmers in Ghana largely depend on natural fallow system to restore the fertility of degraded soils, which is not sustainable due to pressure on land. There is therefore the need to develop sustainable soil management practices to replace natural fallow system for yam cultivation. Farmers in Papua New Guinea have, for centuries, used compost mounds to maintain soil fertility and sustain sweet potato yields. Compost mound is a mound with a quantity of plant residues incorporated. In Ghana, compost mounds are used by some farmers in cocoa growing areas in the Brong Ahafo region to grow yams (personal observation). Results of several studies have shown that mucuna cover crops could control weeds and improve crop yields (Ajebesone et al., 2011, Osei Bonsu, 1998)

Objective: To determine the effects of compost mounds from mucuna residue on yam yield.

Materials and methods

Researcher-managed trials were set up at Ejura and Amanten in the major season of 2014. The experimental design was RCB block with three replications per site and the treatments were as in Table 97.

Table 97. Experimental design with three replications per site and the treatments

Treatment	Major season 2014	Minor season 2014	Major season 2015
1	Maize + Mucuna	Mucuna fallow	Mounds with Mucuna residue but no fertilizer (mucuna and no fertilizer)
2	Maize + Mucuna	Mucuna fallow	Mounds with mucuna residue + fertilizer (mucuna + Fertilizer)
3	Sole maize	Natural fallow	Mounds with natural fallow no fertilizer (Natural Fallow with no fertilizer)
4	Sole maize	Natural fallow	Mounds with natural fallow + fertilizer (Natural fallow + fertilizer)
5	Sole maize	Natural fallow	Mounds after slash and burn no fertilizer (Slash and burn)

Plot size was 4 rows of yam, 5 m long. In the major season of 2014, maize was planted at a spacing of 100 cm x 40 cm and mucuna was intercropped with the maize at 45 days after planting (DAP) the maize. One row of mucuna was planted between two rows of maize. After harvesting the major season maize, the plots planted to mucuna was left to fallow under mucuna while the sole maize plots were left to natural fallow. In the major season of 2015, the existing residues on Treatments 1 - 4 were removed while residues on Treatment 5 were burned. Soil samples were taken from the mucuna and natural fallow plots (with burned and unburned residues). Thereafter mounds were formed on all the plots. Half of the existing residues of treatments 1-4 were incorporated into the mounds before yam was planted. After planting the yam the remaining residues on each plot were used to mulch the mounds. Weed samples were taken from the plots before land preparation and weed incidence was scored at 3 weeks after planting on a scale of 1-5; (where 1 = weed free and 5 = excessive weed pressure).

Results and Discussion

At land preparation in the major season of 2015, the phosphorous content of the soils was low (4.02 mg/kg - 8.68 mg/kg) at both locations. The burned natural fallow had highest phosphorous content at both locations (Tables 98 and 99). Nitrogen content was high on the mucuna plots, but low on the burned natural fallow plots. Potassium levels on the other hand were generally moderate ranging from 0.14 cmol/kg to 0.47 cmol/kg.
Burning resulted in the highest levels of potassium. Conversely organic carbon and organic matter levels were lowest on the burned plots and highest on the mucuna plots.
At land preparation and at 3 weeks after planting, weed incidence was significantly lower on the mucuna plots than on the natural fallow plots (Table 100). Mucuna completely covered the plots throughout the minor season thereby suppressing weed growth.
At Amanten, yam plant population 3 weeks after planting was very low on the burned plots, but there were no significant differences in plant population at Ejura (Table 100). This may be attributed to lack of rainfall at Amanten for two weeks after planting, while it rained on two occasions at Ejura during the same period. Mulch might have conserved soil moisture and enhanced yam germination on treatments 1-4 at Amanten. The number of tubers harvested ranged from 13,300 to 18,333 tubers per hectare at Amanten. At Ejura it ranged from 11,000 tubers to 20,000 tubers per hectare (Table 101). Tuber yield ranged from 10,400 kg/ha to 22,739 kg/ha at Amanten and from 9,600kg/ha to 22,350 kg/ha at Ejura. At both locations, plots with chemical fertilizer consistently resulted in higher yam yields than those without fertilizer. Without fertilizer, yam after mucuna out yielded those after natural fallow.

Way forward

The study will be repeated on the same site to determine the long term effect of compost mound on yield of yam.

Table 98: Soil chemical properties (before chemical fertilizer application) as affected by cropping system at Ejura

Cropping System	Avail P (mg/kg)	% total N	K (cmol/kg)	% Org carbon	% Org matter
Mucuna	5.65	0.068	0.17	0.36	0.62
Natural fallow un-burnt	4.02	0.054	0.14	0.50	0.86
Natural fallow burned	8.68	0.031	0.24	0.36	0.62

Table 99: Soil chemical properties (before chemical fertilizer application) as affected by cropping system at Amanten

Cropping System	Avail P (mg/kg)	% total N	K (cmol/kg)	% org carbon	% org matter
Mucuna	6.34	0.078	0.19	0.58	0.75
Natural fallow no burn	7.29	0.056	0.21	0.32	0.64
Natural fallow burn	8.12	0. 043	0.47	0.29	0.41

Table 100: Weed incidence and plant population of yam as affected by crop management system.

		Amanten		Ejura	
Crop management	Weed dry wt g/m^2	Weed score	No. of Vines/ha	Weed score	No. of vines/ha
Mucuna no fertilizer	22.8	2.0	7000	2.0	8000
Mucuna + fertilizer	11.7	1.0	5000	2.5	8000
Natural fallow + fertilizer	105.5	3.0	6333	4.0	7000
Natural fallow no fertilizer	93.1	3.5	6667	3.5	8333
Natural fallow burn no fertilizer	123.5	4.0	1000	4.5	7667
LSD (0.05)	24.8	0.5	3220	1.0	NS
CV%	19.6	14.2	24.6	13.7	16.7

Table 101: Yam yield as affected by crop management system at Amanten and Ejura (2015).

Crop management	No. of tubers/ha		Tuber weight (kg/ha)	
	Amanten	Ejura	Amanten	Ejura
Mucuna no fertilizer	16667	15000	19266	22050
Mucuna + fertilizer	17657	18500	22739	22150
Natural fallow + fertilizer	18333	20000	21067	22350
Natural fallow no fertilizer	15565	14500	17454	18200
Natural fallow burn (control)	13300	11000	10400	9600
LSD (0.05)	NS	1800	6170	7406
CV%	22.5	21.4	24.7	27.6

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Effects of compost mounds from groundnut residues on yield of sweetpotato

Research Team: P. Osei-Bonsu, G. Bolfrey-Arku and K. Asubonteng* (*CSIR-SRI)

Collaborating Institutions: MoFA and CSIR-SRI.

Source of funding: WAAPP

Objective

- To determine the effects of compost mounds made from groundnut residues on sweetpotato yield.

Introduction

Sweetpotato is a minor crop in many farming communities in Ghana. Farmers depend on natural fallow to grow the crop which is not sustainable. Farmers in Papua New Guinea have for centuries used compost mounds to maintain soil fertility and sustain sweetpotato yields. Compost mound is a mound with a quantity of dry weed residues incorporated. Boueke (1991) reviewed 20 agronomic trials and found that in all the trials compost mounds improved sweetpotato yield relative to non-composted mounding. Leng (1982) also concluded that compost mounds had positive effect on sweetpotato yield and served to control major pests and diseases. Preston (1990) investigated the use of compost mounds and fertilizer and found that compost mounds increased yield by 2.6 t/ha in the absence of potassium fertilizer (KCl) and 6.4 t/ha in its presence. The integration of grain legumes into the cropping system of sweetpotato could improve soil fertility and diversify the source of income and nutrition of farmers. This study investigated the effect of incorporating groundnut residues in mounds on the yield of sweetpotato.

Materials and methods

Researcher-managed trials were established at Ejura and Amantin in the major season 2015. The experimental design was RCB with 3 replications per site and the treatments are shown in Table 102.

Table 102: Treatments of Researcher-managed trials established at Ejura and Amantin. Major season 2015.

Treatments	Major season	Minor season
T1	Sole maize	Mounds without plant residue, no fertilizer (Maize 1)
T2	Sole maize	Mounds without plant residue plus fertilizer (Maize 2)
T3	Groundnut	Mounds with groundnut residue no fertilizer (Groundnut 1)
T4	Groundnut	Mounds with groundnut residue plus fertilizer (Groundnut 2)

Plot size was 4 rows, 5 m long. Maize was planted at 80 cm x 40 cm; groundnut was spaced 60 cm x 20cm. In the minor season (mid-July) mounds were made on all the plots after removing the existing residues. Spacing of mounds was 100 cm x 100 cm; 4 rows, 5 meters long. After making the mounds, 250 g of dry groundnut residues were incorporated in each of the mound on the groundnut plots. Three vines of sweetpotato were planted on each mound. Chemical fertilizer (NPK 15:15:15) was applied at a rate of 500 kg per hectare.

Results and Discussion

At Ejura mean plant stand was 5.2 plants/m^2 and grain yield of maize was 1.85 t/ha in the major season. At Amanten, the values were 4.8 plants/m^2 and 1.63 t/ha respectively. Groundnut nodulation score was 3.5 at Ejura and 2.0 at Amanten (on a scale where 1 = no nodulation and 5 = profuse nodulation). The poor nodulation might be due to the fact that the experimental plots had not been cropped with groundnut in the recent past. Mean grain yields of groundnut at Amanten and Ejura were 1.08 t/ha and 1.72 t/ha respectively; while stove yields were 2.04 t/ha and 1.98 t/ha respectively. Weed incidence was very low (score of 2.0 - 2.5) on the groundnut plots.
This could be due to the fact that some of the weeds on the groundnut plots were uprooted during harvesting of the legume. The number of tubers harvested at Amanten ranged from 69,250 to 80,000 tubers per hectare; the values at Ejura were 77250 to 90,000 (Table 103).
The lowest tuber yield at both locations came from the control plot without chemical fertilizer (ie.6137 kg/ha at Amanten and 6331 kg/ha at Ejura) (Plate 26). At both locations, sweetpotato planted after groundnut generally yielded higher than those planted after maize.

 

Plate 26: Sweetpotato harvested from compost mounds plus fertilizer (left); without fertilizer (right)

Table 103: Weed incidence, plant population and yield of sweet potato as affected by compost mound and fertilizer, at Amanten and Ejura 2015.

Soil management	Weed score at land preparation		Total no of tubers/ha		Total wt of tubers (kg/ha)	
	Amanten	Ejura	Amanten	Ejura	Amanten	Ejura
Maize with no fertilizer	4.5	4.0	69250	77625	6,137	6331
Maize + fertilizer	4.5	4.5	70412	78375	10,200	7538
Groundnut 1 (No fertilizer)	2.0	2.5	80,000	90,000	11,178	7500
Groundnut 2. (Plus fertilizer)	2.5	2.5	74000	77250	11775	7838
CV%	19.3	17.7	31.8	34.0	27.6	29.0
LSD (0.05)	1.5	2.0	NS	NS	1,582	978

Way forward

The trials will be repeated in 2016.

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Verification trials on jab planting of Okro

Research Team: P. Osei Bonsu, G. Bolfrey-Arku, I.O. Ansah and R. Owusu Bio* (*KTI).

Collaborating Institutions: KTI and MOFA

Source of funding: TDTC and WAAPP

Introduction

Migration of the youth to the urban centres in search of non-existent jobs has created severe labour shortages in the farming communities in Ghana. This is worsened by the fact that farmers rely on crude implements to perform critical field operations. One of such operations is planting which is done using hoes, cutlasses or dibbling sticks (Adjei et al., 2003). Planting with these implements is time consuming, tedious and back-breaking. In order to reduce the drudgery during planting, some farmers broadcast seeds of maize and cowpea. Almost invariably broadcasting results in non-uniform plant spacing in the field. Significant yield reductions due to non-uniform plant spacing have been reported in several crop species such as sunflower (Wade, 1990), maize (Pommel and Bonhomme, 1998) and sorghum (Larson and Vanderlip 1994). One strategy that could be exploited to reduce drudgery in planting is the promotion of tractor-drawn seeders through agricultural mechanization service delivery. Another strategy that could alleviate drudgery in planting is the use of efficient hand held tools such as jab planters.

Objective

- To determine the suitability of planting okro with jab planters.

Materials and Methods

On farm experiments were set up at two sites at Woraso in the major season of 2015. The experimental design was RCB with two replications per site and the treatments were:

- Cutlass planting
- Planting with China-made jab planter
- Planting with locally made jab planter

Plot size was 6 rows x 20 m long. Okro was planted at a spacing of 60 cm x 20 cm and the target seeding rate was 3 seeds per hill.

Results and Discussion

It took the least time to plant with the Chinese planter whilst cutlass planting took the longest time (Table 107). It must be noted that different people plant at different speeds with cutlass. In this study, planting was done by the collaborating farmers, and they were careful in planting. Cutlass planting resulted in higher number of okro hills per hectare (76,800) than jab planting but there was no significant difference in okro hills between the two jab planters (Table 104). Planting with the local jab planter resulted in more hills with one plant than cutlass planting while cutlass planting had more hills with two or three plants. The target plant population was 166,667 plants/ha. The achieved population was lowest for the Chinese planter (93,000 plants/ha) and the highest was with cutlass planting (136,800 plants/ha). The lowest okro yield resulted from planting with the Chinese planter and the highest yield was from cutlass planting. However yields between cutlass and the local planter were not significantly different (Table 104).

Table 104: Okro plant establishment and yield as affected by planting device

Planting device	Planting time (hrs/ha)	No of hills/ha	1 plt per hill/ha	2 plts per hill/ha	3 plts per hill/ha	Plant pop/ha	Okro yield (kg/ha)
Chinese planter	11.43	60,000	35,400	19,800.	6,000	93,000	2,711
Local planter	13.28	63,000	38,400	15,600	10,200	100,200	3,120
Cutlass	28.29	76,800	28,200	33,600	13,800.	136,800	3,413
CV%	12.9	15.7	20.1	21.8	19.8	13.4	17.4
LSD (0.05)	12.34	13329	9715	15975	12666	26824	541

Plate 27: Farmers planting with locally fabricated jab planters (painted red) and cutlasses during training and demonstration at Adidwan.

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The agronomic and economic potentials of different rubber-plantain intercropping systems in Western Ghana.

Research Team: T. E. Narteh, J. N. Berchie, K. Agyemang, P.P. Acheampong, V. Logah and J Osei Adu

Collaborating Institution: GREL

Source of funding: GREL

Main Objective

- To assess the agronomic and economic potentials of different densities of rubber/plantain intercrops for smallholder farmers in the Western Region Ghana.

Specific Objectives

- Identify different rubber farming systems and outgrower schemes practised by farmers and their livelihood implications in the major rubber growing areas in the Western and Central regions of Ghana.
- Determine the optimum planting density of plantain when grown in combination with immature (up to 2 ½ years) rubber trees.
- Estimate economic returns for the different rubber-plantain intercropping systems.

- Evaluate the effect of different rubber-plantain intercropping systems on soil fertility and yield of plantain.

Methodology

- **Sociological Survey** (To identify different rubber intercropping systems practised by farmers in the major rubber growing areas in the Western region).

  Participatory Rural Appraisal (PRA) is being used to collect initial data to aid the selection of communities to be interviewed. This will also provide inputs for developing methodology and survey instruments for the formal survey. Data collected will be analyzed using descriptive statistics and graphs. A prepared questionnaire will be administered and economic analysis will be done to determine the most efficient and economically viable plantain intercropping system.

- **Field Experiment** (To determine the optimum planting density of plantain when grown in combination with immature (up to 2 ½ years) rubber trees.

  Experiments were conducted, on-station (at Aiyinasi), and on-farm at Tikobo No. 2 at Ehiamadwen, to serve as a model for education and dissemination of efficient and profitable rubber/plantain intercropping system for improved revenue generation and enhanced food security for rubber farmers. The experimental design was RCB with three replications. The field was prepared by brushing of undergrowth to the height of 15cm. Trees were felled and the debris were burnt. Construction of channels were constructed to drain excess water where necessary. Soil samples were collected for analysis at CSIR-SRI.

  The treatments were: sole rubber crop (R), sole plantain crop (P) and three intercrops consisting of one (PR), two (PPR) and three (PPPR) rows of plantain to one row of rubber. The rubber clone being used is GT1 while the variety of plantain is false horn (*Apantu pa*). Planting densities of the sole crops and intercrops are presented as Table 105. The field size is 102m x102m for each experimental set-up.

Table 105. Treatments applied in Plantain / Rubber intercropping experiment

Cropping System	Sole Rubber (R)	Sole Plantain (P)	Intercrop I (PR)	Intercrop II (PPR)	Intercrop III (PPPR)
Planting densities (plants/ha)	R = 555	P = 1666	R = 555 P = 833	R = 555 P = 1666	R = 555 P = 2500

Results and Discussions

Results of the initial soil chemical analyses and the effect of the treatments on the soil properties are presented as Tables 106 - 108

Table 106: Initial chemical properties of the soil

Depth (cm)	Initial soil chemical properties												
	pH (1:1)	SOC (%)	N (%)	Exchangeable cation (cmol/kg)				Exc. Acidity (cmol/kg)	ECEC (cmol/kg)	TEB (cmol/kg)	Base Saturation (%)	Avai. P (ppm)
				Ca	Mg	K	Na					
0-15	4.45	1.21	0.11	2.14	1.34	0.085	0.065	1.38	5.00	3.62	72.06	4.31
15-30	4.05	0.54	0.05	1.47	1.21	0.055	0.045	1.60	4.38	2.78	63.32	1.64

Table 107: Initial particle size distribution and microbial biomass

Depth (cm)	Particle size distribution				Microbial biomass		
	Sand (%)	Clay (%)	Silt (%)	Texture	C (mg/kg)	N (mg/kg)	P (mg/kg)
0-15	79.11	13.92	6.97	Sandy loam	13.03	5.17	16.79
15-30	72.83	18.81	8.36	Sandy loam	9.06	4.14	9.37

Table 108: Impact of different planting densities of rubber/plantain on some soil chemical properties

Treatments	Depth (cm)	Avai. P (mg/kg)	Ca (cmol/kg)	K (cmol/kg)	Mg (cmol/kg)	Na (cmol/kg)	Exc. A (Al + H) (cmol/kg)	ECEC (cmol/kg)	% Base saturation	TEB (cmol/kg)
P	0-15	1.51 b	1.34 ab	0.18 ab	0.94 b	0.10 abc	0.68 a	3.22 b	78.94 a	2.55 a
R	0-15	1.69 b	0.94 c	0.17 ab	0.67 c	0.09 bc	0.95 a	2.81 bc	66.21 c	1.86 b
PR	0-15	1.78 b	1.21 bc	0.16 b	0.40 d	0.08 c	0.83 a	2.55 c	70.98 b	1.72 b
PPR	0-15	4.28 a	1.61 a	0.17 ab	1.16 a	0.13 ab	0.93 a	3.85 a	79.76 a	2.91 a
PPPR	0-15	4.06 a	1.21 bc	0.20 a	0.94 b	0.14 a	0.87 a	3.04 bc	66.37 c	1.78 b
CV (%)	-	28.9	13.20	10.90	9.20	22.50	18.90	8.70	2.00	12.40
P	15-30	3.08 b	1.07 a	0.14 a	0.43 b	0.07 a	1.05 a	2.41 abc	55.41 b	1.30 b
R	15-30	3.54 b	0.89 b	0.15 a	0.60 c	0.08 a	1.02 a	2.60 a	65.71 a	1.78 a
PR	15-30	0.14 a	0.74 c	0.09 b	0.43 b	0.07 a	0.83 a	2.05 c	58.92 ab	1.22 b
PPR	15-30	0.08 a	1.07 a	0.14 a	0.29 ab	0.09 a	0.97 a	2.56 ab	65.73 a	1.60 a
PPPR	15-30	0.10 a	0.80 bc	0.13 ab	0.26 a	0.07 a	0.96 a	2.18 bc	56.02 b	1.22 b
CV (%)	-	36.10	0.15	16.10	19.10	20.90	15.00	8.80	6.40	11.10

Plate 28: Plantain / rubber intercropping trial at Aiyinasi

Expected Output/Outcomes

- The optimum planting density for plantain when grown in combination with immature rubber trees would be determined
- The effects of planting density on seasonal light and water use efficiency of plantain and rubber would be determined.
- Recommendations on the most efficient and profitable rubber/plantain intercropping system would be made by the end of the second year.
- Farmers' income would increase due to the additional revenue to be obtained from intercropped plantain

Way Forward

Final sampling and analysis of soil from the on-station trial site will be carried out. Other agronomic data would also be collected. Soil samples from the on-farm trial at Tikobo No. 2 will be collected and analysed.

Out-Scaling of Best-Bet Agronomic Model for Sustainable Yam Production in Southern Ghana

Research Team: E. Owusu Danquah, S.A. Ennin, F. Frimpong and H. Asumadu* (* IITA)

Collaborating Institutions: MoFA

Source of funding: BMGF (thro' YIIFSWA)

Introduction

A major challenge to yam production is soil fertility regeneration and maintenance. Farmers address this constraint by clearing new land on yearly basis in search of fertile lands leading to deforestation and soil degradation (Akwaag *et al*., 2000; Ennin *et al*., 2014). This current yam production system where there is annual shifting of farm to new lands is not sustainable and therefore there is urgent need to disseminate an environmentally-sound yam production technology that increases yield and sustains production on continuously cropped fields. As a follow up of work done in 2014, the best-bet agronomic model of planting treated seed yams on ridges with fertilizer rate of 30:30:36 N: P_20_5:K_20 kg/ha plus 15 kg/ha Magnesium (Mg) and 20 kg/ha Sulphur (S) as $MgSO_4$ and trellis staking were verified/demonstrated by comparing it with the farmers' practice on 30 farmers' fields in the Ejura, Atebubu and Kintampo yam growing communities. The use of ridges and treated seed yam helps to maintain an optimum number of stands per unit area; fertilizer application addresses the soil nutrient deficiencies, while the trellis staking (which uses ropes and fewer stakes) addresses the challenge of cutting more trees/bamboo for staking. The study, through participatory approach, demonstrated to farmers that yam production can be sustained on continuously cropped fields.

Objective

- To demonstrate and scale out yam production technologies with improved and local popular varieties.

Specific objective

- To verify/demonstrate improved agronomic packages (from previous year's evaluation) for sustainable yam production on continuously cropped fields by comparing with farmers' practice.

Materials and Methods

Farmer participatory verification/demonstration trials were conducted on continuously cropped farmers' fields, which would usually not be used for yam production by farmers. The experimental design was RCB. The models were farmers' practices, on one plot, and improved agronomic practices (IAP) on another plot. Ridges, seed yam treatment, trellis staking and fertilizer application at a rate of 30:30:36 N: P_20_5:K_20 kg/ha plus 15 kg/ha Mg and 20 kg/ha S as $MgSO_4$ were used on the improved agronomic practices plot while the farmers' practices plot had mounds, no fertilizer and optimum staking of about two stands/plants to a stake. The two plots lay adjacent one another. The demonstrations were set up on 30 farmers' fields made up of 10 each from three districts - (Atebubu-Amantin district (covering communities in Bolga-Nkwanta, Nyomoase and Densi), Ejura- Sekyeredumasi district (covering Hiawoanwu, Aframso, Asomen and Kabrikura) and Kintampo district (covering Apesika, Babaso, Abenaanum and Ampoma). Each farmer's field was considered as a replicate, with an area of a quarter of an acre (0.25ac). Seed yams (vars *Dente* and *Serwaa*) were planted at 1.2m inter row and 0.8m within rows. Planting was done in June/July 2015 in the various communites. The fertilizer treatment was applied in 50% split dose at 5-6 weeks and 11-12 weeks after planting at all the locations. The seed yams /setts planted on the IAP fields were treated with Dursban (Chlorpyrifos from Dow Agro Sciences; 1.25 l/ha) and Mancozeb (Dithiocarbamate from Ag-Chem Africa 80%; 75 g in 15 l of water) before planting. Emerging weeds were controlled with glyphosate (2.5 liter per ha) before the yams sprouted. Five farmer field days were organized in each of the three districts, during the growth (vegetative) stage, with a total of 683 participants made up of adult males, adult females and the youth. Five more farmer field days were also organized in each of the three districts during harvesting for tuber yield evaluation with the farmers. Attendance was 790 also made up of adult males, adult females and the youth Table 109). Harvesting was completed at all locations between Dec, 2015 and Jan, 2016. Data were compiled for each district and analyzed using SAS 2007 version. The results from the farmer evaluations are yet to be analysed.

Location	Date	Number of participants				Total
		Females (elderly)	Females (youth)	Males (elderly)	Males (youth)	
Kintampo	Oct: 1-2, 2015 and Jan. 5-10, 2016	160	60	206	88	514
Ejura	Oct. 8-9 and Dec. 12 - 18, 2015	116	97	181	78	472
Atebubu	Oct.24,25 and Dec. 20-23 & 26-29, 2015	117	82	192	96	487
Grand total of participants						1473

Table 109: Participants at two farmer field days during vegetative and yield evaluation stages of demonstration plots in Ejura, Atebubu and Kintampo farming communities

Results and Discussion

Generally the IAP fields produced significantly ($p \geq 0.05$) higher tuber yields, compared to the farmers' practice fields, at all the locations (Figures 34-36). The use of improved agronomic package (ridges, seed yam treatment, trellis staking and fertilizer application resulted in 192%, 187% and 178% tuber yield increases over the farmer practice fields in the Ejura, Atebubu and Kintampo farming communities respectively. Plant stand establishment on the ridges were significantly ($p \geq 0.05$) higher on the IAP fields than farmers' practice fields for all the locations (Fig. 34-36). This could be attributed to the use of ridges which made it possible to plant at 1.2m between ridges and 0.8m on the ridges resulting in a planting density of 10,416 stands per hectare while the mounds on the farmers' practice fields were more widely spaced (1.5m - 2m apart) resulting in just about 3,400 stands per hectare. Thus ridges would support the optimum number of plants for efficient use of fertilizer than the mounds.

A study by Ennin *et al*., 2014, gave similar tuber yields on fertilized mounds and unfertilized ridges suggesting that fertilizer application would be more profitable on ridges than on mounds. Also the seed treatment before planting on the IAP fields might have reduced rottening of the seed yams and increased sprouting rate than those on the farmers' practice fields which were not treated. There were more ware yams than seed yam (in terms of weight) at all locations for the IAP fields and the farmer practice fields (Figs. 34-36). The tuber sizes (weight per tuber) of the ware yams obtained (1.27 – 1.80 kg) fitted into two size categories of the export market ie 1.0kg – 1.5kg for small, and 1.6kg – 3.5kg for medium (Ghana Standard Board, 2011). The similarities in the tuber sizes obtained might be attributed to the use of similar local yam varieties (*Serwaa* and *Dente*) which were used by the farmers at all the three locations.

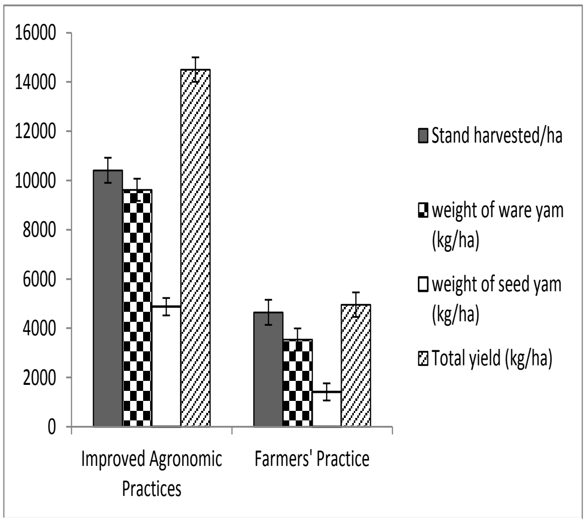

Figure 36. Yam tuber yields as influenced by improved agronomic package and farmers' practice in the Ejura farming communities (2015)

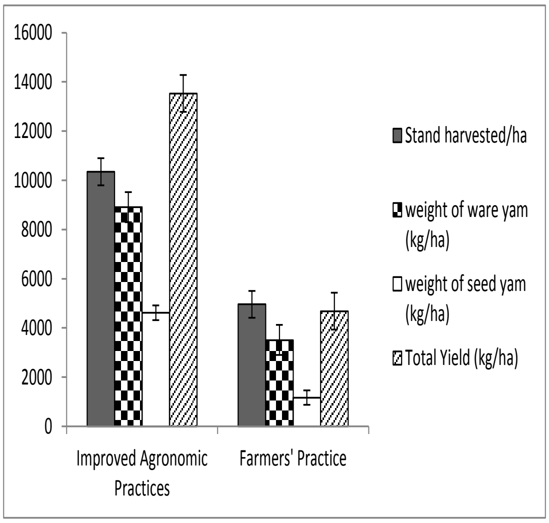

Figure 37. Yam tuber yields as influenced by improved agronomic package and farmers' practice in the Atebubu

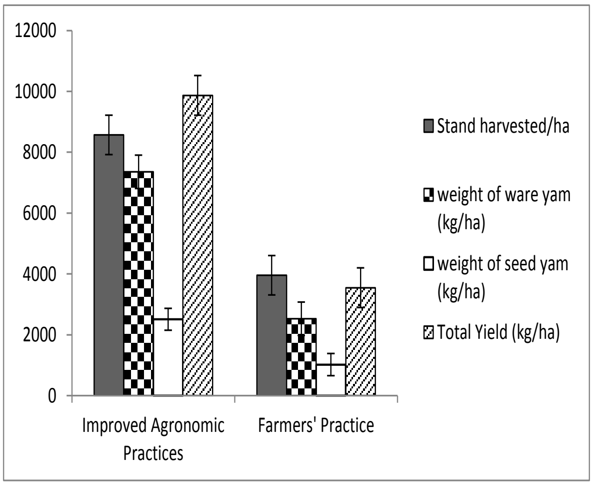

Figure 38. Yam tuber yields as influenced by improved agronomic package and farmers' practice in the Kintampo farming communities (2015)

Plate 29. Seed yam (left) and ware yam (right) harvested from farmers' practice field - Atebubu

Plate 30. Seed yam (left) and ware yam (right) harvested from improved agronomic practices field - Kintampo

Conclusion and Recommendation

Yam yields can be sustained on continuously cropped fields with improved agronomic package to address deforestation and land degradation associated with yam production. There is the need to continue the demonstration and up-scaling and involve more farming communities in the major yam growing area of Ghana.

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Verification of planting density and seed sett size of yam for export (on-station) (ii) demonstration/verification of improved agronomic technologies for sustainable yam production (on-farm)

Research Team: S. A. Ennin, E. Owusu Danquah, P. P. Acheampong and F. Frimpong

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

Ghana is the leading exporter of yams in the world. Tuber size and variety are key criteria for premium price on the export market. Premium price for *Pona* is obtained from a 20 kg box of yam with 10-12 tubers (of about 2kg each) and in some cases 14 tubers (of 1.4 – 1.7kg each). A 25 kg box of other white yam varieties would contain 14 -16 tubers (1.6 - 1.8 kg/tuber), mostly within the medium class. The current exportable white yam varieties are *Araba, Asana, Pona (Kpene)* (Ghana Standards Board, 2011. Roots and Tubers –Specification for fresh yams Ref No. GS 150:2011 2nd Edition). Plant population density and seed/ sett size are agronomic options for achieving different tuber sizes. This study is a verification trial evaluating the effect of seed set sizes and planting density on tuber sizes and yield performance of yam.

Objectives

- To verify the use of planting density and sett sizes to produce tuber sizes and shapes to meet the demands of the yam export market.
- Demonstrate/verify improved agronomic practices for sustainable yam production.

Specific objectives

- To evaluate the effect of planting density and sett size on the growth, yield and tuber sizes of *Dente* and *Pona* (popular and premium white yam varieties in Ghana)
- To evaluate the effect of seedbed option and fertilizer levels on the growth and yield of yam on a continuously cropped farmers' field.
- To evaluate the effect of seedbed and staking options on the performance of yam on newly-cleared farmers' field

Materials and Methods

- **Yam Variety, Sett sizes and planting density study**

  A split-split plot design experiment in three replicates was set up at Fumesua and Ejura, with yam varieties *Dente* and *Pona* as main plot, sett sizes (farmers' sett size – 350g, half farmers' size – 175g and mini-sett – 50g) as subplot and planting density (1.2m x 1.2m; 1m x1.2m; 0.8m x 1.2m; 0.6m x 1.2m; 0.4m x 1.2m) as sub-subplot. Planting was done at Fumesua in April and at Ejura in May, 2015. Harvesting was done in December, 2015 at both locations.

- **Participatory demonstration of ridging, fertilization and minimum staking options**

  This was a farmer-managed demonstration on a continuously cropped farmers' field, which would normally not be used for yam production by farmers. The experimental design was RCB. The factors were farmers' practices and recommended practices. Ridges, trellis staking and fertilizer (45-45-60 $kgha^{-1}$ N – P_2O_5-K_2O) were used as the recommended practices on one plot while another plot was established on which farmers practised their traditional way of yam production. Six farmers, from yam producing communities in the Atebubu-Amantin and Ejura-Sekyeredumasi districts were involved, with each farmer as a replicate. Yam varieties *Dente* and *Serwaa* were used. Planting was done in June/July, 2015. The fertilizer treatment was applied in 50% split dose at 5 and 12 weeks after planting. Soil samples were collected (at 0 and 30cm depth) from the plots, at planting and at harvest, for analysis, data were also collected on stand establishment, rate of sprouting, shoot (leaves and vines) fresh and dry weight, tuber yield components and tuber shape. Harvesting was completed for all the trials in the communities in December, 2015.

Results and Discussion

There were no significant interaction between the variety, sett size and planting density and all the two way factors for both locations. However, significant differences in tuber size (weight per tuber) and yields were observed for the planting density and seed sett sizes at all the locations (Figs 37 and 38). Tuber yields increased as the planting density increased. Planting density of 20,833 plants/ha (1.2m x 0.4m) produced significantly ($P \geq 0.05$) higher tuber yields of 33.4t/ha and 41.4t/ha at Fumesua and Ejura respectively. However, tuber sizes (weight per tuber) generally decreased as the planting density increased. High planting densities between 13,889 and 20,833 plants/ha produced tuber sizes ranging between 1.61kg and 2.03kg at both locations (Fig. 37). The lower planting densities between 6944 – 10417 plants/ha produced tuber sizes ranging between 2.02kg-2.71kg. Seed sett size also significantly ($P \geq 0.05$) influenced the tuber sizes and yield Fig. 38. Mini-sett of 50g produced a significantly lower average tuber size (weight per tuber) of 0.22kg, farmers' sett size of 350g and half farmers' size of 175g had similar and bigger average tuber sizes of 2.04kg and 2.02kg respectively. Mini-sett size of 50g seems to be good for seed production. Planting at 1.2m between ridges and 0.4m on the ridges would be suitable for yam production for the export and local market.

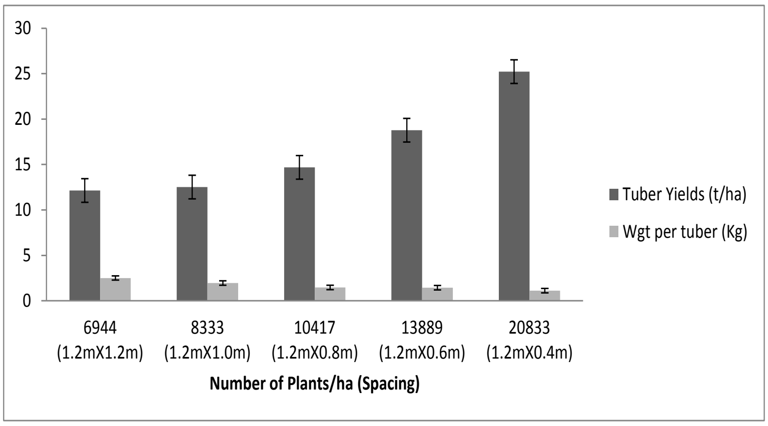

Fig. 39: Effect of planting density on tuber size and yield of yam at Fumesua and Ejura, 2015

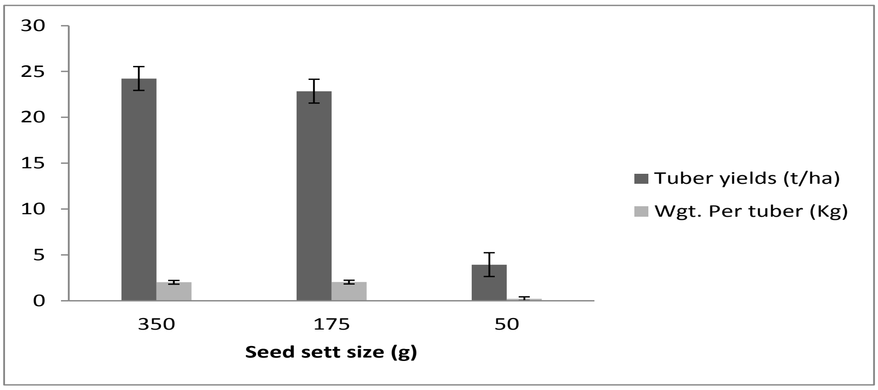

Fig. 40: Effect of seed sett size on tuber size and yield of yam at Fumesua and Ejura, 2015

Community Action in Improving Farmer-Saved Seed Yam (Cay-Seed)

Research Team: A. S. Osuman, S.A. Ennin, K. Osei, J.N. Lamptey, M. Akom, E. Owusu-Danquah, J. A. Sackey and S. Obeng – Antwi

Collaborating Institutions: CRS, IITA, MSHR/DDS, ISSER

Source of funding: Bill and Melinda Gates Foundation

Introduction

Yield of yam in the major producing countries of West Africa (Ghana and Nigeria) is low, (6.6 - 15.6 t/ha) compared to the potential of 22 t/ha (YIIFSWA 2011). Poor seed yam quality has been identified as a major contributor to the observed yield gap. Seed quality is poor because farmers have no access to clean seed to replace their degenerated stock, hence they keep planting the same materials in poorly maintained soils. Viruses and nematodes are biotic factors that contribute to for yield reduction.

The CAY-Seed project is aimed at improving the quality of farmer-saved seed yam to increase the productivity of small holder farmers at the community level, through positive selection and integrated pest and disease management as well as soil improvement for increased food security and poverty reduction in Ghana and Nigeria. This pilot phase of this project is being carried out in four major yam growing communities each in Ghana (Ejura/Sekyeredumase and Atebubu /Amantin districts) and Nigeria (Bwari and Kwali Area Councils).

Component 1: Quality Seed Yam Production and Agronomic Technologies for Improved Seed Yam Productivity

Positive selection

Thirty farmers were selected and registered from two communities each in Ejura Municipal (Nyinasei and Bisiw No.2) and Atebubu district (Abour and Mem). Female farmers who had participated in a YIIFSWA training programme in the previous years were brought on board bringing the total to 120 farmers. Farmers' plots for the positive selection exercise were identified and demarcated. A quarter of an acre was identified in each of the four "positively selected" communities. Demonstrations of the minisett technology were set up in the communities to be managed by the farmers and supervised by research scientists of CSIR-CRI and field staff of the CRS.

Tagging of plants (Positive Selection)

In July 2015 the team visited fields in the Ejura Sekyeredumasi communities to identify and tag symptomless mother plants and plants with symptoms. Plants that showed no sign (score 1) of viral and anthracnose diseases were tagged with blue ribbon whilst plants that showed mild infection (score 2) were tagged with red ribbon (Figs 1 and 2). Retagging became necessary when it was later observed that some of the plants that were initially tagged with blue ribbon showed symptoms of mild infection. The exercise was repeated in October, 2015 on a total of 60 farms. Plants that have moved from mildly infected to highly infected were untagged

Conclusion and Recommendation

There is a high level of viral and fungal disease infections on all the farms visited and therefore the siting of this project in this yam farming area is of importance to the yam industry in Ghana. There is the need to out-scale this project to other parts of the yam producing area. The incidence of virus infection was very high on *D. rotundata* compared to *D. alata.*

It is recommend that:

- farmers should be encouraged to keep their fields free of weeds to reduce the virus infection and also make their farms accessible.
- field staff on the project must be provided with protective clothing for field work.

On-farm demonstration of improved maize varieties/hybrids and complementary crop management options.

Research Team: K. Agyeman, K. Obeng Antwi, M.L. Tengan, J.N. Berchie, A. Agyeman, R. N. Issaka* (*CSIR-CRI)

Collaborating Institutions: MoFA and CSIR-SRI

Source of funding: IITA (SARD-SC)

Introduction

Low productivity of maize (average yields of 1.3t/ha) is hindering food security in sub-Sahara Africa. Plant density is one of the most important cultural practices determining grain yield, as well as other important agronomic attributes of this crop. Stand density affects plant architecture, alters growth and developmental patterns and influences carbohydrate production and partition (Casal, 1985). Maize is more sensitive to variations in plant density than other members of the grass family (Almeida & Sangoi, 1996). Higher plant density beyond the optimum level, results in severe competition among plants for light and nutrients, consequently the plant growth slows down and the grain yield decreases. The yield potential of maize can be realized only when it is grown with adequate fertilization and optimum plant population (Singh and Singh, 2006). Maize yield differs significantly under varying plant density levels due to difference in genetic potential (Liu et al., 2004). However, information on optimal plant populations and its corresponding optimum nutrient resource is lacking for different maturity groups of maize in Ghana. Therefore, the present investigation was formulated to optimize the planting density of the different maturity groups of maize under different nutrient resource availability in the forest and transition zones of Ghana.

Objective

- To study the effect of different plant densities and various nitrogen fertilizer levels on yield and yield components of three maize varieties.

Materials and Methods

The study was carried out in four districts - Mampong municipal, Sekyere Central (Forest agro-ecology), Nkoranza South and Kintampo North (Transition agro-ecology). These areas have a bimodal rainfall pattern; the major rainy season is from April to July and the minor season is from September to November. Maize varieties used were Abontem, Omankwa and Farmers' variety. The treatments were three levels of plant density (as the main plots) and three levels of Nitrogen (as sub-plots). These were randomly arranged in split plot in RCB design with three replications.

The density levels were:

1. DDM2R: Double density maize (two rows on a ridge one plant per stand, at 75 x 25cm with triangular stand display)
2. DD2M1R: Double density maize (one row, two plants per stand at 75 x 25 cm)
3. NDM1R: Normal density maize (one row, one plant per stand at 75 x 25 cm)

The nitrogen levels (sub plots) were:

1. Recommended rate (100:50:50)
2. Double of recommended rate (200:100;100)
3. Recommended rate plus half (150:75:75)

The plot size was 4.5 x 5 m^2 (3 x 3.5) with six ridges measuring 5m in length and 75 cm in width. At full maturity, five guarded maize plants were randomly selected from each sub-plot to record plant height (cm), ear length (cm), days to 50% silking, days to 50% tasseling and grain yield. Data collected were analysed by analysis of variance (ANOVA) using the Genstat Discovery 4th Edition.

Results and Discussion

Results showed that yield of the three varieties increased with the row arrangements that increased plant density and resource availability (Table 110). Abontem produced the highest grain yields, at Nkoranza (6084 kg/ha) and Kintampo (4738 kg/ha), when planted at density DDMR2 and Nitrogen level 2. Increasing nitrogen fertilizer level led to increases in yield in most cases. The highest grain yield, from all three varieties, were obtained by use of 200 kg/ha. The row arrangements produced variation in response to fertilizer levels and location.
In this study, enhanced plant-to-plant variability resulted from increased competition among individual plants at progressively higher plant densities for limiting resources such as N and soil moisture. As has been documented, stand uniformity is essential for high productivity levels, therefore, increased plant-to-plant variability reduces per-unit-area maize grain yields through reduced stress tolerance. Therefore, at higher plant populations, resource must be available adequately to help maintain uniform growth, development, and grain yield of adjacent plants in a maize canopy.

Conclusion

The results of this study have shown that varieties respond differently to increasing density for better growth and yield. Different maize varieties have different plant architecture and root development and hence affect the competitiveness of the crop for nutrient and sunlight interception.

Table 110: Interaction between fertilizer rates and plant density with respect to grain yield (kg/ha) at Kintampo and Nkoranza

	Kintampo			**Nkoranza**		
Treatments	Abontem	Omankwa	Farmer Variety	Abontem	Omankwa	Farmer Variety
DDM2R + 100kgN/ha	2364	2907	2422	3617	3937	3768
DDM2R + 150kgN/ha	2813	2409	3342	4160	3528	4688
DDM2R + 200kgN/ha	4738	3489	3498	6084	4835	4844
DD2M1R + 100kgN/ha	2924	2609	1987	4088	3955	2800
DD2M1R + 150kgN/ha	3204	2884	1813	4551	4231	2631
DD2M1R + 200kgN/ha	3511	2982	2347	4857	4328	3555
NDM1R+ 100kgN/ha	1742	2702	1733	2951	4048	2853
NDM1R+ 150kgN/ha	2067	2804	1627	3008	4151	2880
NDM1R+ 200kgN/ha	2440	2964	2582	3786	4311	3746
CV	23.5			27.3		
SED	738.5			876.4		
Mean	2700			3933		

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On-farm testing of drought tolerant maize (DTMA) varieties and hybrids in the Brong Ahafo region.

Research Team: K. Agyeman, K. Obeng Antwi, M.L. Tengan, J.N. Berchie, A. Agyeman, R. N. Issaka* (*CSIR-CRI)

Collaborating Institutions: MoFA and CSIR-SRI

Source of funding: BMGF through IITA

Introduction

On-farm trials were conducted in two districts to test whether introduced maize varieties identified on research stations perform better than farmers' varieties on farmers' fields. The on-farm trials were to test the hypothesis that the varieties can produce yields above local maize varieties on farmers` field with no extra inputs, or changes to agronomy.

Objectives

- To involve farmers in evaluating and selecting drought tolerant maize varieties and hybrids by the use of mother-baby model approach to on-farm research.
- To provide information to support the Maize Breeding Programme on the suitability of the varieties/hybrids for release to farmers.

Materials and Methods

The Mother and Baby trial approach was adopted to evaluate promising maize varieties and hybrids using RCBD. The Mother trial plot measured 4.5m x 5m long with three replications. The Baby trial plot measured 20m x 20m. Each farmer served as a replicate with the Baby trials. Varieties were ramdomly assigned to experimental units. Eight farming communities in the Techiman and Wenchi districts were involved in the study. The study involved eight farming communities in the Techiman and Wenchi districts. Seven intermediate-maturing maize varieties (M0926-2, M1026-10, M1026-7, M1124-10, M1124-7, M1126-5 and M1227-12) and seven early-maturing maize varieties (DTE-WSYR SYNCI x ENT12, ENT 11 x TZEI-4, TZEI 3 POP STRC 4 x TZEI 17, TZEI 124 X TZEI-25, TZEI 60 x TXEI 86, TZEI-5 x TZEI-98 and TZEI-W-POP DYSYR 4 x TZEI 4) were used in the study. Data collected were analysed by analysis of variance (ANOVA) using the Genstat Discovery 4th Edition statistical package.

Results and Discussion

Mother trial

Grain yields of introduced intermediate varieties across the two locations ranged from 3,333kg/ha to 4,747 kg/ha for M1124-7 and M0926-2 respectively (Table 111). Data from the different locations showed high variability among varieties within some locations, probably due to genetic expressions of individual entries and soil variability expressed as yield. The introduced varieties performed better than the farmer variety. One promising variety (M0926-2) out yielded the farmer variety by 41%.

Table 111: Grain yield (kg/ha) and agronomic performance of intermediate maturing hybrids and farmer variety evaluated under "mother trial" in 2015

Treatment	Days to 50% silk			Days to 50% tassel			Grain yield (kg/ha)		
	Techiman	Wenchi	Across locations	Techiman	Wenchi	Across locations	Techiman	Wenchi	Across locations
Farmer variety	53	55	54	48	50	49	4004	2822	3371
M0926-2	57	53	55	47	48	48	5043	4450	4747
M1026-10	53	54	53	47	46	46	3659	4908	4283
M1026-7	58	55	56	46	49	48	5590	3365	4477
M1124-10	57	55	56	46	49	48	5115	3663	4389
M1124-7	52	53	52	45	46	46	3260	3406	3333
M1126-5	63	69	66	54	61	58	3921	5342	4673
M1227-12	53	54	53	47	49	48	4651	4234	4443
CV	10	2.1	5.4	5	3.4	3.4	25	25.9	20.7
SED	4.53	0.97	2.4	1.9	1.3	1.35	898.5	850.5	712.6
Mean	56	56	56	48	50	48	4405	4024	4215

Grain yields of the early-maturing varieties for the locations are presented as Table 112. Grain yields across the two locations were moderate ranging from 2190kg/ha (by ENT 11 x TZE1 4) to 3398 kg/ha (by TZE1 3 POP STRC 4 x TZEI 17) with a grand mean of 2780 kg/ha. The best performing variety outyielded the farmer variety by 20% under the same growing conditions.

Table 112: Grain yield (kg/ha) and agronomic performance of Early maturing Hybrid and farmer variety evaluated under "mother trial" in 2015

Varieties	Days to 50% Silk			Days to 50% Tassel			Grain yield (kg/ha)		
	Techiman	Wenchi	Across locations	Techiman	Wenchi	Across locations	Techiman	Wenchi	Across locations
DTE-WSYRSYNCIX ENT12	54	52	53	48	48	48	3641	2075	2858
ENT 11 X TZEI-4	57	54	55	50	50	50	2167	2213	2190
Farmers Variety	66	63	64	60	58	59	2667	2982	2825
TZEI 3 POP STRC 4 X TZEI 17	56	50	53	50	47	49	4345	2430	3398
TZEI 124 X TZEI-25	55	51	52	50	49	48	4109	2451	3270
TZEI 60 X TXEI 86	55	52	53	50	48	49	3398	1916	2657
TZEI-5XTZEI-98	53	61	53	48	49	49	3175	2112	2644
TZEI-W-POP DYSYR 4 X TZEI 4	56	52	54	51	49	50	3110	1686	2398
CV	2.1	3.6	2.1	1.5	2.2	1.4	23.4	14.4	14.2
SED	0.98	1.5	0.95	0.6	0.9	0.6	635.5	263.2	322.3
Mean	56	53	55	51	50	51	3327	2233	2780

Baby Trial

Two each of the early and medium maturing maize varieties were compared with farmers' variety. Data on the agronomic performance of the hybrids evaluated in the two districts are presented as Tables 113 and 114. For all the measured traits (days to silking and days to tasseling), significant ($p<0.05$) differences were observed among the various entries. Data from the different locations showed high variability among the varieties within some locations, probably due to genetic expressions of individual entries and soil variability expressed as yield. Data on grain yield are presented in Table 113 and 114. Across the locations grain yield ranged from 2687 kg/ha (Farmer variety) to 3222 kg/ha (M1124-10) among the intermediate- maturing hybrids, with a grand mean of 3001 kg/ha.

Table 113: Grain yield (kg/ha) and agronomic performance of Intermediate maturing Hybrid and farmer variety evaluated under "baby trial' in 2015

	Days to 50% Silk			Days to 50% Tassel			Grain yield (kg/ha)		
Varieties	Techiman	Wenchi	Across locations	Techiman	Wenchi	Across locations	Techiman	Wenchi	Across locations
Farmer Variety	64	57	60.6	58	53	55	2687	2687	2687
M0926-2	55	63	59	50	58	54	4417	1773	3095
M1124-10	56	55	55	50	50	50	3422	3121	3222
CV	1.3	0.9	1	1	1.2	1	2.3	2.4	2
SED	0.6	0.4	0.5	0.4	0.5	0.4	64.8	48.2	50.2
Mean	58	58	58	53	54	54	3509	2494	3001

For the early-maturing group, grain yield across the locations, ranged from 3588 kg/ha (Farmer variety) to 5011 kg/ha (DTE-WSYR SYNCI x ENT12) with a grand mean of 4166 kg/ha. DTE-WSYR SYNCI x ENT 12 out-yielded the farmer variety by 40%.

Table 114: Grain yield (kg/ha) and agronomic performance of early-maturing hybrid and farmer variety evaluated under "baby trial' in 2015

	Days to 50% Silk			Days to 50% Tassel			Grain yield (kg/ha)		
VARIETIES	Techiman	Wenchi	Across locations	Techiman	Wenchi	Across locations	Techiman	Wenchi	Across locations
DTE-WSYR SYNCI x NT12	60	53	53	55	49	47	2361	5620	5011
Farmer variety	67	63	65	63	58	59	2153	3722	3588
TZEI-5 x TZEI-98	50	52	52	45	49	48	3540	5672	3900
CV	1.6	1.2	0.6	0.8	0.6	0.9	3.4	4.3	3.3
SED	0.8	0.5	0.3	1.1	0.3	0.4	74.2	177.3	111.1
Mean	59	56	56	54	52	52	2684	5009	4166

Conclusion

Drought is the most important environmental agent which decreases growth and development of plants among all the environmental stresses (Aslam et al., 2006). It has been considered a serious yield limiting factor in developing countries (Ceccarelli and Grando, 1996). Ghana would rely on maize varieties which are drought tolerant and are able to provide good yields under drought.

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PLANT HEALTH

Managing nematode pests infestation in sweet potato production using different organic substances with potential nematicidal properties

Research Team: K. Osei, J. Adomako, A. Agyemang and Y. Danso

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

Plant-parasitic nematodes represent a significant problem in sweetpotato production, causing reduction in yield and quality of the storage roots (Cervantes-Flores, 2000). Infected storage roots crack easily and the cracks provide the avenue for penetration and establishment of many secondary pathogenic organisms affecting the quality of the storage roots. The application of synthetic chemicals though very effective is both capital intensive and environmentally unfriendly (Luc *et al.,* 2005). The identification and use of organic materials with nematicidal properties provides an alternative approach in managing plant parasitic nematodes (Sipes and Arakaki, 1997). The option would be cheaper, environmentally acceptable and readily available to the farmer.

Objective

- To determine the nematicidal potential of two organic materials (poultry manure and neem leaves) in managing nematode pests of sweetpotato in three agro ecologies of Ghana.

Materials and Methods

Field trials were conducted at Atebubu, Wenchi and Kintampo to evaluate the nematicidal potential of poultry manure and neem leaves powder applied as a pre-plant soil amendment on parasitic nematodes population on sweetpotato varieties - *Apomuden, Hi Starch, Okumkom, Santom pona* and *Sauti*. Poultry manure and neem leaves powder weighing 100g and 30g respectively were applied two weeks before planting. The trial was laid out in a RCBD with four replications. Pre-plant and harvest soil samples were collected to assess parasitic nematode situation before planting and at harvest. Galling, dry rot and cracks on sweetpotato tubers, nematode population density on tubers and yield were determined at harvest. The modified Baermann tray method was used in extraction of nematodes (Whitehead and Hemming, 1965).

Results and Discussion

The two organic materials; poultry manure and neem leaves have been identified as good candidates for the management of nematodes in sweet potato production. Results from the study across the three locations showed that poultry manure and neem leaves powder reduced nematode population significantly. It was established that, applying poultry manure and neem leaves at rates of 100g and 30g per plant respectively as a pre plant soil amendment was optimum for managing nematode pests at the various locations. Nematodes of economic importance identified at the various locations in order of abundance were *Meloidogyne* spp, *Pratylenchus* spp and *Helicotylenchus* spp. Compared to the untreated plots, poultry manure and neem leaves reduced the population of *Meloidogyne* spp by 80% and 76.2% respectively. Also by using poultry manure and neem leaves, *Pratylenchus* spp were reduced by 72.5% and 70% respectively. In effect, the final nematode populations recovered from the rhizosphere of sweetpotato planted on the amended soils across the locations were significantly reduced. More importantly, there was a yield increase of 15.0% when sweetpotato was planted on poultry manure amended soil compared to the non-amended soil.

Conclusion

The preliminary results indicated the potential of poultry manure and neem leaves in reducing nematode population when applied as a pre-plant soil amendment.

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Bio-control of plant parasitic nematodes in yam production using *Trichoderma* spp.

Research Team: K. Osei, A. Agyemang, J. Adomako and Y. Danso

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

Yams have both economic and social values in many growing areas (Opara, 2003). They are extremely important for at least 60 million people comprising rural producers, processors and consumers in West Africa and provide a multiple opportunity for poverty reduction and nourishment for poor people in the sub-region (IFAD, 2004). Yam production is highly affected by several biotic threats especially plant-parasitic nematodes. The economically important plant parasitic nematodes are the yam nematode (*Scutellonema bradys*), the root lesion nematode (*Pratylenchus coffeae*) and the root-knot nematode (*Meloidogyne incognita*) (Adegbite *et al.,* 2005). These parasitic nematodes cause characteristic physical malformations on tubers and actually reduce yields. The malformations render tubers unattractive which result in lower market value (Agbaje, *et al.,* 2003). The easy accessibility, reliable and quick action against target pests, continues to render synthetic chemical control the first choice of farmers (Sabir, 2013). However, the detrimental environmental effects associated with chemical control have spurred research into nematode control alternatives. Biological control of soil-borne plant pathogens and plant parasitic nematodes by antagonistic microorganisms is a potential non-chemical means of plant disease control. Several bacterial and fungal agents such as *Trichoderma* spp. have been used to reduce the population of root-knot nematodes. Apart from serving as nematode antagonistic organisms, their activities have also been reported to enhance plant growth and yield improvement.

Objective

- To evaluate the potential of indigenous *Trichoderma* spp. in managing the effect of root-knot nematodes in yam production

Materials and methods

Field trials, on plots each measuring 0.3 acre, were established at Kintampo, Atebubu and Wenchi during the 2015 planting season using three yam varieties (*Pona, Afebetua* and *Dente*). Planting was done on raised mounds at a planting distance of 1m x 1m after the field had been manually prepared and laid in a RCBD with five replications. *Trichoderma* spp. were isolated, cultured and identified from soils from each of the locations after developing protocols. *Trichoderma* spp. spore suspensions were prepared from pure cultures and applied at all locations 30 days after planting. Soil and tuber samples were collected to estimate reproduction levels of *Trichoderma*. Soils samples were collected before planting and at harvest from all locations and nematodes extracted from the samples using the Modified Baermann's tray method (Whitehead and Hemming, 1965).
Data collected at harvest included; number of tubers, weight of tubers, root-knot nematode gall index, tuber cracks and final nematode population extracted from the rhizosphere soil and 5g peels from harvested tubers.

Results and Discussion

Results from the pre-planting soil sampling, extraction and identification revealed that *Meloidogyne* spp., *Scutellonema bradys* and *Pratylenchus coffeae* were the most abundant and economic nematodes at all the locations. Plots inoculated with *Trichoderma* spp. had less mean galling rate and cracking tubers compared to the control plots. None of the indigenous *Trichoderma* strains used proved superior to the other. Also population build-up of the various nematode species recovered from 5g peels of tubers on the yam varieties were less compared to tubers from plots that were not inoculated with the bio agent. Observations from the fields indicated that virus incidence across the locations was minimal. However, Atebubu recorded more tubers with symptoms of soft rot compared to Kintampo and Wenchi. Atebubu also recorded the highest total number of tubers while Wenchi recorded the highest number of tubers with holes compared to the other locations.

Conclusion / Way Forward

The trial would be repeated in 2016 to validate the results obtained in 2015.

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Studies to mitigate outbreak and spread of common cassava diseases and East African cassava mosaic disease

Research Team: J.N.L. Lamptey, J. Manu-Aduening, M.D. Quain, R.N. Prempeh and A. Oppong

Collaborating Institutions: CIAT (Columbia) and Tuskegee University (USA)

Source of funding: WAAPP

Introduction

One of the greatest constraints to cassava production in Africa is the attack by arthropod pests and diseases. The most important disease of cassava is the cassava mosaic disease (CMD), and is associated with national and regional epidemics with root yield losses as high as 100 per cent (Jennings, 1994; Thresh *et al*., 1994). Even in the absence of a serious outbreak, yield losses of 30-40% are common in farmers' fields (Thresh *et al*., 1997). The high exchange of germplasm and unauthorized transfer of cassava germplasm across our borders, have contributed to the introduction of new pathogens hitherto absent in the West African sub-region. One of such important pathogens is the East African cassava mosaic virus (EACMV). The occurrence of EACMV in the sub-region has serious implication for the cassava industry, as there is increase in severity of symptoms when there are double infections of ACMV and EACMV (Fondong *et al*., 2000). Mixed infections of African cassava mosaic virus (ACMV) and EACMV may provide further opportunities for the recombination that gave rise to the pandemic associated with EACMV-UG (Ugandan strain) where yield losses of up to 100% led to farmers in Uganda abandoning cassava production and financial losses were estimated at more than 100 million dollars.

During WAAPP Phase 1, ACMV and EACMV as single infections and as mixtures were identified in field trials at Fumesua (forest ecological zone) and Ejura (forest-transition ecological zone) on some CRI released varieties and some local varieties. However, field infections were not very severe for the improved varieties possibly indicating tolerance to the mosaic disease or the presence of the mild strains of EACMV and ACMV. Under WAAPP Phase 2, screening of all the previously released CRI cassava varieties as well as those released by other institutions (numbering 17) are being carried out yearly to constantly determine their mosaic status as well as the status of other major diseases such as anthracnose and bacterial blight. Disease monitoring is being carried out at three locations (Fumesua, Ejura and Ohawu) in three different agro ecological zones. Dissemination of improved materials found to be susceptible to the major diseases will be curtailed to avoid creating disease reservoirs, spread of EACMV and also losses in yield.

Objectives

- To determine the presence of diseases of economic importance in Ghana
- To constantly validate the disease status of previously released varieties as a means of determining their status for dissemination.

Methodology

Seventeen varieties of cassava that have been released by CSIR-CRI (10), CSIR-SARI (2), KNUST (3) and UCC (2) and a local variety from each location (Table 115) have been planted at Fumesua (forest ecological zone), Ejura (forest-transition) and Ohawu (coastal savanna zone). The design of the trial was lattice with three replications.

Table 115. Seventeen released cassava varieties and local varieties planted for the trial

Institution	Variety Released
CSIR-CRI	Sika bankye, Ampong, Broni bankye, Otuhia, Essambankye, Doku duade, Bankyehemaa, Agbelifia, Afisiafi and Abasafitaa.
CSIR-SARI	Fil Indiakona and Nyerikogba
KNUST	Tek bankye, Nkabom and IFAD
UCC	Bankyebotan and UCC bankye
Local varieties	Debor (Fumesua), Debor (Ejura) and Penyivi (Ohawu)

At one, three and six months after planting (MAP), by visual examination, data on disease incidence (% infection) and disease severity of cassava mosaic disease (CMD), cassava anthracnose disease (CAD), and cassava bacterial blight (CBB) were collected from all three locations. Disease severity ratings were determined using a 5-point scale (where 1 = apparently no infection and 5 = very severe infection (IITA, 1990) - Table 116. For each variety, 10 middle row plants were assessed per replication. Thus a total of 30 plants were assessed per each variety. Varieties that had mean severity scores above 2.0 were considered as susceptible to CMD, CAD and CBB.

Table 116. Symptom expression for ranking Cassava mosaic disease

Ranking	Symptom
1	No symptom observed
2	Mild chlorotic pattern on entire leaflets
3	Strong mosaic pattern on entire leaf, narrowing and distortion of lower one third of leaflets
4	Severe mosaic; distortion of two-thirds of leaflets and general reduction of leaf size
5	Severe mosaic; distortion of four-fifths or more of leaflets, twisted and misshapen leaves

Source: IITA (1990)

Results and Discussion

At one MAP *Abasa fitaa and Bankye botan* showed high susceptibility to the mosaic disease (incidence, 33% and 64% respectively and severity scores of 2.8 for both) at Fumesua where the disease pressure is normally high confirming last year's observation. At Ohawu and Ejura, almost all the varieties showed no infection (Table 117)

At three months after planting, a similar observation was made with *Abasa fitaa* and *Bankye botan* showing high susceptibility to mosaic infection at Fumesua. At Ohawu, *Bankye botan* also showed moderate mosaic infection. *Afisiafi* and the local varieties showed slight infection at Fumesua and Ejura. The rest of the improved varieties showed resistance (Table 118). CBB infection was observed at Fumesua and Ohawu but was more prominent at Fumesua.

IFAD showed moderate CBB infection (mean severity score of 3) while *Essam bankye, Abasa fitaa, Doku duade* and *Nkabom* showed slight infection of CBB (mean severity score of 2).

At six MAP, only *Abasa fitaa* and *Bankye botan* showed susceptibility to CMD at Fumesua, with mean percentage infection of 36% and 69% and mean severity scores of 2.3 and 3.0 respectively (Table 119). The rest of the varieties either showed resistance or tolerance to the disease. At Ohawu, *Abasa fitaa* was susceptible to CMD, while the rest of the varieties either showed resistance or tolerance to the disease. At Ejura, no infection of CMD was recorded. For CAD, at Fumesua, *Agbelifia, Tek bankye, Bankye hemaa, Essam bankye, Otuhia, Fil Indiakona, Broni bankye* and *IFAD* showed tolerance. (Table 120). The rest of the varieties showed varying degrees of susceptibility to the disease. CBB, was only recorded at Fumesua on few plants of *Agbelifia, Debor, IFAD, Nyerikogba, Tek bankye, UCC, Fil Indiakona* and *Nkabom.* However those few plants exhibited moderate to severe infection of the disease (mean severity scores ranging from 3 to 4) thus showing the potential of these varieties succumbing to the disease in the event of a serious epidemic.

Conclusion and Recommendation

Generally during WAAPP Phase 2, period most of the improved varieties have showed high level of resistance/tolerance to the major cassava diseases at the three locations considered as hot spots for these diseases. This observation is good for the cassava industry and gives an indication of the low potential threat EACMV and other virulent strains of ACMV might have on our improved varieties. However, *Abasa fitaa, Bankye botan* and to some extent *Afisiafi* have consistently showed susceptibility to CMD and their continual dissemination should be seriously reconsidered to avoid creating a high reservoir of virus in the system. In 2015, CAD and CBB were observed to pose a potential threat to some of the improved varieties such as *Abasa fitaa, Bankye botan, Agbelifia, Debor, IFAD, Nyerikogba, Tek bankye, UCC, Fil Indiakona* and *Nkabom* and these varieties should be well monitored.

Way Forward

For the laboratory-based studies, DNA has been extracted from the infected samples collected from the three locations in 2014, and are yet to be assayed using the PCR technique. The PCR assay will conclude the project activities.

Table 117. Incidence and severity of mosaic disease recorded one month after planting at three locations

Cassava varieties	Fumesua		Ejura		Ohawu	
	Mean % infection	Mean severity (1-5)	Mean % infection	Mean severity (1-5)	Mean % infection	Mean severity (1-5)
Nyerikogba	0.0	1.0	0.0	1.0	0.0	1.0
Ampong	0.0	1.0	0.0	1.0	0.0	1.0
Agbelifia	4.0	1.3	0.0	1.0	0.0	1.0
Doku duade	0.0	1.0	0.0	1.0	0.0	1.0
UCC	0.0	1.0	0.0	1.0	0.0	1.0
Tekbankye	0.0	1.0	0.0	1.0	0.0	1.0
Bankyehemaa	0.0	1.0	0.0	1.0	0.0	1.0
Essambankye	0.0	1.0	0.0	1.0	0.0	1.0
Otuhia	0.0	1.0	0.0	1.0	0.0	1.0
Afisiafi	0.0	1.0	0.0	1.0	7.0	1.3
Abasafitaa	33.0	2.8	0.0	1.0	0.0	1.0
Bankyebotan	64.0	2.8	0.0	1.0	0.0	1.0
Fil Indiakonia	0.0	1.0	7.0	1.3	0.0	1.0
Sika bankye	13.0	1.0	0.0	1.0	0.0	1.0
Broni bankye	0.0	1.0	0.0	1.0	0.0	1.0
Nkabom	0.0	1.0	0.0	1.0	0.0	1.0
IFAD	0.0	1.0	0.0	1.0	0.0	1.0
Local	12.0	1.7	0.0	1.0	0.0	1.0

Table 118. Incidence and severity of mosaic disease recorded three months after planting at three locations

Cassava varieties	Fumesua		Ejura		Ohawu	
	Mean % infection	Mean severity (1-5)	Mean % infection	Mean severity (1-5)	Mean % infection	Mean severity (1-5)
Nyerikogba	0.0	1.0	0.0	1.0	0.0	1.0
Ampong	0.0	1.0	0.0	1.0	0.0	1.0
Agbelifia	0.0	1.0	3.0	1.3	0.0	1.0
Doku duade	0.0	1.0	0.0	1.0	0.0	1.0
UCC	0.0	1.0	0.0	1.0	0.0	1.0
Tekbankye	0.0	1.0	0.0	1.0	0.0	1.0
Bankyehemaa	0.0	1.0	0.0	1.0	0.0	1.0
Essambankye	0.0	1.0	0.0	1.0	0.0	1.0
Otuhia	0.0	1.0	0.0	1.0	0.0	1.0
Afisiafi	3.0	1.5	4.0	1.8	0.0	1.0
Abasafitaa	63.0	3.0	7.0	1.7	0.0	1.0
Bankyebotan	47.0	2.8	5.0	1.7	16 .0	2.3
Fil Indiakonia	8.0	2.0	3.0	1.3	0.0	1.0
Sika bankye	0.0	1.0	0.0	1.0	0.0	1.0
Broni bankye	0.0	1.0	0.0	1.0	0.0	1.0
Nkabom	0.0	1.0	0.0	1.0	0.0	1.0
IFAD	0.0	1.0	0.0	1.0	0.0	1.0
Local	10.0	2.2	7.0	1.8	0.0	1.0

Table 119. Incidence and severity of mosaic virus disease recorded six months after planting at three locations

Cassava varieties	Fumesua		Ejura		Ohawu	
	Mean % infection	Mean severity (1-5)	Mean % infection	Mean severity (1-5)	Mean % infection	Mean severity (1-5)
Nyerikogba	0.0	1.0	0.0	1.0	0.0	1.0
Ampong	0.0	1.0	0.0	1.0	0.0	1.0
Agbelifia	0.0	1.0	0.0	1.0	0.0	1.0
Doku duade	4.0	1.3	0.0	1.0	0.0	1.0
UCC	9.0	1.3	0.0	1.0	0.0	1.0
Tekbankye	0.0	1.0	0.0	1.0	0.0	1.0
Bankyehemaa	0.0	1.0	0.0	1.0	0.0	1.0
Essambankye	0.0	1.0	0.0	1.0	0.0	1.0
Otuhia	0.0	1.0	0.0	1.0	0.0	1.0
Afisiafi	0.0	1.0	9.0	1.7	0.0	1.0
Abasafitaa	36.0	2.3	18.0	2.3	0.0	1.0
Bankyebotan	69.0	3.0	15.0	2.0	0.0	1.0
Fil Indiakonia	6.0	1.3	0.0	1.0	0.0	1.0
Sika bankye	0.0	1.0	0.0	1.0	0.0	1.0
Broni bankye	0.0	1.0	0.0	1.0	0.0	1.0
Nkabom	8.0	1.3	0.0	1.0	0.0	1.0
IFAD	0.0	1.0	0.0	1.0	0.0	1.0
Local	7.0	1.3	0.0	1.0	0.0	1.0

Table 120. Incidence and severity of anthracnose disease recorded six months after planting at three locations

Cassava varieties	Fumesua		Ejura		Ohawu	
	Mean % infection	Mean severity (1-5)	Mean % infection	Mean severity (1-5)	Mean % infection	Mean severity (1-5)
Nyerikogba	50.0	2.3	0.0	1.0	38.0	2.7
Ampong	39.0	2.3	0.0	1.0	19.0	1.7
Agbelifia	36.0	2.0	0.0	1.0	0.0	1.0
Doku duade	38.0	2.3	0.0	1.0	0.0	1.0
UCC	4.0	2.3	0.0	1.0	0.0	1.0
Tekbankye	30.0	2.0	0.0	1.0	7.0	1.7
Bankyehemaa	0.0	1.0	0.0	1.0	0.0	1.0
Essambankye	34.0	2.0	0.0	1.0	11.0	1.3
Otuhia	10.0	1.3	0.0	1.0	0.0	1.0
Afisiafi	38.0	2.3	0.0	1.0	13.0	1.7
Abasafitaa	38.0	3.0	0.0	1.0	10.0	1.3
Bankyebotan	77.0	3.0	0.0	1.0	0.0	1.0
Fil Indiakonia	19.0	2.0	0.0	1.0	8.0	1.3
Sika bankye	59.0	2.3	0.0	1.0	5.0	1.7
Broni bankye	37.0	1.7	0.0	1.0	6.0	1.3
Nkabom	28.0	2.3	0.0	1.0	5.0	1.3
IFAD	23.0	1.7	0.0	1.0	0.0	1.0
Local	57.0	2.7	0.0	1.0	8.0	1.7

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Efficacy of garlic (*Allium sativum*) bulb and ginger (*Zingiber officinale*) rhizome extracts in controlling seed-borne fungi of rice (*Oryzae sativa*)

Research Team: A.K. Aidoo and Z. Appiah-Kubi

Collaborating Institution: Nil

Source of funding: CSIR-CRI Resources

Introduction

Pathogens play a significant role in reducing seed quality and vigour leading to weakness of the plant at its initial growth stages (Burt et al., 2003). Most of the major diseases in rice are seed borne (Fakir, et al., 2002). Of the seed borne diseases of rice, twenty-two are said to be caused by fungi (Fakir, G.A. 2000). Seed-borne fungi of rice such as *Rhizopus sp., Aspergillus flavus, A. niger* and *Fusarium oxysporum* are reported to have the capacity of spreading into the growing crop (Moses, et al., 2009). *A. flavus* is well known to be the casual agents of farm product diseases and food poisoning (Anjorin, 2012). *Bipolaris, Fusarium* and *Curvularia* are fungi species which cause leaf spot, black kernel, root rot and seedling blight in rice (Wikipedia, 2012). The indiscriminate usage of different types of dangerous and poisonous chemicals to control these pathogens have resulted in poisoning of the environment as well as living organisms. It has therefore become important to find a non-toxic, cost effective, available and practical way to prevent fungal diseases of stored rice. Several edible plant extracts have been reported to have antifungal activity. Plant extracts from garlic (*Allium sativum*) and ginger (*Zingiber officinale*) have been reported to have antibiotic and anti-fungal properties (Adetumbi, et al., 1986; Kim, et al., 2005; Hibert, S. 2006).

Objective

- To evaluate the effectiveness of garlic and ginger extract treatments *in vitro* in reducing the growth of four fungal pathogens isolated from rice seeds.

Materials and Methods

The studies were carried out in the Mycology laboratory of CSIR-CRI, in May, 2015. Isolates of *Aspergillus flavus, Bipolaris oryzae, Curvularia lunata, Fusarium moniliforme* were obtained from rice seeds were sub-cultured and maintained on Potato Dextrose Agar (PDA) until required. Ginger and garlic samples were peeled, washed thoroughly and cut into pieces. A ginger extract of 60% w/v concentration (GIN 60) was prepared by blending 120g ginger rhizomes with 80ml of distilled water. Another extract of 40% w/v concentration (GIN 40) was also prepared by blending 80g of ginger with 120 ml distilled water. Concentrations of 60 w/v and 40 w/v of garlic (GAR 60, GAR 40) were also prepared in the same manner as the ginger extract. Four equal sections were made on each of petri-dishes by drawing two perpendicular lines at the bottom of the plate, the point of intersection indicating the centre of the plate. Potato Dextrose agar (PDA) was dispensed into each of the plates. About 2mls of the extracts of the ginger and garlic were separately introduced into different petri dishes containing the media (PDA) and spread thinly. This was allowed to dry for about 10-15 minutes in a sterile laminar flow chamber. A mycelia disc (8 mm diameter) of five-day old pure cultures of each of the four test fungi (isolated) was placed on the dried extract, just at the point of intersection of the two lines drawn at the bottom of the petri dish. Control experiments were set up by spreading distilled water on the PDA (without the addition of any plant extract). The experiment was replicated three times. Mycelial growth of the test fungi were recorded daily by measuring the mean diameter of the fungal growth along the two perpendicular lines. Data were taken at 24, 48, 72, 96 and 120-hour periods. The data were statistically analysed with Genstat package (9.0 Edition).

Results and Discussion

Results showed that, both ginger and garlic extracts at 60% w/v and 40% w/v concentrations inhibited mycelia growth of all the four fungi, evidenced by lower mean growth of mycelia per day, compared to the control (Fig. 39 a, b, c and d). For instance, GAR 40 and GAR 60 completely supressed mycelia growth of *F. moniliforme* up to 72 hours of incubation. At 72 hours of incubation, *C. lunata* on GAR 60 recorded no mycelia growth. However, with *A. flavus*, At 24 hour incubation, GIN 60 was able to inhibit mycelia growth of *A. flavus* more than GAR 60.

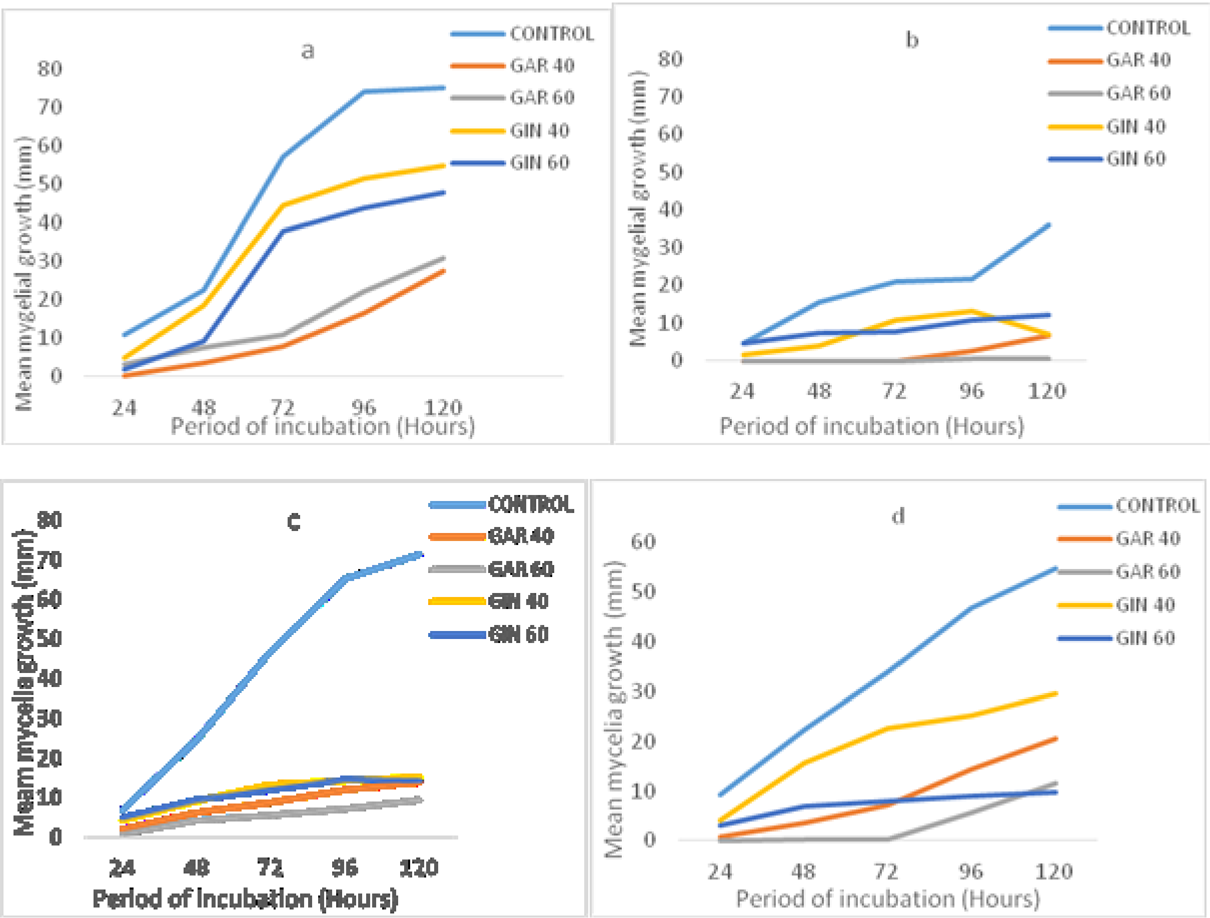

Fig. 41: Mean mycelial growth of (a) *A. flavus,* (b) *F. moniliforme*, (c) *B. oryzae* and (d) *C. lunata* on plant extracts compared with the control

The mean mycelial growth of the four test fungi on the plant extracts were statistically different from growth on the control (Table 121). Data on the growth of the fungi on both plant extracts at the two concentrations showed that the inhibiting effect of garlic extract on the organisms was significantly higher than ginger extract ($P < 0.001$). *F. moniliforme* (with the minimum mean growth) recorded 1.83 mm and 0.23 mm growth on GAR 40 and GAR 60 respectively, compared to *A. flavus* (the highest mean growth of) that had 11.13 and 15.03 mm for GAR 40 and GAR 60 respectively. Comparing with ginger extracts, *F. moniliforme* recorded mean growth of 7.2 mm and 8.5mm for GIN 40 and GIN 60 respectively, while *A. flavus* had 34.83 mm and 28.07mm for GIN

40 and GIN 60 respectively. GAR 40 and GAR 60 also caused lower mean mycelial growth on *B. oryzae* and *C. lunata* than GIN 40 and GIN 60. All the four treatments (botanical extracts) were able to suppress growth of all the test organisms compared to the control.

Table 121: Effect of plant extracts on mycelial growth of test fungi.

	Mean fungal mycelial growth (mm) on treatments				
Fungus	Control	GAR 40	GAR 60	GIN 40	GIN 60
A. flavus	48.37	11.13	15.03	34.83	28.07
B. oryzae	43.03	8.6	5.5	11.27	11.1
C lunata	33.43	9.27	3.5	19.43	7.3
F. moniliforme	19.77	1.83	0.23	7.2	8.5
LSD (P <.001) = 3.817 CV% = 32.9					

Fig. 40 shows that GAR 60 had the highest inhibitory property on three of the test organisms (*B. oryzae* 87.22 %, *C. lunata* 89.53 %, and *F. moniliforme* 98.83 %). This was followed by GAR 40, GIN 60 and GIN 40. However, on *C. lunata*, GIN 60 had a higher inhibitory effect (78.16%) than GAR 40 with 72.27%. GIN 40 had the least effect in inhibiting mycelia growth of all the test fungi except for *F. moniliforme* where GIN 40 had 63.85 % as against GIN 60 with 57% inhibitory effect.

These findings suggest that ginger and garlic extracts have antifungal properties that are effective against the growth of *A. flavus, B. oryzae, C. lunata, F. moniliforme.* In a related work (Tagoe, *et al.,* 2011), it was concluded that extracts from ginger, garlic and onions have the ability to prevent fungal infections and contamination of food and other plant products. The results also suggest that in controlling mycelia growth of *A. flavus, B. oryzae, C. lunata* and *F, moniliforme* on rice seeds, garlic extract has an advantage over ginger extract in terms of potency. These results agree with a related work (Shahidul, *et al.,* 2015), which showed that garlic extracts was the most effective; as it showed the highest performance in reducing infection of both *Aspergillus niger* and *Aspergillus flavus* on wheat seeds, compared with allamanda, neem, and marigold extracts.

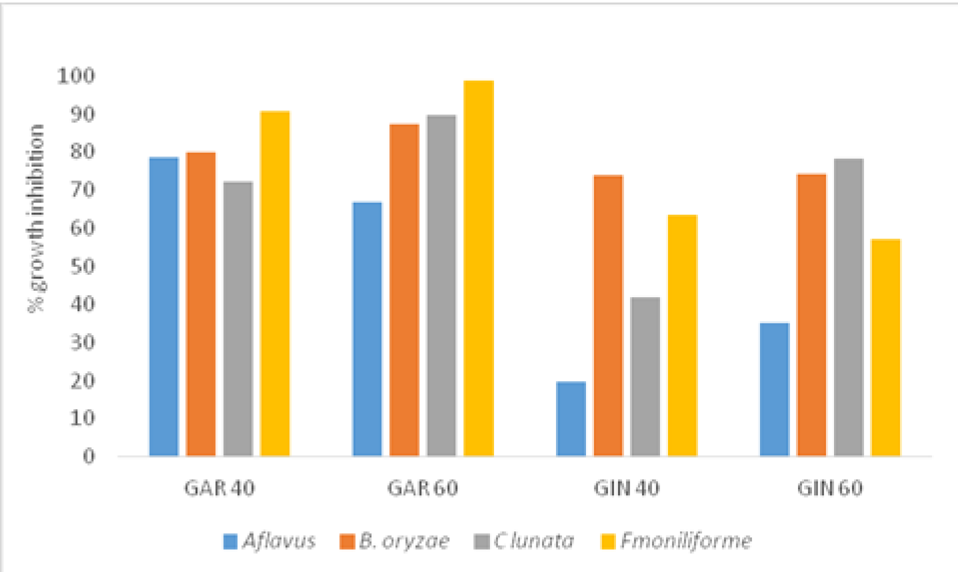

Fig. 42: Mean growth inhibitory effect of garlic and ginger extracts on four test fungi.

Conclusion

Seed treatment with garlic and ginger extracts can be effective in reducing or eliminating seed-borne fungi on rice seeds. Though ginger extracts used were effective, they were not as effective as garlic extracts. Using these extracts to treat rice seeds can be recommended as an effective means to control seed-borne fungi on rice seeds. Rhizomes of ginger and bulbs of garlic are readily available and are not costly. Extracts from these plants are also not harmful to the environment and their application on rice seeds does not require any special skills.

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Developing efficient and cost-effective on-farm storage technology for harvested fresh white yam tubers through participatory research.

Research Team: A.K. Aidoo Snr. and Z. Appiah-Kubi

Collaborating Institution: MoFA

Sources of funding: RTIMP and CSIR-CRI

Introduction

Rot is a major factor limiting the post-harvest life of yams and losses can be very high. Losses due to post-harvest rot significantly affect farmers' and traders' income, food security and seed yams stored for planting. Rot makes yam tubers unappealing to consumers. Some white yam varieties such as *Dente*, *Pona* and *Labreko*, which are preferred by most consumers in Ghana, do not store for long due to attack by rot organisms. Because of their poor storability, farmers sell their produce immediately after harvest to avoid losses, and this results in a glut, low income or reduced profits. Export of yam tubers from the country to the global market is currently threatened by poor tuber storability. While yam growers across major growing areas are being encouraged to increase productivity through the application of fertilizer at the recommended rate and time, some actors along the yam value chain attribute most storage rots to the application of fertilizer by farmers. Some farmers and exporters apply chemicals (fungicides and insecticides) to harvested tubers prior to storage as a control measure against rot. The residual effect(s) of these chemicals on the edible tissues of yam needs to be investigated from treatment time to the end of storage needs to be investigated.

Objectives

To determine the effect of:

- fertilizer application on storage rots of commercial white yam tubers.
- postharvest chemical treatment on the edible parts of commercial white yam tubers.

Materials and Methods

Trials were conducted on farmers' fields at Abour (Atebubu-Amanten district) and Akropong (Nkoranza North district) in May/June 2015. Seed yams of white yam variety *Dente* bought from farmers were planted on about 1,600 mounds at each location, using Complete Randomized Design. NPK fertiliser was applied at 30g per mound when the vines and leaves have sprouted. Good field sanitation was practised. At harvest the yams would be stored in barns. Samples would be picked from the barns and assessed for the incidence of rot. Data would be collected on weight of tubers, rot types, storage temperature and relative humidity on monthly basis for about six months and statistical analysis done. Some of the harvested tubers would also be treated with fungicides and insecticides and stored in barns. Samples would then be taken every month and their edible tissues analyzed for the presence of chemical residues.

Way Forward

The yams would be harvested in January 2016 and stored for the postharvest studies.

Evaluation of Extra early, Early and Intermediate drought tolerant Maize

Research Team: A. Oppong, K. Obeng Antwi, M. Tengan and K. Agyemang

Collaborating Institutions: IITA and CSIR-SARI

Source of funding: IITA

Introduction

Maize is an important food and cash crop in Ghana. However, its production is faced with a number of constraints including low soil fertility, erratic rainfall pattern, drought and lack of access to improved quality seed. In Ghana, maize is the most important cereal grain in terms of total production and utilization. It is produced in all the five major agro-ecological zones in the country, namely the Coastal Savanna, Forest, Forest-Savanna transition, Guinea Savanna and Sudan Savanna zones. The crop is grown by over 60% of the 3 million households of small-scale farm operators in Ghana (MOFA, 1997) with a total grain production of well over 1 million tons per annum (FAO STAT, 2007). Maize is used as a main base for several local food preparations and the main feedstuff for commercial poultry production and other farm animals. Drought affects maize yields by restricting season length resulting in unpredictable stress that can occur anytime during the cropping cycle (Edmeades *et al*., 1995). This has led to loss of income and increasing food insecurity among farmer households. Developing, distributing and cultivating drought tolerant maize varieties is one highly relevant intervention to reduce vulnerability, food insecurity and the damage to local markets accompanying food aid in Sub-Sahara Africa. The goal of the project is to develop and promote the production and utilization of high and stable yielding open-pollinated and hybrid maize varieties that are tolerant to the major biotic and abiotic stresses in Ghana to promote food security and increase farmers' income.

Objectives

- To identify high and stable yielding drought tolerant maize germplasm
- To develop drought tolerant experimental varieties (EVs), hybrids and synthetics from these germplasm
- To evaluate promising drought tolerant varieties in multi-location trials
- To release superior drought tolerant maize hybrids and varieties to farmers in Ghana and other interested national programmes
- To produce breeders' seeds of released drought tolerant maize hybrids and varieties for interested stakeholders

Materials and Methods

Drought tolerant maize germplasm were obtained from IITA. The lines received were (for) Regional Intermediate/Late maturing DT variety trial (M15-33), Regional early white DT hybrid (M15-32), Top-cross DT and DTSTR hybrid trial (M15-26), Regional extra-early white DT hybrid trial (M15-30), three way cross DT white and yellow hybrid trial (M15-27) and three way cross DTSTR (M15-29). An experimental field was ploughed, harrowed and laid out in incomplete block design (Alpha lattice). Each plot (5m long) consisted of two rows with maize planted at a spacing of 70cm x 40cm with two stands per hill. The trials were established at Fumesua, Pokuase, Kpeve and Ejura. Data were collected on dates of tasselling and silking, plant aspects, yield data, disease incidence and ear aspects. Breeder seed fields were established at Ejura, Fumesua and Akomadan for the following varieties: *Abontem, Omankwa, Tintim* and *Obantanpa*.

Results and Discussion

A serious drought adversely affected the growth of plants. Even though this is good for a trial on drought tolerance, the severity of the drought adversely affected the yield performance of the materials. The trials have been harvested and collection of yield data was on-going at the time of writing this report. Data collected will be statistically analyzed (using Genstat Version 15) to identify promising genotypes for selection and further evaluation. Similarly, the breeders' seed fields have been harvested and the materials are being processed.

Conclusion

Analysis of data from the trials has not been completed however, it is anticipated that promising genotypes will be identified and selected. Some of the breeder seed fields at Ejura and Akomadan did well and it is anticipated that good quantities of seed will be made available to interested stakeholders for planting in the coming season.

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Cassava Viral Disease survey in Ghana.

Research Team: A. Oppong, J.N.L. Lamptey, B.M. Mochiah, R. Prempeh, L. Abrokwa, L. Ohemeng Appiah and A. Agyekum

Collaborating Institutions: University of Felix Houphouet Boigny (Abidjan, Cote d' Ivoire), University of Cambridge (UK) and University of Pennsylvania (USA)

Source of funding: BMGF (through WAVE project for root and tuber crops)

Introduction

The most important root and tuber crops grown in the West African sub-region are cassava (*Manihot esculenta*, Crantz), sweetpotato (*Ipomoea batatas* L.) and yams (*Dioscorea* spp.). They are cultivated mainly for subsistence and are a major source of dietary energy for low-income consumers in both urban and rural communities.

According to FAOSTAT (2013), West Africa is producing about 30.8% of the world's cassava which is about half of Africa's total cassava production. However, the demand for cassava still exceeds supply, because much of the potential yield from smallholder or small-scale commercial farms is lost through pest and disease attack. Cassava production is greatly limited by a number of diseases among which is cassava mosaic disease (CMD) and cassava brown streak disease (CBSD) each of which can cause yield losses of up to 100% (Hahn, 1980, Bellotti, 2001). CMD alone causes an estimated loss of 24% of the production which is equivalent to more than 28 million tons annually in Africa. An extremely severe epidemic of CMD started in Uganda in 1990, devastated cassava fields and caused food shortages. The disease was caused by the new *East African cassava mosaic virus* (EACMV) variant called EACMV-UG (Uganda strain).

West Africa, and for that matter Ghana, cannot wait to experience such widespread and catastrophic effects of plant viral epidemics. This is why the WAVE project is important because it seeks to equip and prepare Scientists, Policy makers and other stakeholders to take pre-emptive steps aimed at preventing famine caused by viral diseases.

The main objectives of the WAVE project are to:

- ensure a clear understanding of virus threat of root and tuber crops in West Africa.
- equip breeders with accurate information needed for identification and deployment of resistant/tolerant root and tuber crops (especially those in use by West African breeders).
- strengthen national and regional capacity to respond to viral disease threats.
- facilitate increased demand and availability of clean planting materials as a component of integrated management of root and tuber crop viruses.

Materials and Methods

To achieve these objectives a nationwide field survey was carried out during the last quarter of the year to assess the disease status of cassava farms in the country. The methodology used for the survey followed the harmonized protocol that has been developed by WAVE project to be used in all implementing countries within the sub-region. Viral infected cassava samples, alternate weed hosts and white fly vectors were collected from five plants in each field visited. Data were collected on location, disease severity score of the sample, mode of infection of the disease and number of farms between any two locations where samples were picked, among others. The samples collected were kept in herbarium pressers and brought to the laboratory for analyses. Stem cuttings of viral infected plants were also taken and then brought to the screen house for analyses.

Results and Discussion

Two hundred and fifteen cassava fields were visited across the 10 regions of the country. However, majority of samples were collected from the Ashanti, Volta, Brong Ahafo and the Central regions where cassava is mostly grown. The distribution of farms visited during the survey is presented as Table 122. Over 1000 leave samples showing varying symptoms of viral infections were collected and are yet to be analyzed using PCR and specific primers that can amplify various strains of the ACMV and the CBSV. This will be done at the Virology laboratory of the Institute at Fumesua. In addition, over 400 cassava sticks are being maintained in the screen house at Fumesua to serve as back up material during laboratory diagnostics. The white fly vectors that were also collected are currently being maintained at 0°C and will be analyzed to identify strains of cassava viruses found in them and also determine their biotypes.

Table 122. Cassava fields visited in the 10 regions of Ghana.

Region	Number of farms visited
Ashanti	40
Brong Ahafo	41
Eastern	20
Western	28
Central	18
Volta	37
Greater Accra	3
Upper East	1
Northern	23
Upper West	4
Total	**215**

This work is on-going. The field data that were collected are being analyzed at the University of Cambridge (UK) to generate disease maps and also develop viral disease epidemiological model for Ghana and beyond. It is anticipated that when analyses of the samples collected from the various regions, had been completed, all cassava viruses in Ghana will be identified, and will help to guide breeding for virus resistant cassava varieties in the country.

Conclusion and Recommendation

Another round of field survey will be carried out in 2016 and data from the two surveys will be analyzed to draw the appropriate conclusions that will be beneficial to researchers on cassava, cassava farmers and consumers in Ghana and beyond.

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Development of high yielding aflatoxin resistant maize hybrids for improved nutrition and health in Ghana.

Research Team: A. Oppong, R. Prempeh, M. Asante, Z. Appiah-Kubi and L. Abrokwa

Collaborating Institutions: USDA and University of Mississippi (Starkvile, USA)

Source of funding: USAID (through National Science Foundation, Washington DC, USA)

Introduction

Maize is Ghana's number one cereal, providing food for millions of Ghanaians daily. However, productivity of the crop in farmer fields is generally low compared to the global averages and when compared to countries such as the USA and China (FAOSTATS, 2008). Aflatoxin infection of maize has also been a major challenge because it has been reported that most of the maize harvested from farmers' field are contaminated with aflatoxin which makes it a major health issue and an impediment to the export potential of the crop (Kpodo et al., 2005). Developing high yielding maize hybrids with resistance to aflatoxin will positively impact on productivity and general wellbeing of the entire Ghanaian populace who depend on maize for their nutritional needs.

The overall aim of this project is to develop high yielding, aflatoxin resistant maize hybrids for improved productivity, nutrition and health of Ghanaian maize farmers and consumers.

Materials and Methods

Field trials were established at Fumesua and Ejura to evaluate aflatoxin-resistant maize hybrids obtained from IITA. The materials were developed through collaboration between the University of Mississippi and IITA. There were four trials made up of:

- A1509 - New 3-way hybrid involving aflatoxin resistant lines and consisted of 16 entries. They were planted in two replications, 1 row per plot at a spacing of 75cm x 20cm, two plants per hill.
- A1525 – A new test cross of advanced aflatoxin resistant lines with 54 entries and also planted at a spacing of 75cm x 50cm, 1 row per plot (length of 5m).
- A1509 - Advanced 3–way cross hybrids of aflatoxin resistant white lines consisting of 18 entries and planted at a spacing of 75cm x 50cm, 1 row per plot.
- A1506 - Elite 3–way cross hybrids of aflatoxin resistant inbred lines consisting of 48 entries and planted at a spacing of 75cm x 50cm, 1 row per plot.

Five plants of each trial were artificially inoculated with pure cultures of *Aspergilus flavus*, obtained from maize seeds, at a concentration of 1.5×10^7 spores/ml. The inoculation was done at the milk stake and the plants were left on the field to mature for harvest and storage. Agronomic data including disease incidence, dates to silking and tasseling were collected.

Results and Discussion

This activity started in the minor season and the fields had just been harvested. Yield data were being collected at the time of reporting is on-going. The fields suffered late drought which is anticipated to impact negatively on grain yield. Promising genotypes that would combine high yield and low levels of aflatoxin accumulation (compared to the controls) will be selected for further evaluation.

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Effects of SPVD on yield of Sweetpotato cultivars in Ghana.

Research Team: A. Oppong, I. Adama, V. Amankwah, K. Adofo and L. Abrokwa

Collaborating Institution: CIP (through the SASHA project)

Source of funding: WAAPP

Introduction

Sweetpotato viruses adversely affect crop yields greatly. However the extent to which SPVD affects the elite sweetpotato varieties in Ghana have not been properly estimated, (personal communication; JNL Lamptey). It is imperative to know the extent of yield losses when tissue culture derived planting materials are re-infected in the field.

Objectives

To determine:

- yield losses caused by sweetpotato virus diseases in Ghana
- the degree of yield loss caused by SPVD on re-infected tissue culture derived planting materials

Materials and Methods

The treatments consisted of three sweetpotato varieties (*Bohye, Ligri,* and *Dadanyuie*) and four infection regimes in a (3 x 4 factorial) format. The four infection levels were virus indexed tissue culture derived planting materials (healthy), field healthy (apparent healthy) planting materials, field infected planting materials and artificially infected (using whitefly and aphid vectors) planting materials. Each plot consisted of two rows, one plant per hill at a spacing of 1m between row and 30cm within rows. The field was prepared by ploughing, harrowing and ridging. Artificial inoculation of virus indexed tissue culture derived planting materials of the three varieties was done in a screenhouse at Fumesua. The white fly (*Bemisia sp.)* and aphid *(Aphis sp)* vectors were multiplied on cowpea (*Vigna unquiculata*) sweetpotato *(Ipomoea batatas)* plants and later transferred to virus-infected sweetpotato plants for virus acquisition. The artificial inoculation of the disease-free (healthy) vines was done by introducing the white flies and aphids from viral-infected sweetpotato plants to the healthy plants for about 48 hours before they were taken to the field for planting.

Results and Discussions

The field was harvested in the last quarter of the year and yield data are being analysed. Visual observation indicted that *Ligri* produced better yield than the other two varieties. The trial went well even though there was a late drought. However it is anticipated that this will not adversely affect the trend of results as all the three genotypes used were equally affected.

Conclusion and Recommendations

Data collected will be analyzed and compared with those obtained last year. Combining data for the two years will give a better picture of the effect of viral diseases on sweetpotato which hopefully will justify the need to provide farmers in the country with healthy planting materials.

Integrated management of soil arthropod pests of cocoyam

Research Team: B.W. **Amoabeng**., M. B. Mochiah., I. Adama, A. Gyimah., A. Agyekum and P. Opoku

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

Tania, *Xanthosoma sagittifolium* (L.) Schott) (Araceae), also known as cocoyam, is an important food security crop which has gained increased prominence in the diets of many poor people in the Americas, West Africa, Asia and the Pacific (Essumang et al., 2007; Okoye et al., 2007). The starchy cormels of tania provide a cheap source of carbohydrate, and a good source of essential mineral nutrients (Mwenye et al., 2011). The leaf of tania is also a good source of vitamins and it is an important vegetable in the diet of many Ghanaians. Tania is also a raw material for the production of quality starch for industrial purposes (Omoruyi, et al., 2007). Despite the importance of tania in several economies, the crop faces challenges including pests attack. In Ghanaians, successful production and consumption of the crop is hampered by pests such as millipedes and termites. Infestation by these pests results in reduced yield, unattractive and unmarketable cormels (Adepoju, A., & Awodunmuyila, 2008). There is the need to develop a viable pest management strategy to ensure increased yield
and quality of Tania in Ghana and other West African countries. This study aimed at managing soil arthropod pests of tania using Indian neem tree (*Azadirachta indica*) leaf paste.

Objective

To develop integrated strategies for the management of arthropod pests of *Xanthosoma* cultivars. Specifically, the study is to:

- assess the range of arthropod pests on three improved cocoyam varieties – *Gye me di, M'ayεyie* and *Akyεdeε*
- assess the incidence and severity of the various arthropod pests
- determine which of the three varieties better tolerates arthropod pests
- determine the effect of 'botanical insecticide' (neem leaf powder) on the management of arthropod pests of cocoyam
- determine the effect of pest management intervention on yield and quality of cocoyam cormels

Materials and Methods

The study started in the 2014/15 cropping season at Kukuom (Brong Ahafo region) and was repeated in 2015/16 at Kukuom and Kwaso (Ashanti region). For the 2015/16 study, about 0.6 acre field was established at each location. Three improved cocoyam varieties - *Gye me di, M'ayɛ yie* and *Akyɛdeɛ* and a local variety (as check) were planted in June /July using RCB design with three replications. Each plot measured 8 m x 4 m with 2 m alley between plots. Cocoyam was planted at 1 m apart, giving nine rows with five stands per row (45 plants per plot). Each of the four materials will receive (as treatment) either 200g of neem leaf paste per plant, 2% Chlorpyrifos (positive control) or no treatment (negative control) for the management of soil arthropod pests. Fresh neem leaves would be pounded in a mortar with a pestle and left overnight before samples are taken, weighed and applied to the soil at the base of each cocoyam plant. The neem would be compared with Chlorpyrifos as a standard positive control. Effects of the treatments on the soil arthropods will be determined using the damage symptoms on cormels at harvest. Harvesting will be done in July, 2016.

Results

Yield data from the 2014/15 experiment are presented as Table 123. Plots treated with Chlorpyrifos had similar yields, while the control (no treatment) plots had slightly lower cormel yields.

Table 123. Mean cormel yields of improved and local cocoyam varieties.

	Mean cormel yield per plant (kg)			
	Akyɛdeɛ	*Gye me di*	*M'ayɛ yie*	Local
Chlorpyrifos	0.69	0.68	0.57	0.55
Neem leaf paste	0.62	0.50	0.49	0.43
Control	0.54	0.53	0.48	0.33

Soil arthropod pests found were mainly millipedes and termites. The control plots had a mean of 1.4 millipedes per stand while the Chlorpyrifos and neem leaf treated plots had 0.74 and 0.83 respectively. Both neem leaf paste and Chlorpyrifos reduced the effect of the soil arthropods on the crops. *M'ayɛ yie* suffered the highest incidence of arthropod pests and damage. It is expected that the 2015 experiments will follow similar trend to enable a good discussion and conclusions.

Challenges and Way Forward

Application of the treatments for the 2015/16 study (scheduled for November 2015) was delayed because plant growth and development were adversely affected by poor rainfall so the plants could not reach the desired stage required for the treatment application. Application will be delayed until plants have reached the desired stage. Routine field maintenance would be done.

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Using Applied Research and Technology Transfer to Minimize Aflatoxin Contamination and Increase Production, Quality and Marketing of Peanut in Ghana

Research Activity: Determine steps in the supply chain that is most vulnerable to development of aflatoxin and practice (s) that influence aflatoxin contamination in peanut.

Research Team: M.B. Mochiah, I. Adama, B.W. Amoabeng, M. Owusu-Akyaw, J.Y. Asibuo, G. Bolfrey-Arku and A. A. Dankyi.

Collaborating Institutions: CSIR-SARI, KNUST, NCSU (USA) and MoFA

Source of funding: Peanut Mycotoxin Innovation Lab. (PMIL)

Objectives

- Assess on-farm production of groundnut and aflatoxin mitigation in both major and minor seasons
- Evaluate new groundnut germplasm for tolerance to aflatoxin
- Compare different drying methods of groundnut to minimise aflatoxin contamination
- Determine the effect of calcium on pod filling and aflatoxin mitigation

Introduction

A recent World Bank study indicated that the European Union regulation on aflatoxins cost Africa $750 million annually in export of cereals, dried fruit and nuts (Agyei, 2013). Although losses faced by the global economy are estimated at $1.2 billion, African economies lose about $450 million annually to aflatoxin contamination (Atser, 2009). Peanut is an important component of the diets of Ghanaians with its production mostly in the Central and Northern regions, especially in the Savanna region where conditions are favorable for aflatoxin development (Craufurd et al., 2006). Peanut in the supply chain continues to contain aflatoxin at levels exceeding those defined as safe for human consumption. Inefficient and marginally effective production and pest management strategies, poor soil fertility, limited irrigation, susceptible cultivars, and weather patterns as well as poor drying and storage practices create high risk conditions for contamination by aflatoxin of food crops for human and livestock consumption. Improved production and pest management in the field and more effective postharvest handling and storage practices are known to mitigate *Aspergillus* survival and subsequent production of aflatoxin. Timely sowing can minimize exposure to droughts which exacerbate aflatoxin incidence (Craufurd et al., 2006). Drought-tolerant cultivars are less susceptible to aflatoxin contamination. Effective field drying and sorting and discarding aflatoxin-contaminated pods will improve quality of peanut. Sorting peanut prior to processing can impact on aflatoxin contamination (Awuah et al., 2006). Research is being conducted at the CSIR-CRI is engaged in research to develop appropriate production and pest management strategies and to evaluate new germplasm to minimise the incidence of aflatoxin. Results from this work would be shared with farmers using the Farmer Field School approach and publications such as posters, bulletins and manuals.

Activity 1

On farm production of groundnut and aflatoxin mitigation in major season 2015

Methodology

Trials were established with 12 farmers each at Ejura and Drobonso (Ashanti region). The farmers (males and females) were selected with the assistance of a resident Agricultural Extension Agent of MoFA. At each location, two plots, each measuring 25 metres long, were established and planted with 20 rows of a local groundnut variety –*Konkoma,* in the second week of April 2015. One plot was labelled as Researcher plot (managed by a researcher with recommended interventions). The other plot was labelled as Farmers' Practice plot (managed by the farmers). On the researcher plot the following interventions (also described as Best Management Practice - BMP) were applied: Application of *Alata* (local) soap (1g/litre) to manage aphids (vector of rosette virus disease) and application of Oyster shell (Calcium) at flowering stage. Weeds were managed at least twice during the trial period. On the Farmers' Practice plot the farmers adopted their traditional production practices. They weeded the field once.

Results and Implications

Due to erratic rainfall, the fields at Ejura suffered a serious attack by rosette virus which wiped out groundnut fields in the community so the trial there was therefore abandoned. Conditions at Drobonso were better and some data on percent filled pods, damaged pod and kernels, haulm weight and grain yield, were collected from both Researchers' and Farmers' Practice plots. The data from Drobonso are presented as Table 124. Generally on plots where the BMP were in adopted there was higher percent of filled pods and increased haulm weight. Though the BMPs increased cost of production and pest management, there was an increase in yield (and revenue). There would be the need for economic analysis.

Table 124: Percent filled pods, haulm weight and grain yield from trials conducted at Drobonso: Major season 2015

No.	Farmers' Names	Intervention	% Filled Pods	Haulm Weight	Yield Weight (Kg/ha)
1	Iddirissu Musah	*BMP	83.85	2.00	3747.58
		Farmer Practice	76.19	1.50	2646.78
2	Abdul Karim Ishahaku	BMP	77.31	2.50	3909.40
		Farmer Practice	69.03	1.20	2868.93
3	Samatu Yahaya	BMP	87.07	1.80	3612.11
		Farmer Practice	55.71	1.40	2406.15
4	Karim Yahaya	BMP	85.39	1.90	3466.95
		Farmer Practice	70.89	1.20	3193.34
5	Fishatu Abdulai	IPM	81.58	1.30	4005.55
		Farmer Practice	75.00	1.11	2877.53
6	Samatu Dawuda	BMP	82.67	1.50	3107.35
		Farmer Practice	78.33	1.30	2982.28
7	Asibi Dogo	BMP	82.35	1.70	3291.84
		Farmer Practice	77.55	1.80	3262.92
8	Mariatu Abrahmani	BMP	83.18	1.90	3740.55
		Farmer Practice	71.91	1.50	3244.15
9	Sadia Bashiru	BMP	89.09	2.00	3849.99
		Farmer Practice	70.45	1.50	2163.03
10	Lateefa Abubakari	BMP	84.08	2.50	4622.33
		Farmer Practice	64.44	1.40	3838.26
11	Banbanshia Sanatu	BMP	73.51	2.00	4271.34
		Farmer Practice	67.86	1.70	3917.22
12	Hawa Sule	BMP	88.81	2.20	4699.72
		Farmer Practice	74.47	1.40	3925.82

*BMP= Best Management Practice

Activity 2

Evaluation of new groundnut germplasm

Methodology

Twenty-three groundnut lines/varieties made up of 14 from ICRISAT identified as aflatoxin tolerant/resistant, eight released varieties from CSIR-CRI and CSIR-SARI and a local variety, were planted on-station at Kwadaso in April, 2015. The design was a RCBD replicated three times. Data were collected on number of days to 50% flowering, incidence of early and late leaf spot and rosette diseases as well as yield and aflatoxin levels. Harvesting was done between done in July.

Results

Data collected showed significantly differences ($p < 0.05$) among the lines/varieties for all the parameters. The ICRISAT materials took five days to emerge after planting. *Shitaochi* and *Yenyawoso* took three days to emerge while Otuhia and Adepa took six days (Table 125). Most of the ICRISAT germplasm took 27 days to reach 50% flowering, while *Otuhia* recorded 31 days. Incidence of rosette was between 2 and 74%. *Yenyawoso* and *Shitaochi* had the least and highest % incidence of rosette respectively. Three lines from ICRISAT had incidence of rosette greater than 60%.

Table 125: Performance of groundnut lines/ varieties evaluated at Kwadaso. Major season, 2015

No.	Groundnut line/Variety	Days to emergence	Days to 50% Flowering	% incidence of rosette
1	ICGV-01094	5.00±0.00b	27.00 ± 0.00c	25.73 + 0.14i
2	ICGV-02171	5.00±0.00b	27.00 ±0.00c	44.17 ± 0.64ef
3	ICGV-02184	5.00±0.00b	27.00 ± 0.00c	44.23 ± 0.35ef
4	ICGV-02206	5.00±0.00b	27.00 ± 0.00c	11.09 ± 0.33k
5	ICGV-02207	5.00±0.00b	29.00 ± 0.00b	40.97 ± 0.33g
6	ICGV-03308	5.00±0.00b	27.00 ± 0.00c	62.19 ± 0.33d
7	ICGV-03315	5.00±0.00b	29.00 ± 0.00b	66.79 ± 0.27c
8	ICGV-03331	5.00±0.00b	27.00 + 0.00c	24.95 ± 0.34i
9	ICGV-03392	5.00±0.00b	27.00 + 0.00c	42.64 ± 0.29fg
10	ICGV-03395	5.00±0.00b	27.00 + 0.00c	41.26 ± 0.31g
11	ICGV-03396	5.00±0.00b	27.00 ± 0.00c	36.41 ± 0.36h
12	ICGV-03398	5.00±0.00b	27.00 ± 0.00c	63.96 ± 0.22d
13	ICGV-03401	5.00±0.00b	27.00 ± 0.00c	11.73 ± 0.35jk
14	ICGV-03405	5.00±0.00b	27.00 ± 0.00c	45.40 ± 0.31e
15	KONKOMA	5.00+0.00b	27.00 ± 0.00c	71.77 ± 0.35b
16	NKOSUOR	5.00+0.00b	27.00 ± 0.00c	12.21± 0.33jk
17	OBOLO	5.00+0.00b	27.00 ± 0.00c	36.41 ± 0.68h
18	OBOSHIE	5.00+0.00b	27.00 ±0.00c	5.38 ± 0.29l
19	OTUHIA	6.00±0.00a	31.00 ± 0.00a	5.14 ± 0.29l
20	NKATEE-SARI	5.00±0.00b	29.00 ± 0.00b	13.88 ± 0.30j
21	SHITAOCHI	4.00±0.00c	27.00 ± 0.00c	74.15 ± 0.36a
22	YENYAWOSO	4.00±0.00c	27.00 ± 0.00c	1.59 ± 0.27m
23	ADEPA	6.00±0.00a	28.67 ± 0.33bc	3.89 + 0.24l
	P<0.05	0.0001	0.0001	0.0001

Note: Means with the same letter(s) are not significantly different (P < 0.05, Tukey test) within columns.

Data on unfilled pods, pod and kernel damage as well as grain yield are presented as Table 126. Generally materials that showed lower incidence of rosette had higher yields compared to those with higher incidence. The highest grain yield was obtained from Oboshie (3157kg/ha) while the least was from ICGV-03395.

Table 126. Percentage unfilled pods, damaged pods and kernels and yield from groundnut evaluated at Kwadaso. Major season, 2015.

No.	Groundnut line/Variety	% unfilled pods	% damaged pods	% damaged kernels	Mean yield (kg/ha)
1	ICGV-01094	37.03±0.84bcde	0.00±0.00g	0.00±0.00f	570.58±16.67k
2	ICGV-02171	47.40±0.59a	0.00±0.00g	0.00±0.00f	905.06±4.78hi
3	ICGV-02184	25.01±1.87hi	0.00±0.00g	0.00±0.00f	821.54±25.17ij
4	ICGV-02206	36.23±0.94cde	0.00±0.00g	0.00±0.00f	1459.22±17.47de
5	ICGV-02207	29.85±0.52fgh	6.66±0.39b	6.75±0.03b	930.32±38.83hi
6	ICGV-03308	42.05±0.17abc	8.83±0.35a	9.32±0.34a	917.59±48.08hi
7	ICGV-03315	32.01±1.85efg	0.00±0.00g	0.00±0.00f	823.87±17.11ij
8	ICGV-03331	41.51±1.53abc	0.00±0.00g	0.00±0.00f	939.51±30.04ghi
9	ICGV-03392	32.88±1.22ef	2.80±0.35de	3.13±0.57de	1235.80±50.80ef
10	ICGV-03395	15.63±0.59j	0.00±0.00g	0.00±0.00f	575.14±4.58jk
11	ICGV-03396	42.66±0.74ab	0.00±0.00g	0.00±0.00f	1078.95±35.69fgh
12	ICGV-03398	20.97±1.15 ij	0.00±0.00g	0.00±0.00f	953.87±12.50ghi
13	ICGV-03401	33.03±0.68ef	0.00±0.00	0.00±0.00f	939.51±30.04ghi
14	ICGV-03405	23.50±0.61 i	3.47±0.25d	3.90±0.23d	1235.80±50.80ef
15	KONKOMA	41.56±0.87abc	2.26±0.07ef	3.12±0.01de	575.14±4.58jk
16	NKOSUOR	36.34±0.68cde	0.00±0.00g	0.00±0.00f	1614.02±82.98d
17	OBOLO	43.06±2.84ab	2.29±0.03ef	2.44±0.01e	1295.24±47.17ef
18	OBOSHE	34.77±0.80def	4.46±0.29c	4.98±0..38c	3157.32±71.37a
19	OTUHIA	40.37±0.55bcd	0.00±0.00g	0.00±0.00f	2247.23±59.90b
20	NKATEE-SARI	40.96±0.90bcd	1.67±0.04f	2.41±0.03e	1189.20±107.64fg
21	SHITAOCHI	41.56±0.89abc	0.00±0.00g	0.00±0.00f	1055.22±38.17ghi
22	YENYAWOSO	26.10±1.52ghi	0.00±0.00g	0.00±0.00f	1969.57±64.30c
23	ADEPA	32.06±0.98efg	3.57±0.36cd	4.02±0.31cd	2264.93±59.18b
	P<0.05	0.0001	0.0001	0.0001	0.0001

Note: Means with the same letter(s) are not significantly different ($P < 0.05$, Tukey test) within columns.

Activity 3

Comparison of different drying methods

One groundnut line, F– MIX (X) ICG (FDRS) -20 -1– 45 planted on-station was dried using three different methods (on the ground, tarpaulin and A-frame) after harvest. Moisture contents after drying using the three methods namely on ground, tarpaulin and A-frame were 8.8%, 7.2% and 7.8% respectively. Samples of materials dried under each drying method have been collected by our collaborators from KNUST to determine their aflatoxin contamination levels.

Activity 4

Effect of calcium on pod filling and aflatoxin mitigation

Three groundnuts varieties: CRI-Yenyawoso, CRI-Otuhia and Konkoma were planted on 21st April, 2015, at Kwadaso, at a spacing of 50 cm x 15cm. The design was RCB with three replications. A treatment of Oyster shell powder (containing 40% of Calcium) was applied at 180 kg/ha at flowering stage. The control treatment was “No Calcium”. Each plot measured 1.5 m x 5 m. There were two weed management interventions for the trial plots. Data were collected on number of days to 50% flowering, incidence of early and late leaf spot, incidence of rosette, yield and aflatoxin contamination levels.

Results

The percentage of unfilled pods ranged from 28 to 44 % (Table 127). Generally, a higher percentage of unfilled pods were noted for the ‘control’ plots compared with the oyster shell powder treated plot. Similarly percentages of insect-damaged pods and kernels were relatively lower on oyster shell powder-treated plots than the 'control' plots. Calcium is known to enhance pod filling as well as pod strength. Applying oyster shells powder at the flowering stage produced higher yields compared with the control. *Otuhia* treated with Oyster shell powder produced the highest yield (2266 kg/ha) while *Konkoma* without Oyster shell treatment produced the least yield (535 kg/ha) (Table 127).

Table 127. Response of groundnut to oyster shells powder treatment at Kwadaso. Major season, 2015.

Variety + Treatment	% unfilled pod	% damaged pod	% damaged kernels	Mean yield (kg/ha)
Otuhia + Oyster shell	30.83±0.32d	0.00±0.00d	0.00±0.00e	2266.44±76.79a
Otuhia + No Oyster shell	37.79±0..33b	1.34±0.05c	2.16±0.03d	1900.26±13.85b
Yenyawoso + Oyster shell	27.65±0.84e	1.30±0.05c	2.36±0.03c	1805.89±25.77b
Yenyawoso + No Oyster shell	34.53±0.57c	2.02±0.02b	3.12±0.01b	1434.12±32.37c
Konkoma + Oyster shell	38.23±0.59b	1.56±0.24bc	2.33±0.01c	712.55±5.86d
Konkoma + No Oyster shell	43.81±0.57a	3.00±0.07a	3.55±0.02a	535.12±14.23e
P<0.05	0.0001	0.0001	0.0001	0.0001

Note: Means with the same letter(s) are not significantly different (P < 0.05, Tukey test) within columns.

Discussion

Data on the relation of environment to growth and sporulation of many storage fungi have been documented by several investigators (Diener, 1973). Lamptey et al. (2014) found that when *alata* soap was applied bi-weekly beginning from two weeks after planting, it was effective in reducing the incidence and impact of rosette. Buss (2006) also indicated that soaps apart from being effective in the control of aphids are safe for people and the environment. Unfilled or empty pod formation in peanut is mainly caused by calcium (Ca) deficiency (Kogram *et al.* 1999). Previous studies showed that limited pod filling was associated with low calcium levels in the soils at Kwadaso and Hiawoannwu (S. Osei-Yeboah *et al.,* unpubl. data). A considerable variation in the percentage of unfilled pods was noted and few differences in percentages of damaged pods and kernels were recorded when Oyster shell powder plots were compared with the control.

Conclusion

The trials will be repeated in 2016 so that meaningful conclusions and recommendations can be made.

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Evaluation of Cassava Mosaic Virus (CMV) transmission efficiency by *B. tabaci* on cassava varieties in selected locations

Research Team: M.B. Mochiah, J.N.L. Lamptey, R.N.A. Prempeh, J. Manu-Aduening, I. Adama and B. W. Amoabeng

Collaborating Institution: MoFA

Source of funding: WAAPP

Objective
To determine the efficiency of disease transmission y the vector and also identify variety (ies) on which transmission is poor/low.

Specific Objectives

- Determine CMV transmission efficiency by *B. tabaci* on resistant and susceptible cassava varieties
- Assess different species of mosaic virus (ACMV & EACMV) and possible occurrence of cassava brown streak virus (CBSV) on farmers' fields
- Determine /quantify effect of CMVD on the yield of cassava in fields

Introduction
The whitefly (*Bemisia tabaci*) carries and readily transmits damaging and widespread pathogens including the Cassava mosaic virus complex, which reduces the size and number of roots. Africa Cassava Mosaic Disease (ACMD) is caused by several geminiviruses (Thresh et al., 1994), and it has been speculated that the absence of ACMD in the Americas may be related to the inability of its vector, *B. tabaci*, to colonize cassava. Prior to the early 1990s, the *B. tabaci* biotypes found in the Americas did not feed on cassava (Costa and Russell, 1975; Wool et al., 1994).
Knowing the specific/type of biotypes in a particular location is important in the management of whiteflies. In 2014 efforts were made to identify the biotypes of whitefly (if they exist), in the Ashanti, Brong Ahafo and Central regions of Ghana. DNA has been extracted from the samples collected and molecular identification of the biotypes is on-going. To augment the breeding efforts of cassava improvement programme, studies were initiated in 2015 to determine CMV transmission efficiency by *B. tabaci* on resistant and susceptible cassava varieties. Control of the whitefly (vector of ACMVD) is not practicable under field conditions, therefore using varieties which are resistant/tolerant to the disease will be a sure way of managing the disease.

Methodology
Six cassava genotypes (including two being considered for release) obtained from the Cassava improvement programme, and two landraces were planted at Fumesua (forest ecological zone), Ohawu (coastal savanna ecological zone) and Ejura (forest-savannah transition zone) in April, 2015. The design was RCB consisting of three treatments replicated three times. Each plot

measured 5 m x 5 m. The spacing was 1 m x 1 m. The fields were weeded twice at each location. The names of the materials planted at the locations are presented as Table 128.

Table 128. Cassava genotypes/ varieties planted at three locations

Location	Genotypes / Varieties planted
Fumesua	*Bankyehemaa, Bankyebotan, Tekbankye, Ampong, Anka*/10/003, 12/0197 Land races: *Debor* and *Agyari*
Ohawu	*Bankyehemaa, Bankyebotan, Tekbankye, Ampong, Anka*/10/003, 12/0197 Land races: *Basuka* and *Hushivi*
Ejura	Bankyehemaa, Bankyebotan, Tekbankye, Ampong, Anka/10/003, 12/0197 Land races: *Debor* and *Afosa*

Data were collected from the three middle rows (with an average of 15 cassava plants per plot) at early stage (up to 3 MAP) and mid vegetative stage (6 MAP) at each location. Data collected included *Bemisia* population score, severity score and disease incidence.
Population of *Bemisia* was assessed using a scale of 0-5; where: 1= No *Bemisia* on plant; 2 = 1-20; 3 = 21-200; 4 = 201-500 and 5 = 501-1000. The extent of ACMV disease damage to the cassava leaves by the vector (*Bemisia*) was also scored using a scale of 0-5 according to standard procedure by Bellotti and Arias (2001), where 1 = no leaf damage; 2 = young leaves still green but slightly flaccid; 3 = some twisting of young leaves, slight leaf curling; 4 = apical leaves curled and twisted; yellow-green mottled appearance; 5 = considerable leaf necrosis and defoliation, sooty mold on mid and lower leaves and young stems).

Results and Discussions

Generally, *Bemisia score*, ACMD incidence and severity were high at Fumesua compared to Ejura and Ohawu especially at the early and tender stage (up to 3 months) (Tables 129, 130 and 131). At Fumesua, *Ampong, Tekbankye*, 12/0197, *Bankyehemaa* and *Anka* /10/003 recorded high *Bemisia* populations but ACMD incidence and severity were very low. This is indicative of low transmission efficiency of the vector of the disease on those cassava materials. However, *Bankyebotan, Debor* and *Agyari* recorded lower *Bemisia* population, but high disease incidence and severity showing high transmission efficiency of the disease by the vector on these materials. *Bemisia* score and disease incidence and severity at Ejura showed a similar trend to that of Fumesua. However, at Ohawu, *Bemisia* score and disease incidence as well as severity of ACMD were low. It was evident that the disease was more pronounced on crops aged less than three months compared to six months (Tables 129 and 130). This observation is expected because previous findings and records have shown that younger plants are more susceptible and therefore show more severe symptoms of the disease than older plants. Assessment based on incidence and severity of ACMD from this study has indicated that CMD is currently endemic at Fumesua and other cassava growing areas in Ashanti region. The effect of the disease was more pronounced on the local varieties such as *Debor, Agyari* and *Afosa* in terms of incidence and severity. However, *Bankyebotan,* an improved variety, showed evidence of susceptibility to the disease and should be well monitored and if found to be consistently susceptible it should be withdrawn from dissemination activities and replaced with better ones.
At locations where local varieties and *Bankyebotan* dominate, as observed in this study, it is suggested that the susceptible varieties should be replaced with improved varieties that have consumers' acceptability. The results of this study lend support to Bellotti and Arias (2001) that research on cassava whitefly management should emphasize on the development of varietal resistance. There is therefore the need to intensify our dissemination efforts in the use of farmer preferred improved varieties in the cassava growing areas in Ghana to manage mosaic infection which is one of major constraints of cassava production.

Table 129. ACMD transmission studies - Means of Bemisia population score, severity score and disease incidence up to 3 MAP and 6 MAP at Fumesua, 2015

	3 MAP			6 MAP		
Cassava variety	*Bemisia* pop	ACMV severity	% incidence	*Bemisia* pop	ACMV Severity	% incidence
Bankyehemaa	2.47	1.00	0.0	0.5	1.00	0.0
Bankyebotan	2.33	3.33	53.0	0.53	3.50	100.0
Tekbankye	2.47	1.00	0.0	0.70	1.00	0.0
Ampong	3.27	1.30	3.0	1.10	1.00	0.0
Anka/10/003	3.07	2.00	15.0	0.63	1.50	8.0
12/0197	1.70	1.00	0.0	0.13	1.00	0.0
Debor	2.37	2.67	34.0	0.87	1.70	13.0
Agyari	2.00	4.00	47.0	0.47	3.20	100.0

Table 130. ACMD transmission studies - Means of Bemisia population score, severity score and disease incidence up to 3 MAP and 6 MAP at Ejura, 2015

	3 MAP			6 MAP		
Cassava variety	*Bemisia* pop	ACMV severity	% incidence	*Bemisia* pop	ACMV Severity	% incidence
Bankyehemaa	2.23	1.67	15.0	0.53	1.00	0.0
Bankyebotan	1.93	2.30	22.0	0.27	2.70	32.0
Tekbankye	2.03	1.00	0.0	0.67	1.00	0.0
Ampong	2.37	1.00	0.0	0.47	1.00	0.0
Anka/10/003	2.33	1.70	10.0	0.53	1.00	0.0
12/0197	2.10	1.00	0.0	0.47	1.00	0.0
Debor	2.13	2.00	10.0	0.40	1.30	3.0
Afosa	2.03	2.30	10.0	0.57	3.00	35.0

Table 131. ACMD transmission studies - Means of Bemisia population score, severity score and disease incidence up to 3 MAP and 6 MAP at Ohawu, 2015

	3 MAP			6 MAP		
Cassava variety	*Bemisia* pop	ACMV severity	% incidence	*Bemisia* pop	ACMV Severity	% incidence
Bankyehemaa	2.23	1.00	0.0	0.10	1.00	0.0
Bankyebotan	1.93	1.00	0.0	1.10	1.00	0.0
Tekbankye	2.03	1.00	0.0	0.20	1.00	0.0
Ampong	2.00	1.00	0.0	0.20	1.00	0.0
Anka/10/003	1.87	1.00	0.0	0.20	1.00	0.0
12/0197	1.70	1.00	0.0	0.13	1.00	0.0
Basuka	1.80	1.00	0.0	0.23	1.00	0.0
Hushivi	1.93	1.00	0.0	0.33	1.00	0.0

Note:
Scale *for Bemisia* population score: 1= No *Bemisia* on plant; 2=1-20; 3=21-200; 4=201-500; 5=501-1000

Scale for damage/disease symptoms score:
1 = no leaf damage
2 = young leaves still green but slightly flaccid
3 = some twisting of young leaves, slight leaf curling
4 = apical leaves curled and twisted; yellow-green mottled appearance
5 = considerable leaf necrosis and defoliation, sooty mold on mid and lower leaves and young stems.

Conclusion and Recommendations

- Based on the data collected at 3 MAP and 6 MAP, it can be deduced that *Ampong, Tekbankye*, 12/0197, *Bankyehemaa* and *Anka* /10/003 have shown promise of ACMD tolerance.
- The effect of CMVD on the yield of cassava is yet to be determined/quantified
- In 2016, this study shall be repeated to collect more data to support any conclusions and recommendations that would be made

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WEED SCIENCE

Participatory Integrated Crop and Weed Management (ICWM) Practices for Enhanced Cassava Production.

Research Team: G. Bolfrey-Arku and J. Manu-Aduening

Collaborating Institutions: MoFA and EPA

Source of funding: WAAPP

Introduction

Weeds are the most under-estimated crop pests – though they are most influential in crop production activity (Akobundu, 1987, Chikoye *et al*., 2007). The perception of abundant and cheap labour supply is no more tenable due to social issues (Child labour, maternal health etc); also continuous cropping, climate and social development have put a lot of stress on the hitherto unlimited soil water supply and nutrients. Furthermore, the problem of weed interference is compounded by land tenure and cropping systems and soil degradation leading to increased/accelerated dissemination of weed seed and propagules. Cassava, one of the major food security crops and much grown by women is very susceptible to weed infestation due to its initial slow growth after planting (Alabi, 1999). A very fast growing and competitive weed such as *Euphorbia heterophylla* causes significant crop loss. Thus, farmers resort to all kinds of interventions, mostly chemical control, to minimize or mitigate the weed menace. Consequence of indiscriminate use of herbicides is shifts in weed composition or pressure, proliferation of noxious weeds and possibility of unwittingly introducing herbicide resistance weeds, health and environmental pollution. In lieu of this, the need, then, to develop an integrated weed management strategy that targets the small scale farmers, with lower income becomes imperative.

Objectives

- To improve existing weed control practices through integration of weed control practices for monocrop and intercrop cassava systems.
- To determine economic benefits and environmental implications of technologies
- To evaluate farmer perception of weed management strategies

Materials and Methods

Two cassava – maize intercrop trials laid out as a factorial experiment in RCB design with four levels of cropping systems and two levels of weed control on ridged fields were established at Fumesua and Wurompo in June 2015. The cassava and maize varieties were *Doku-Kpakpa* (late branching cassava) and *Omankwa* respectively. Plots measured 6m x 5m with 1m alley between plots in each replicate and 3m alley separating replications. Data on weed biomass, density and crop performance were collected. Cassava-maize trial at Fumesua was re-established in October 2015. The trail at Wurompo involved 10 farmers (7 males and 3 females) and one Agricultural Extension Agent (of MoFA). Field days were organised with the farmers.
Two monocropped cassava weed trials established in 2014, at Fumesua and Nsuta using *Sika bankye* (early branching) and *Doku duade* (late branching) varieties planted at a spacing of 80 x 80cm and 100 x 100cm respectively were harvested. In collaboration with EPA, the harvested roots were evaluated for herbicide residue at the Ghana Standards Authority.

Results and Discussion

Generally, application of pre-emergence herbicide coupled with reduced spacing was more effective in weed control than manual weeding irrespective of time of weeding or plant spacing (Table 132). Also, reducing cassava spacing to 80cm X 80cm improved weed control considerably compared to current recommendation of 1m X 1m spacing. At 4-8 weeks after planting (WAP), the lowest weed growth was recorded on plots treated with pre-emergence 80 X 80 herbicide Lumax at planting distance of 80cm X 80cm (Table 132) According to Johnson and Frick (2012), early weed removal protects yield. This translated to 61% reduction in weed growth relative to manual weeding within 3-4 WAP at 1 m spacing. The highest yield of 27778 kg/ha was also obtained from Lumax-treated plots.
For the early branching variety, *Sika bankye*, difference in weed growth was as a result of the type of herbicide application and or time of hand weeding.

Weed-free days required for cassava to prevent low yield is 84 days after planting (Obuo *et al*., 1999), however, current trends in farming operations makes it impossible thus, just reducing cassava spacing to effect significant weed suppression in late branching cassava may be a welcome relief. Iyagba, (2005) recommends manipulation of plant population in pumpkin as effective tool for weed control.

Table 132. Effect of spacing and pre-emergence herbicide application on weeds and cassava (var. Doku) growth

Treatment	Weed density plt/m2 4 WAP	Weed density plt/m2 8 WAP	Weed Biomass g/m2 14 WAP	Canopy Spread cm 20 WAP	Roots wt/plant (kg)	Yield (Kg/ha)
Terbulor @ 0.8 x 0.8 m	37.3	12.1	22.1	117.7	1.0	15625.0
Butachlor @ 0.8 x 0.8 m	41.7	11.5	27.3	130.5	1.2	18663.0
Lumax @ 0.8 x 0.8m	26.3	16.5	9.2	104.5	1.0	27778.0
Activus @ 0.8 x 0.8 m	58.7	31.8	46.5	110.1	1.8	15625.0
HW 3-4 WAP @0.8 x 0.8	47.8	40.6	7.5	113.1	1.4	21267.0
HW 3-4 WAP @1 x 1m	67.0	42.3	12.1	121.1	0.9	9144.0
HW 4 -5 WAP @1 x 1 m	59.8	32.9	7.0	125.0	1.1	17361.0
SE	13.3 (10%)	9.3	7.9	8.0	NS	5428.9

Results of chemical analysis of roots from the 2014 Fumesua trial indicated zero or minimal residue of evaluated herbicides in cassava roots. Butachlor detected in the fresh cassava roots was < 0.0l MRL (Minimum Residue Level) and therefore within acceptable range.

Conclusion and Recommendation(s)

It can be inferred that planting late branching cassava at a spacing of 80 x 80 cm alone or in combination with pre-emergence herbicides could be more beneficial in terms of weed control and root yield. The herbicides were relatively safe and did not leave any residue in the roots.

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Establishment of linkage between spear grass infestation and root rot incidence in root and tuber crops.

Research Team: G. Bolfrey-Arku and E. Moses

Collaborating Institution: MoFA, EPA

Source of funding: WAAPP

Introduction

Cassava production in West Africa, according to FAO (2006), has roughly doubled from 25.8 million tons to 52.3 million tons in 2004, serving as a source of income for farm households (Adjei-Nsiah et al., 2012) and also much of it is used in the agro-industries (Iyagba, 2010). However, noxious weeds such as *Imperata cylindrica* (Speargrass), described as one of the 10 most infamous weeds in the world (Holm et al. 1977) exerts detrimental effects on cassava including reduction in root yield and quality due to the piercing mechanism of the rhizomes (Willis, 2010; Khanh et al., 2007). Udensi *et al*. (1999) reported yield losses of 62-80 % in maize and cassava. Hitherto, the interest has been on just controlling speargrass without recourse to its deleterious effect on root quality. Bolfrey-Arku (2004) reported of speargrass being a possible pathway for root and tuber rot pathogens. Thus, studies were initiated to minimize the menace of speargrass infestation on cassava yield and quality.

Objectives

- To develop a sustainable speargrass management system
- To verify if piercing mechanism of the rhizomes of speargrass serve as secondary pathway to disease infection and root rot.

Materials and Methods

Trials were established at Nkonsia and Amponsakrom using split plot factorial design in mid- July, 2015. Main plot treatments comprised slashing without burning and slash –burn. Sub plot treatments consisted of four herbicides and a manual weed control and 2 levels of fertilizer application. The field at Amponsakrom was ridged whereas that at Nkonsia was mounded in accordance to the land preparation method practised by farmers in the areas. The trials involved the participation of 22 farmers (14 males and 8 females) at Nkonsia and 36 farmers (20 males and 16 females) at Amponsakrom; field days were organized at each location. The 2014 trial at Subinso was harvested in December.

Results and Discussion

Speargrass control using herbicide treatments ranged 80 – 96 %, while control was 25% for manual control (Table 133) while changing the weed flora to more broadleaves, consistent with observations by Aflakpui and Bolfrey-Arku (2007). About 50 % of roots harvested from the manual controlled plots were pierced by speargrass rhizomes compared to ≤ 16% on the herbicide treated plots. The severity was also very pronounced on the manual controlled plots, while applying the recommended rate of Glyphosate-based or Gallant herbicides greatly improved root quality relative Glyphosate at farmer rate. Root yield increased by 130% on the herbicide treated plots compared to the manual treatment confirming reports by Aflakpui and Bolfrey-Arku (2007).

Plate 31: Casssava root pierced by speargrass rhizome

Table 133. Effect of speargrass control on cassava root quality and yield

Treatment Means	Speargrass control (%)	Roots pierced (%)	Severity Score	Yield (kg/ha)
Glyphosate	93.3	15.6	1.0	27916.0
Zoomer	95.8	8.1	1.0	27604.2
Gallant	75.0	11.4	1.8	28625.0
Handweeding	25.0	46.5	5.5	11958.3
Glyphosate Farmer rate	88.3	14.8	2.3	28625.0

Conclusion and Recommendation

It can be inferred from the means of root yield that, managing speargrass with judicious use of herbicides greatly improved cassava root yield and quality. The results have been consistent for two years across different locations and the technology must be promoted.

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Development of adaptable integrated weed management technologies for sweetpotato (*Ipomoea batatas* (l.) lam.) production.

Research Team: S. O. Ekyem and F. Sarfo

Collaborating Institution: MOFA

Source of funding: WAAPP

Introduction

Sweetpotato is one of the vital household crops that make significant contribution to our economy (1).Weed control during production can be difficult. Early-season competition from weeds is extremely critical (2). Different methods of weed management have been employed in Nigeria to combat weed infestation in sweetpotato production, these include cultural control by hand pulling, hand slashing hoeing and mowing of weeds. In Ghana, farmers seldom use herbicides because of the high cost of herbicides. Herbicide application in conjunction with timely cultivation can effectively reduce weed competition, improve harvest efficiency and increase crop productivity (3). Controlling weeds with herbicides has become necessary because farm labour is limiting and expensive. (4) reported higher net economic return from the use of herbicide than hand weeding. The aim of this study therefore is to assess the influence of herbicides in the management of weeds, the growth and yield of sweetpotato

Specific Objectives

- Determine the influence of herbicides in the management of weeds in sweet potato production.
- Determine the influence of herbicides on the growth and yield of sweet potato.
- Assess the net economic return from the use of herbicide compared to hand weeding.

Materials and Methods

Field experiments were conducted at Jukwa and Ohawu during the rainy and dry seasons of 2015. The design was RCB, replicated four times. The field was manually cleared with cutlass and ridges constructed 1m apart. Plots measuring 6m x 4m were laid out with 1m border between plots. Vines of sweetpotato, variety *Okumkom,* with five nodes were planted in June 2015, at a spacing of 30cm at both locations. Different herbicides were subsequently applied to control weeds on the plots. The herbicides (treatments) applied are presented as Table 134.

Table 134: Herbicides applied as treatments on sweetpotato plots

Treatments
Activus + Slashing – T1
Terbulor + Slashing – T2
Atrazila + Slashing – T3
Butachlor + Slashing – T4
Diuron + Slashing – T5
Vezir + Slashing – T6
Lumas + Slashing – T7
Hoeing/Slashing (Control) – T8

The spraying machine was calibrated to deliver 250L per hectare of the herbicides. Weed density and biomass were recorded at 5, 10 and 15 weeks after transplanting (WAT). Fresh weed samples were collected and oven dried at 85°C for 48h to obtain the dry biomass. The crops were harvested at 16 WAT.

Results and Discussions

At Jukwa, weed density under T1 and T4 were not significantly different. T1 produced the lowest weed density, followed by T2 which was also not significantly different from T4 at 6 WAP. This was the best treatment in terms of suppressing weed growth at the early stages of crop growth. Effective weed suppression at the early crop growth stages results in healthy crop stand. In terms of weed dry matter, the effects of T1, T2, T4 and T6 were not significantly different with T1 producing the lowest as compared to the control which had the highest.

Root yields under T1, T2, T4, T6 and the Control were high but not significantly different compared to T3, T5 and T7 (Table 135) which produced relatively low yields and showed some level of phytotoxicity to the crop.

Table 135: Weed density, weed dry matter and root yields at Jukwa at 6 WAP

Treatment	Weed density/m^2	Weed Dry Matter Yield (Kg/m^2)	Root Yield (t/ha)
T1	9.50 E	0.0975 D	9.725 A
T2	15.75 CD	0.1550 D	9.850 A
T3	27.00 A	1.1625 AB	3.900 B
T4	13.25 DE	0.1950 D	9.675 A
T5	21.75 B	0.7775 C	4.700 B
T6	19.00 BC	0.1675 D	10.025 A
T7	21.00 B	0.8650 BC	4.600 B
T8	30.25 A	1.4500 A	9.450 A
CV	17.59	41.49	13.52
LSD (5%)	5.0927	0.3714	1.5387

At Ohawu, the effects of T1, T4, T2 and T6 on weed density were not significantly different and were lower as compared to the control (T8). T1 has been outstanding, as the most effective treatment. This was the best in terms of suppressing weed growth at the early stages of crop growth. In terms of weed dry matter, T1, T2, T6 and T4 were not significantly different and lower as compared to the control (T8).

Root yields under T1 (Activus), T2 (Terbulor), T4 (Butachlor), T6 (Vezir) and T8 (Control) were not significantly different and were higher than yields under T3 (Atrazila), T5 (Diuron) and T7 (Lumax) which showed some level of phytotoxicity to the crop (Table 136).

Table 136: Weed density, weed dry matter and root yields at Ohawu at 6 WAT

Treatment	Weed density/m^2	Weed Dry Matter yield (kg/m^2)	Root yield (t/ha)
1	8.50 D	0.1100 D	5.500 A
2	13.00 CD	0.1700 D	5.625 A
3	22.25 B	1.2100 B	0.582 B
4	12.75 CD	0.2075 D	5.225 A
5	18.50 BC	1.0350 C	1.067 B
6	13.50 CD	0.1700 D	5.550 A
7	15.50 BC	0.9375 C	1.037 B
8	40.00 A	1.7475 A	4.725 A
CV	25.55	13.06	30.89
LSD (5%)	6.7635	0.1342	1.6645

Conclusion

Activus, Terbulor, Atrazila have followed a consistent trend and are promising herbicides, with Activus leading in chemical weed management in sweetpotato at 6 WAP.

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Development of adaptable integrated weed management technologies for cocoyam production.

Research Team: S. O. Ekyem and F. Sarfo.

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

Cocoyam (*Xanthosoma sagittifolium*) (L.) Schottis, is a herbaceous perennial plant belonging to the family Araceae and is grown primarily for its edible cormels, although all parts of the plant are edible (1). A major militating factor in the production of cocoyam in this part of the world is weed infestation especially during the early growth stage of between 4-12weeks. For cocoyam, there could be serious yield reduction when weed competition is high during canopy formation and early tuberization (2). Losses in cocoyam due to weed infestation could be substantial (3). It has been reported that a larger proportion of labour requirement in crop production goes into weed management. Generally, manual weeding alone accounts for around 30% to 45% of the total cost of production (8). In Ghana, farmers seldom use herbicides because of their high cost. Controlling

weeds with herbicides has, however, become necessary because farm labour is limiting and expensive. (4) reported higher net economic return from the use of herbicide than hand weeding. The aim of the experiment therefore is to understudy the influence of herbicides in the management of weeds, the growth and yield of cocoyam.

Specific Objectives

- Determine the influence of herbicides in the management of weeds in cocoyam production.
- Determine the influence of herbicides on the growth and yield of cocoyam.
- Assess the net economic returns from the use of herbicides compared to than hand weeding.

Materials and Methods

Field experiments were conducted at Ejisu-Kwaso and Kukuom-Datano during the rainy and dry seasons of 2015. The field was initially manually cleared with cutlass and plots measuring 8m x 4m were laid out with 1m border between plots. The design was RCBD and replicated four times. Cocoyam cormels were nursed for four weeks and seedlings transplanted one per hill at a spacing of 1m x 1m, on April 27 and May 04, 2015 at Kukuom-Datano and Ejisu-Kwaso respectively. The variety used was "*Gyemedi*". Different herbicides were applied (as treatments) for subsequent weed control on the plots and to assess their efficacy (Table 137).

Table 137. Herbicides applied as treatments on cocoyam plots.

Treatments	
Activus + Slashing	- T1
Terbulor + Slashing	- T2
Atrazila + Slashing	- T3
Butachlor + Slashing	- T4
Diuron + Slashing	- T5
Vezir + Slashing	- T6
Lumas + Slashing	- T7
Hoeing/Slashing (Control)	- T8

Results and Discussions

At Kukuom–Datano, T1 produced the least weed density at 6 WAP. This was the best in terms of suppressing weed growth at the early stages of crop growth. T1 was followed by T2 and T4 (Table 138). Weed suppression at the early crop growth stages results healthy crop stand. This is remarkable compared with the "Control" which produced a weaker crop stand.

In terms of weed dry matter, T1, T2, T4 and T6 produced low figures and were not significantly different. The control produced the highest. T1 had the lowest, followed by T2.

Table 138: Weed density and dry matter yield at Kukuom – Datano at 6 WAT

Treatment	Weed density/m^2	Weed Dry Matter Yield (Kg/m^2)
T1	14.00 F	0.0875 D
T2	19.00 E	0.1375 D
T3	38.00 B	1.4925 B
T4	19.50 E	0.2100 D
T5	31.50 C	1.3275 C
T6	25.50 D	0.2050 D
T7	29.25 CD	1.1975 C
T8	49.00 A	2.1225 A
CV	10.26	11.93
LSD (5%)	4.259	0.1486

Table 139: Weed density and dry matter yield at Ejisu – Kwaso at 6 WAT

Treatment	**Weed density/m^2**	**Weed Dry Matter yield (Kg/m^2)**
T1	10.75 E	0.0825 D
T2	17.50 D	0.1425 D
T3	29.75 B	1.1725 B
T4	15.25 DE	0.1775 D
T5	24.25 C	0.9625 C
T6	17.50 D	0.1450 D
T7	20.00 CD	0.8750 C
T8	38.00 A	1.7350 A
CV	15.37	15.39
LSD (5%)	4.8877	0.1498

At Ejisu – Kwaso, T1 had the lowest weed density at 6 WAP and was the best herbicide in terms of suppressing weed growth at the early stages of crop growth. It was followed by T4, T2 and T6. In terms of weed dry matter, T1, T2, T6, T4 and T3, were not significantly different (Table 139).

Conclusion

Activus, Terbulor, Atrazila have followed a consistent trend and are promising for chemical weed management on cocoyam fields in the early stages of crop growth.

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SOCIO-ECONOMICS

Diagnostic survey of Taro Industry in Ghana

Research Team: P. Acheampong, R. Sagoe, K. Agyemang and L. Brobbey

Collaborating Institutions: MOFA and **Taro stakeholders**

Source of funding: WAAPP

Introduction

Taro plays a critical role in household, community and national food security. It supplies carbohydrate, protein, vitamins and minerals from both the corm and the leaves (Wilson and Siemonsma, 1996). Its role in rural development with respect to the provision of employment and the alleviation of rural poverty cannot be underestimated. Surpluses from subsistence production manage to find their way to market, thereby playing a role in poverty alleviation. More recently, taro has become a source of income for individuals, and foreign exchange earner, especially in some countries in Asia and Oceania (Onwueme, 1999).

The potential of the crop is largely untapped in Ghana due to many constraints associated with it, and this has contributed to its low production in recent years. Over the years, taro leaf blight, the most destructive disease of taro has reduced taro production in Ghana.
The disease continues to devastate taro fields and is impacting negatively on the livelihoods and welfare of farmers and rural communities where taro is a staple food Ghana (Omane et al., 2012). In order to revamp the taro industry, WAAPP has offered support for research on the crop. This study has an overall goal of investigating the taro industry - production, processing, marketing and consumption - to come out with recommendations for policy interventions. The objective of this work is to conduct baseline survey to quantitatively diagnose the problems and constraints to taro production, processing, marketing and consumption in Ghana.

Objectives

- To assess the constraints to taro production, processing and marketing in Ghana
- To identify potential areas for possible revamping of the taro industry in Ghana

Methodology

- Participatory learning and action (PLA) survey

  Transect walks were used to map out resources (soils and land types, crops, trees and animal types) in the community which were mapped to identify specific problems and potential opportunities for development. Timelines were used to trace historical trends of taro production. Problem trees were used to mark out causes and effects of problems from production through to utilization. Constraints and perceptions were deduced through ranking activities. Three PLA surveys were conducted in the Sekyere South, Bekwai Municipal and Ahofo Ano South districts of Ashanti region. This approach was used so that future interventions would easily be adopted by stakeholders.

- Quantitative survey

  Structured questionnaires were used to collect data from sampled taro farm households, marketers, processors and consumers in the Ashanti, Brong Ahafo and Eastern regions covering the Ahafo Ano South, Sekyere South, Asutifi North and South and Fanteakwa districts. Data collected included socio-economic characteristics (sex, age, occupation, marital status, preferences, farm size, household size etc) of respondents. Multistage sampling technique was used to randomly select the sample units and face-to-face interviews were conducted with them.

Results and Discussion

- **Socio-demographic characteristics**

  Four hundred taro stakeholders (producers, processors, marketers and consumers) made up of 62.3% males and 37.7% females participated in the interviews. Their mean age was 48 years and mean number of years in education was 8 years. Mean household size was 4 members.

- **Taro production**

  In all the areas, farmers identified two to three varieties of taro - the white taro, the purple taro and '*Asante kooko*' - for production. All were local varieties which have been cultivated for many years. The '*Asante kooko*' seemed to be indigenous while the others are introductions from other parts of the country. The varieties and their characteristics are presented Table 140.

Table 140. Taro varieties and their characteristics

Variety	Characteristics
'Asante kooko'	• Difficult to cook (cooks overnight) • Very sweet • Grown upland • Has white patches on the leaves
White taro (*Kooko fitaa*)	• Easy to cook • Tasty • Grown lowland and upland • Has light green leaves
Purple taro (*Kooko kɔkɔɔ*)	• Easy to cook • Sticky when cooked • Tasty • Grown lowland and upland • Has light green leaves

The '*Asante kooko*' is hardly cultivated due to the difficulty in cooking. According to the farmers, the white and the purple taro have been disseminated through the informal seed system. The purple taro is more preferred than the white taro. Farmers used their own seeds from the previous harvest or obtained seeds from other farmers. Four types of planting materials (seeds) were used - side suckers, small corms, headsetts and corm pieces. The small corms and the headsetts were often used for planting. The use of headsett is very advantageous because it does not include the edible part of the plant. It also establishes quickly. The only disadvantage is that it has to be planted soon after harvesting. Taro production had dwindled due to the effect of taro leaf blight and only 1% of farmers interviewed had taro fields.

- **Improved technologies**

  No improved technology for taro production has been developed in Ghana. Producers relied on indigenous technologies. Of the farmers interviewed, 84% planted randomly in the field, 94.3% had never applied fertilizers and 72.4% had never applied herbicides on their taro fields. No producer had ever heard of improved taro varieties.

- **Constraints to production**

  Very few (1%) of the farmers in the study area had taro on their fields, due to the devastating effect of taro leaf blight that has almost wiped out the whole taro population. The disease affects the leaves and petioles of the plants, causing extensive damage of the foliage (Singh et al., 2012). Other constraints to production include drying up of inland valleys, illegal mining activities, decline in soil fertility, contamination from chemicals applied on rice and vegetable fields.

- **Processing**
  Taro is not processed on a large scale in Ghana. Processing of taro is at the household level, mainly into traditional dishes. The main food/dishes prepared from taro corms are presented as Table 141.

Table 144. Traditional food products from taro corms

Food product	Description
Eto	Sliced taro is roasted or boiled and mashed with pepper, onion and palm oil in earthen ware pots.
Nuhuu	Taro is cut into smaller pieces and boiled in prepared palm nut or vegetable and fish soup.
Ampesi	Sliced taro is boiled and eaten with vegetable sauce
Roasted taro	Taro is roasted in an open fire with the skin, which is later peeled off
Taro chips	Taro is cut into pieces (chips) and fried in vegetable oil
Fufu	Taro is boiled and pounded into a paste (only the upland varieties can be used for fufu)

There used be roadside processors who processed taro into fried chips or roasted the sliced corm. Currently taro is processed only in the homes of producers, as they are not able to produce in commercial quantities. Ninety five percent (95%) of producers, however, expressed willingness to produce taro on a larger scale, should they have access to improved disease free varieties.

- **Marketing of taro**
  Marketing of taro is either carried out at the farm or in an open market. The harvested corms are either packed in baskets or in sacks. In the Sekyere South district where there was brisk business as buyers were coming from Kumasi and Takoradi to buy from the farmers. Farmers were informed in advance about the coming of most of the buyers and they would harvest the crop and pack them in heaps in the farm. The buyers would select the medium to large sized cormels and re-bag them into 50kg bags which they would transport to the road side and then to their destinations. Other local buyers or the farmers themselves would carry the remaining corms to the local markets and sell to local consumers or processors.
  Prices of taro are relatively lower than other crops, but farmers are able to make sales all year round and that encouraged them to produce continuously. In the study area much of the taro was produced for home consumption and the excess sold in the market for income. All producers interviewed used to sell taro during the lean season. Though they complained of low prices, they still made some money from the crop.

- **Impact of taro production**
  The impact of taro production on livelihoods was enormous as producers used the proceeds to pay school fees (55.2%) and medical bills (57.6%), purchase of other food items (64%) and clothing (61.2 %) as well as for savings and social events. Taro is eaten when farmers are planting new crops. It also served as convenient food for school children during the lean season.

Conclusion and Recommendation

The impact of taro on livelihoods is enormous in some areas, though production is mostly for home consumption. Taro leaf blight disease is a threat to the crop. Ninety-five percent of producers asked for improved and disease-free varieties. There is need for intensive research on the crop to develop improved varieties and to mitigate effect of the blight disease on the crop.

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Towards the establishment of CAY-Seed Innovation Platform: Stakeholder Analysis

Research Team: P. Acheampong, S. Ennin, K, Osei, S. Alimatu and L. Brobbey

Collaborating Institutions: Catholic Relief Services, MOFA and Yam stakeholders

Source of funding: BMGF

Introduction

Innovation platforms (IP) are ways to bring together different stakeholders to identify solutions to common problems or to achieve common goals. Members ensure that their different interests are taken into account, and various groups contribute to finding solutions (Pali and Swaans, 2013). CAY-Seed IPs were formed in the two project implementation sites - Ejura-Sekyeredumase and Atebubu Amantin districts. The goal is to ensure that different stakeholders with different backgrounds and interests mainly farmers, agricultural input suppliers, traders, traditional leaders, researchers, government officials, transporters, etc, come together to develop a common vision concerning seed yam production and to find ways to achieve higher productivity and market linkage. To get farmers to produce clean seed yams, there is the need for researchers to engage more with farmers and other stakeholders to explore, design and implement solutions.

Objectives

- To identify stakeholders under seed yam production
- To gather information to determine whose interests should be taken into account in the implementation of positive selection for seed yam production.

Methodology

In June-July 2015, stakeholders under seed yam production in the Ejura and Atebubu districts were identified with district MoFA Extension units and asked to be part of the IPs. A preliminary meeting was held with the stakeholders at Ejura and Atebubu on August 19 2015 and August 21 2015 respectively to introduce the project's objective and to conduct stakeholder analysis. A power analysis was carried out to determine a stakeholder's ability to affect or block the implementation of the positive selection technology. For this analysis, the stakeholders were divided into three groups (Table 142)

Group 1: Those who have leadership and high power (stakeholders who have direct influence on the CAY-Seed project)

Group 2: Those who have leadership and medium power (those that have moderate influence on the project but have the capacity to lead an action against or for the project)

Group 3: Those who do not have leadership but have high to medium power (stakeholders that do not influence the project directly but still have the ability to influence or lead an action against or for the project) (Crosby, 1992).

Results and Discussion

At Atebubu 82 stakeholders made up of farmers (60), traders (8), transporters (4), MOFA extension workers (6), a traditional leader, research scientists (3) and an NGO representative attended the preliminary meeting. At Ejura there were 59 stakeholders of similar composition.

Table 142. Leadership and the power groupings under the CAY –Seed project.

Group 1	**Group 2**	**Group 3**
Researchers	Traders	Laborers
Farmers	Transporters	Loading boys
MOFA	Land owners	
Ministry of Local government	Financial institutions	
Tractor operators	Transport ministry	

The above grouping is based on the principle that those with leadership and power will be most able to affect the implementation of the CAY-Seed project, although less powerful stakeholders e.g. laborers who lack leadership may still be able to affect the implementation.

The knowledge of stakeholders about the project was also analyzed in order to focus our communication during the implementation of the project. The stakeholders were grouped into three according to their knowledge levels - those with low knowledge, those with some (medium) knowledge and those with high knowledge. Table 143 shows the knowledge groupings of the stakeholders.

Table 143. CAY-Seed stakeholder knowledge levels

Group 1 (Low)	Group 2 (Medium)	Group 3 (High)
Traders	Farmers	Researchers
Transporters	MOFA	
Land owners		
Financial institutions		
Laborers		
Land owners		

It was realized that most of the stakeholders had low knowledge about the project. The need for the project leadership to educate all stakeholders about the project is therefore important.

Stakeholders were also asked to mention potential stakeholders that might oppose the successful implementation of the project. This was done in order for the project to target those actors in their project implementation process. Figure 1 presents the supporting groups and the opposing groups.

The identified potential opponents have the ability to impede the project implementation and therefore must be involved in the implementation of the project. Thus their continuous participation in the innovation platforms is imperative.

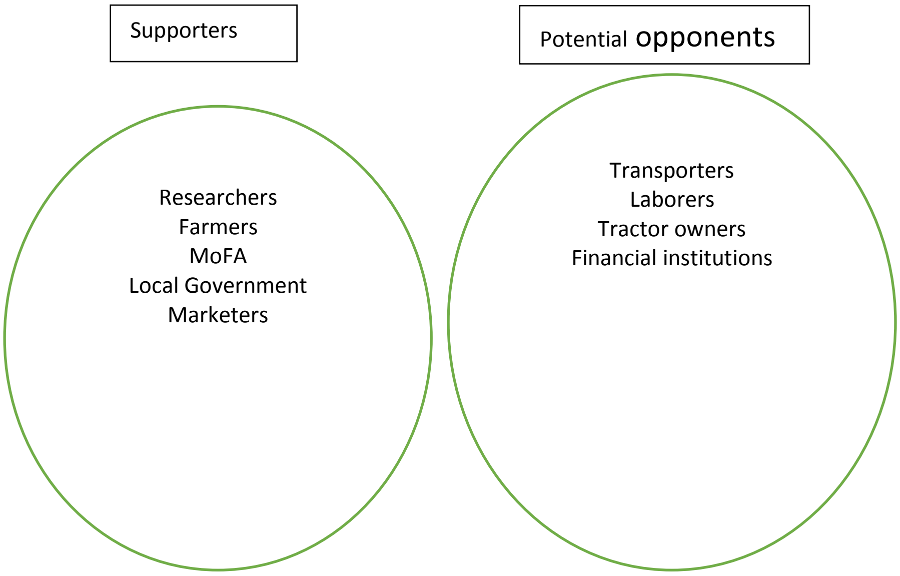

Fig. 43. Supporters and potential opponents of the CAY-Seed project in the study area

Stakeholder expectations and commitment

Stakeholders from both districts identified several potential benefits from the project such as:

- Improvement in knowledge in seed yam production
- Ability to differentiate between diseased and healthy yam plants
- Opportunity to learn good cultural practices
- Access to improved yam variety
- Access to capital to expand yam production
- Access to improved roads
- Ability to negotiate for good prices
- Capacity to store yams

Several possible disadvantages to the implementation of the project were also identified. These included:

- Low access to inputs such as laborers and fertilizers
- High cost of production
- Poor roads
- Lack of financial support
- Low prices of produce
- High cost of transport
- Poor post-harvest handling

Stakeholders conditioned their support for the project on:

- Transparency in the project implementation process
- Active involvement in the implementation of the project
- Support in accessing factors of production

Conclusion and recommendations

The stakeholder analysis revealed that various stakeholders could influence the successful implementation of the CAY-Seed project. Since some potential opponents of the project have been identified there is the need to convince them to buy into the project. There is the need to educate the stakeholders since most of them have little knowledge about the project. Efforts should also be made to meet the expectations of stakeholders.

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Willingness to Adopt Biochar Soil Amendment Technology for Yam Production in Ghana

Research Team: Jonas Osei-Adu, M. Akom, S.A. Ennin, E. Otoo, E. Yeboah, E. Owusu Danquah and F. Frimpong

Collaborating Institution: CSIR-SRI

Source of funding: WAAPP

Introduction

Yam is an important crop for at least 60 million people (producers, processors and consumers) in West Africa providing income and nourishment for people in the sub-region. In Ghana yam is the most important food crop in terms of output value (Asante et al; 2014). It contributes about 17% of agricultural gross domestic product and also plays a key role in guaranteeing household food security (Kenyon and Fowler, 2000). Soil nutrient depletion, however, is a fundamental cause of declining per capita food production in sub-Sahara Africa. Integrated soil fertility management (ISFM) is a promising tool. Despite the proven increased yields and improved soil fertility attributable to ISFM, the adoption of ISFM techniques among smallholder farmers remains low. This has led to the need to search for alternative soil management practices such as the biochar amendment technology, which has additional environmental benefits in terms of reduced green house emissions.

Objectives

- To generate baseline data on farmers' willingness to adopt biochar technology

Specific objectives

- Estimate farmers' willingness to adopt and its socio-demographic determinants
- Analyse gender diversity of soil management for production
- Understand and establish the constraints to soil fertility management

Materials and Methods

The study was conducted in the Ejura-Sekyeredumase district in the Ashanti region. The two stage multi-stage sampling procedure was used to sample a total of 100 farmers across nine communities in the district. Data were generated through face-to-face interviews using a standardised questionnaire and analysed using parametric and non-parametric methods.

The non-parametric methods involved the use of tables, graphs and descriptive statistics in establishing relationships and trends. The parametric method was based on regression analysis in estimating a conditional logit model for willingness to adopt and its determinants.

Results and Discussion

- **Willingness to adopt biochar**

  To determine respondents' willingness to adopt the biochar technology, a conditional logit model was estimated (Table 144). From the model, planting of nitrogen-fixing crops, use of mulch/cover crops, and use of inorganic fertilizer and manure had significant effect on farmers' willingness to adopt biochar technology at 1%, 5%, 10% and 1% level respectively. In terms of direction, the negative coefficient for planting nitrogen fixing crops (-6.071), mulching/cover crops (-2.071) and inorganic fertilizer (-1.973) indicates that respondents are mostly likely to adopt biochar rather than these options. They are however most likely to adopt manure application (5.249) instead of biochar since the former gave a positive coefficient. These results imply that the biochar technology has a high rate of success if promoted on the basis of the attributes respondents are made aware of, during the study. Promoting it along with manure application will be advantageous since respondents are less willing to adopt biochar compared to manure application.

Table 144. Conditional Logit Model estimates for willingness to adopt biochar soil amendment

Variables	Coefficient	S.E	P-value
Planting of nitrogen fixing crops	-6.071***	1.713	0.000
No /minimum tillage	-1.263	0.896	0.159
Mulching /Cover crop	-2.071**	0.852	0.015
Inorganic (Chemical fertilizer)	-1.973*	1.021	0.053
Organic (Manure)	5.249***	1.089	0.000
Inter cropping	0.737	0.708	0.298
Shifting cultivation	-0.284	0.675	0.674
Crop rotation	0.087	0.636	0.892
Constant	2.615	1.253	0.037
Log likelihood	77.613		
Cox & Snell R Square	0.418		
Nagelkerke R Square	0.571		

Note: *** indicates significance @ 1%, ** @ 5% and *@ 10%

- **Socio demographics determinants of willingness to adopt Biochar soil amendment**

Estimating a conditional logit model for socio demographic determinants revealed that residential status (10%), farming experience (1%), membership of FBO (1%) and household size (5%) had significant effect on respondents' willingness to adopt the biochar technology. The direction of their coefficient indicated that a respondent who is an indigene is more likely to adopt biochar than a migrant since it had a positive coefficient of 2.959. Respondents with more years of farming experience (0.076) were also most likely to adopt biochar. As household size increases (-0.196), respondents are less willing to adopt biochar which means the promotion could focus on smaller households with less dependency and that can save resources to invest in the technology. The negative coefficient for FBO membership (-2.437) indicate that members of FBOs are less willing to adopt biochar. This can be linked to the motivation for joining FBOs which was focused on access to credit rather than improved soil technologies.

Table 145. Conditional Logit Model estimates for socio demographic determinants of willingness to adopt biochar soil amendment

Variables	Coefficient	S.E	P-value
Gender of respondent	-0.244	1.004	0.808
Marital Status	-1.334	1.357	0.326
Education Experience	-0.001	0.088	0.987
Residential status	2.959*	1.565	0.059
Farming Experience	0.076***	0.026	0.003
Participation in training	-0.608	0.659	0.357
Membership of FBO	-2.437***	0.752	0.001
Age of household head	0.016	0.037	0.663
Household Size	-0.196**	0.078	0.012
Constant	1.636	1.981	0.409
Log likelihood	74.116		
Cox & Snell R Square	0.438		
Nagelkerke R Square	0.598		

Note: *** indicates significance @ 1%, ** @5% and *@ 10%

Conclusion and Recommendation(s)

From the study, it can be concluded that yam farmers within the Ejura Sekyeredumase district are willing to adopt the biochar technology to planting nitrogen fixing crops, use of inorganic fertilizers and mulching. They are however less willing to adopt biochar compared to the use of manure. Four main socio-demographic factors determines their willingness to adopt biochar namely; household size, membership of FBO, residential status and farming experience. To promote biochar within the district will require improved awareness creation since only 29% of respondent were aware of technology.

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Economic Assessment of the Ghana Seed Yam System

Research Team: J. Osei-Adu, N. E. Amengor and A. Adu Appiah

Collaborating Institution: MOFA

Source of funding: WAAPP

Introduction

Access to quality seed yam for production is one of the major constraints to production. Farmers have generally used the milking technique to generate seed yams for planting. To improve access to quality seed yam, improved techniques such as minisett, vine technology and application of tissue culture have been developed to increase the multiplication ratio. However, after years of disseminating these imrpoved techniques, data are limited on the economic viability and cost effectives of these techniques. There is also lack of data on how the seed systen functions in terms level of awareness and use of the various multiplication techniques. Gender diversity of the seed system has also not been assessed, making it difficult to develop gender-focused programmes to empower the minority groups. It is to these effects that This study was therefore commissioned to generate relevant data for improving the seed system leading to improved ware yam productivity and output.

Objectives

The specific objectives of this study were to:

- Identify the socio-economic drivers of adoption
- Establish the level of awareness of the different seed multiplication techniques
- Estimate economic viability of the seed system

Methodology

This study took place in the Techiman and Ejura Sekyereduamse districts. Using multi-stage sampling, a total of 200 households were sampled and interviewed with a standard questionnaire. Data were analysed using descriptive statistics and graphs.

Results and Discussion

- **Seed Multiplication Method**

In the study areas an average of 93% of respondents used milking to generate seed, with 11% using small-sized ware yams as planting materials. The practice of milking was higher in Techiman (98.9%) than Ejura (93%) – Fig. 44. This system prevents ware yam from growing to maturity which affects tuber size and subsequently the price. The multiplication ratio is low compared to minisett and other improved methods. The need to introduce improved methods to increase the amount of planting materials is therefore paramount.

Reasons for milking

Yam farmers in the study areas used milking to generate seed yams for the following reasons:

- Lack of alternative means of generating seed yam (90% of respondents in Ejura and 49% in Techiman with a mean of 69.5%) – Fig 45.
- Lack of quality seed yam on the market. This calls for intensive education on alternative seed multiplication techniques.
- Inadequate self-generated seed

- **Source(s) of seed**

  Among the respondents 92% had access to seed yam from their own sources – by the milking method (Fig 46). Very few (2.5%) of them bought seed from the market. Farmers did not buy seed from the market due to the belief that such seed normally do not germinate. Further studies are required to substantiate this claim. To develop an efficient seed system at the commercial level there is the need for education and sensitisation.

- **Awareness of improved seed multiplication techniques**

  Respondents were aware of only the minisett technique for generating seed yam, among others such as the vine technology, application of tissue culture and aeroponics. The level of awareness of the minisett technique was 46% and 14% for Ejura and Techiman respectively (Fig 47). Awareness level for Ejura was higher than for Techiman due to the conduct of research activities at research stations in the area. Research projects such as CAY Seed, WAAPP and YIIFSWA, which are all promoting improved technologies were being carried out at Ejura. There is the need to go beyond awareness creation to promote adoption to improve productivity.

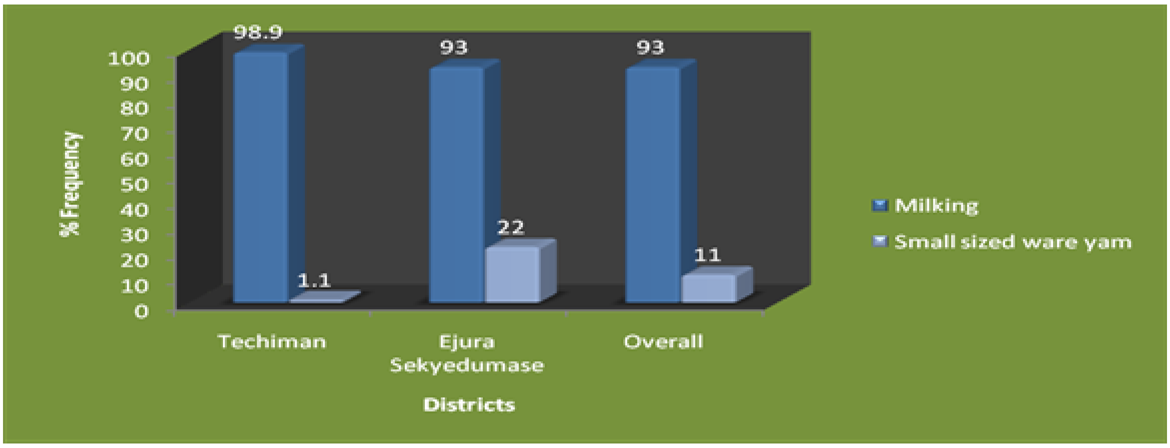

Fig. 44. Seed multiplication methods

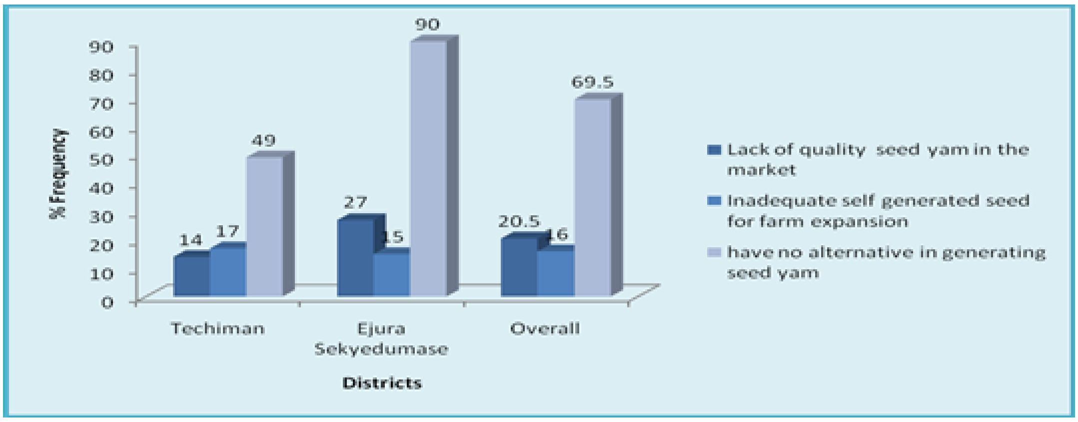

Fig. 45. Reasons for milking Source: Field Survey, 2015

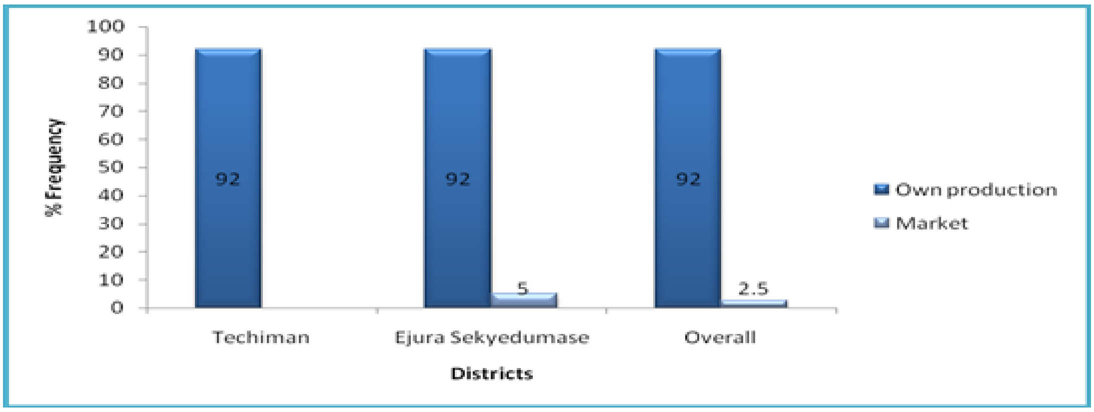

Fig. 46. Source of seed Source: Field survey, 2015

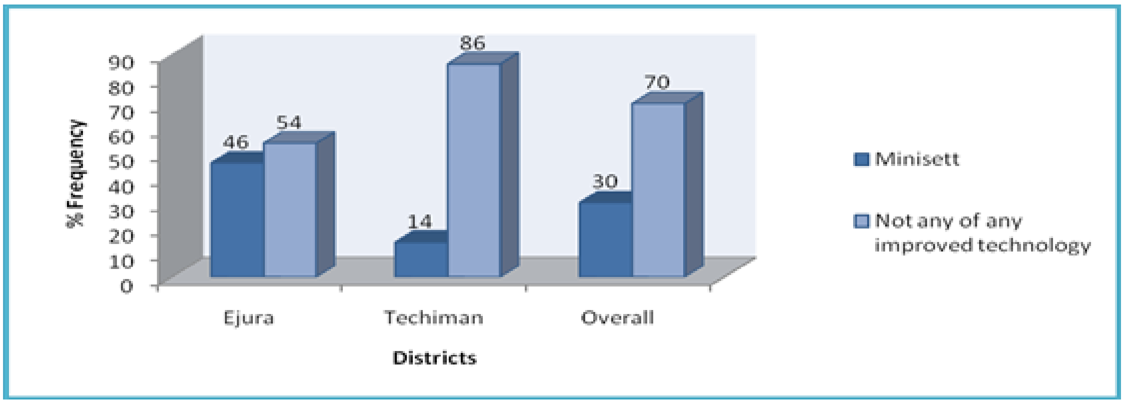

Fig. 47. Awareness of improved multiplication techniques Source: Field Survey, 2015

Conclusion and Recommendation

From the study, it is clear farmers still rely on the traditional milking system to generate seed yam. This method has a low multiplication ratio and cannot meet the farmers' demand. Lack of adequate knowledge about alternative means of generating seed was cited as the main reason for relying on milking. To improve on the rate of adoption of improved seed generation methods will require intensive promotion and a favourable policy environment. This will improve productivity and increase output. Getting the youth into yam production would help to sustain the seed system

Integrated Agricultural Research for Development (IAR4D)-Innovation Platform (IP)

Research Team: J. Osei-Adu and S. Darkey

Collaborating Institution MOFA

Source of funding: WAAPP

Introduction

The concept of Integrated Agricultural Research for Development (IAR4D) is seen as the new paradigm for Research for Development (R4D) in terms of its ability to ensure effective technology dissemination through complex social interaction. IAR4D has been operationalised through the formation and management of Innovation Platforms (IPs). IPs are multi stakeholder organisations developed to create innovations based on identified opportunities or challenges for the development of society. To ensure that WAAPP-Ghana makes the needed impact, IAR4D has been adapted as a central tool for project implementation.

Targets/Objective(s)

Activities for the year focused on:

- Capacity building for facilitators
- Establishment of community innovation platforms
- Material supply and support for effective adoption
- Monitoring and coaching visit by ICRA (CORAF CONSULTANT)

Methodology

Capacity building was led by ICRA and resource persons from CSIR-CRI. Resource persons from CSIR-CRI established community IPs as part of the training programmes. Mentoring and coaching was jointly done by CSIR-CRI and 3'A Agribusiness Consult (ICRA consultant).

Results and Discussion

- **Capacity building for facilitators**

  To ensure that the needed human resource is well equipped to establish and manage IPs, a two- phase approach to capacity building was adopted. Two trainer-of-trainers workshops were organised at Koforidua and Sunyani for the southern and northern sectors respectively. These trainings were facilitated by ICRA (who are consultants to CORAF). Sixty-eight participants made up of MoFA extension workers, MoFA District and Municipal Directors, other MoFA staff and staff of CSIR participated in the workshops.

  As a follow up to the two workshops, regional training workshops for community IPs facilitators were also organised. These workshops brought together extension officers from selected Districts/Municipals within the regions. These officers were trained in IP formation and functionality. There were 70 participants from MOFA (68) and CSIR-CRI (2). Cumulatively, capacity building activities benefitted 138 people across the regions.

- **Establishment of New IPs**

  For effective technology dissemination and adoption, 24 new community IPs were established in Northern region (6), Upper East (5), Upper West (6) and Brong Ahafo (7). This was also a follow-up to the regional trainings for extension facilitators where extension facilitators together with resource persons established community IPs as part of the training. Entry points were identified using Strength, Weakness, Opportunities and Treats (SWOT) analysis. Major challenges identified included; lack of tractor services and planting materials, lack of working capital, low demand of produce and poor pricing, among others. Opportunities included the presence of markets, financial institutions and MoFA Extension workers. After the SWOT analysis, entry points for the various IPs were identified namely; improved access to tractor services, planting materials and capital, among others. Work plans were developed for the first quarter of 2016 to guide IP operations. A monitoring framework is needed to ensure that planned activities are undertaken effectively.

- **Support for Effective Adoption**

  Some level of support was provided to the IPs at Adziedu kope, Nyankumasi and Sofa to make them effective. For Nyankumasi, a cocoyam growth chamber was established to produce cocoyam planting materials. Three improved cocoyam varieties - *Akye de, Mayeyie* and *Gye medi* were under multiplication and as at September 2015, 152 plantlets of *Akye de*, 148 of *Maye yie* and 77 of *Gyeme di* were in the growth chamber.
  Two solar dryers and a smokeless stove were constructed at Adziedu Kope as part of the process of transforming the community into an integrated technology transfer village. Ten improved pens for housing goats and sheep were also provided to strength the crop-livestock integration aspect of the cassava value chain.

Plate 31: Cocoyam growth chambers (at Nyankumasi)

Plate 33: Solar dryer (at Adziedu Kope)

Conclusion and Recommendation

Enough IP facilitators have been trained and awareness have been created among major stakeholders such as RELC coordinators, District and Regional MoFA Directors, other staff of MoFA and CSIR staff. There is the need for developing an effective framework for ensuring functionality and sustainability of the IPs and up scaling them into regional and national IPs for large scale impact. Addressing major operational challenges such as difficulty in resourcing extension facilitators to organise IP meetings, lack of resources to engage service providers to discuss issues affecting the IPs and provision of basic infrastructure / facilities in some communities and high expectations from beneficiaries, amomg others will provide the enabling environment for efficient IP operations.

Gender Sensitization and Training Needs Assessment of CAY Seed Project Partners

Research Team: J. Haleegoah, S. Ennin. P. Acheampong, B. Nsiah Frimpong and L. Brobbey

Collaborating Institutions: Catholic Relief Services (CRS) and MOFA

Source of funding: CAY Seed Project

Introduction

The CAY Seed Project is a three-year project sponsored by the Bill and Melinda Gates Foundation (BMGF) on community action for improving farmers' saved yam seeds for increased productivity in Ghana and Nigeria. It is being implemented in Ghana by CSIR- CRI in collaboration with other partners in Ghana and in Nigeria. Gender sensitization is an activity under Component 3 of the project which deals with gender and social dynamics in seed yam production. Studies have shown that women play some roles in yam production (Philips et. al., 2013) but there are differing constrains to women and men in yam production (Ojo et al., 2013). According to Simonyan and Obiakor (2012), gender is important and relate positively to technical efficiency in yam production with men reported as being more technically efficient than women. The main objectives of this component is to mainstream gender into project activities and assess and document the gender and social dynamics of community behaviour change in yam production practices in Ghana and Nigeria. This will help to build capacities of all genders on the positive selection of seed yams and agronomic packages for improved yam productivity.

Objectives

- Sensitize project partners on the need for equal representation and participation of gender in project implementation
- Ensure equal representation and participation of all genders in project activities.
- Mainstream gender in all project activities
- Assess the gender training needs of partners

Activity 1

Materials and Methods

A workshop was organised in the project communities namely Abour, Asanteboa, Mem, Watro, Densi, and Ahotor in the Atebubu Amantin district and Masuo, Nyinasie, Bisiw No. 1, Kramokrom, Nokwareasa, and Kasei in the Ejura Sekyeredumasi Municipal. There was power point presentation on key gender issues (why, what, and how), group discussions on perceptions on gender and gender issues in yam production, group presentations on the issues raised during the discussions, discussions and assessment of gender training needs (with a questionnaire). The workshop was evaluated by participants at the end of all the activities. Data from training needs assessment were analysed using the SPSS program version 16.

Results and Discussion

Results from analysis of partners' training needs indicated that all partners had knowledge about gender. However, some of the partners needed training to understand the application of the concepts in their everyday work. Participants identified some gender issues and perceptions, their causes and possible solutions (Table 146). Some of the issues centred on male dominance in yam production, the laborious nature of yam production, women not being skilful in yam production and limited access to yam production resources such as land, technical know-how and seed yams. Other issues are the cultural and spiritual connotations attached to yam production that prevent women from participating in some activities such as seed planting. During the evaluation, participants expressed their knowledge and how they have understood gender, some of the expressions are presented below:

- They have understood the rationale, and thus Component 3, of the project.
- They have gained re-inforced understanding of gender and how they can deepen it through community interaction and sensitization.
- Gender is not sex, rather, it is the roles people play; thus, it can be changed while sex cannot be changed.
- Gender equity calls for fairness in allocation of resources.
- Gender equality is giving equal access to resources to all gender groups whilst equity is about fairness to be able to address the needs of those who need special attention.
- Women are side-lined in yam production activities but if they are given equal opportunities they can also perform.

Participants shared how they would apply what they had learnt in their daily activities in the CAY Seed project. These include being gender sensitive in all their activities and consciously involving all the different gender groups in their activities.

Conclusion and Recommendation

Participants' knowledge about gender, has been enhanced. It is recommended that a continuous awareness creation and information sharing programme on gender issues, among project team members, should be instituted, for effective gender mainstreaming in project activities.

Way forward

Some of these perceptions and issues on gender will be verified and confirmed during the next activity - community gender sensitization for all the 12 communities under the CAY Seed project.

Table 146. Participants' ideas on gender: Perceptions and Issues in Seed Yam Production

Perception/Issues	Causes	Solution
All yam farmers are men (men's crop).	Yam farming is more masculine; Cultural and spiritual beliefs	Adopting ridging instead of mounding; Chemical hoeing. Mechanizing yam production activities
Women are not skilful in yam production	Cultural belief	Train men and women and be gender sensitive in project activities.
Land preparation and mounding in yam production is laborious (need for extra resources).	Mounding is difficult and yam production often requires virgin land which is difficult to prepare; Land tenure inheritance systems	Introduction of ridging as an alternative to mounding in yam production and also considering mechanized system of farming ; Access to credit for the vulnerable; Mechanization to reduce drudgery
Land ownership, example in northern region; Limited access to land for women and youth.	Unavailability of land and acquisition of land generally does not favour women; Land tenure inheritance systems	Review of land tenure system to be gender sensitive; Education on their need to own land ; Provide rental arrangements that are favourable to women (including share cropping)
Limited technical know-how on yam production on the part of women	Most yam groups are formed around men and so they receive most training as compared to their female counterparts	Facilitate formation of sole female groups and provide direct and indirect technical support; Programs and Projects on yam should be gender sensitive to involve women.
Limited access to seed yam by women especially for new entrants	Unavailability and not affordability	Dissemination of seed yam technology and support to vulnerable groups to produce seed yam.
Difficulty in carting yam after harvest	Cultural	Education and introduction of tricycle and training women to use it.
Sale of yam at farm gate	Cultural ownership of farm business	Education and business management training
Cultural ethics/spiritual beliefs that surround yam production.	Lack of sensitization and awareness creation in yam production	Awareness and sensitization creation
Where women are involved, they produce water yam and men produces white yam	Customs and cultural beliefs	Research and development to demonstrate that women can manage yam fields.
Different roles played by gender	Complementing each other	Policy makers should support technology up scaling in the districts to involve all gender groups
Yam is planted on newly cleared fields/lands	Belief that it thrives well on such lands	The use of fertilizer for yam production should be encouraged

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Activity 2

CAY Seed Project Community Gender Sensitization at Ejura Sekyeredumasi Municipal and Atebubu-Amantin District

Research Team: J. Haleegoah, B. Nsiah Frimpong, S. Ennin, L. Brobbey, I. Suleman*, K. W. Akwei*, L. Adomako**, A. Kyeremeh** and G. Agyei** (*CRS, **MoFA).

Collaborating Institutions: CRS and MoFA

Source of funding: CAY Seed Project

Objectives

- To create gender awareness and to sensitize CAY Seed community members on some key gender issues in seed yam production.
- Identify gender roles and responsibilities, ownership, access to and control over resources as well as in decision-making processes in yam production
- Identify gender constraints to yam production

Materials and Methods

Workshops were organised in 12 communities in the Atebubu Amantin district and Ejura Sekyeredumasi Municipal under the CAY Seed project. There were power point and pictorial presentations on some key gender concepts relating to yam production, focus group discussions (with a checklist) and plenary discussions.

Results and Discussion

There were 558 farmers (participants), comprising the youth (males and females- 39%), men (35%) and women (25%) - (Table 147). They were sensitized on key gender concepts such as the definition of gender and sex; why gender; gender roles, identifying gender triple roles and why the focus is on women.

Table 147. Participants (per location) in workshop on gender

Gender	Atebubu Amantin	Ejura Sekyeredumasi	Total	%
Youth	115	103	218	39
Men	110	88	198	35
Women	72	70	142	25
Total	297	261	558	100

This report covers the outcome of the workshop held in Ejura Sekyeredumasi Municipal. During group discussions participants explained the importance of yam in their communities, the gender roles in yam production; access to land, seed and inputs for yam production by men, women and the youth, ownership of yam production assets, decision making and constraints to yam production.

Importance of yam production in the Ejura Sekyeredumasi Municipal

Yam has many advantages as enumerated below.

- It is a traditional and food security crop for the district
- It is a source of income to support other farm activities
- It has a higher market value compared to other crops
- It is presented as gifts to relatives (in-laws) and friends especially during religious celebrations such as “Salah” and Christmas seasons.
- It is a special festival crop; eg. “Nunugye” / “Bayeredie” (Eating of yams)
- It is used as barter (used to pay for labour) and no other crop can be used
- Can be used as feed for animals
- Served as food for labourers working on the farms
- Used to prepare diverse food kinds such as fufu, ampesi, konkonte, tubani, wasawasa, etc

- Easy to intercrop with other crops resulting in efficient use of the land

The whole yam production process was critically reviewed to explain "who does what" and "why" is shown in Table 148. It came out that

- Men are solely involved in land scouting, search for yam seed, cutting of seed yams, planting of yams, directing of vines on stakes, harvesting, sorting and marketing of yams at the farm gate.
- The youth are involved in land clearing and removal of stumps, burning of weeds and mounds making.
- Women are solely involved in the carrying of seed yam, placing of seed yams on mounds and mulching of mounds. There were other roles shared by all - men, women and the youth; or by the youth and men or the youth and women (Table 148).

Assessment of 'access to' and 'control of resources' has been a fundamental tool of gender analysis. Resources are critical to people's identities and livelihoods and to advance autonomy, agency and rights. The access to, control and decision making on these resources depend greatly on the holder of the farm. Where a male or female is the holder, they all have access and control and decide on the use of the resources independently with the exception of land and seed yam. Even if a female would be the holder of the yam farm, in searching for land, in most communities, an adult male has to lead her to the chief and the adult male also helps in choosing a land suitable for the purpose. In selecting seed yams, the female seeks assistance from the adult male since they (men) are more knowledgeable in the true-to-type varieties and their viability (Table 149).

Labour is available to all gender groups provided one has money to pay but when there is competition, for this resource, the adult male wins because of the scale of operation. Decision on the total labourers to hire rests with the adult male since he knows the actual size of the farm and therefore the number needed. Marketing of ware and seed yams is mostly done by men but on the open market one can find women also involved (provided they are experienced). The man would also allow his wife to market the yams based on trust and given guidelines. When the farm is owned by the household, the adult male takes charge of everything with support from the adult female and youth. He may sometimes consult the wife in taking decisions but the final authority rests with him.

Constraints in yam farming presented at the workshop included the following:

- Limited land for yam production compared to other crops
- Unavailability of seed yam especially white yams
- Attack of crop by pests (including nematodes, termites, yam beetles, millipedes, yam storage caterpillar, white flies and aphids) and diseases (including yellowing of leaves, fungal attack and red strains in the yam flesh)
- Staking is difficult, harvesting (milking) is also difficult during the dry season
- Low yields
- High tuber spoilage in the mounds and in storage
- Lack of proper storage facilities on-farm and on the market
- Financial challenges
- Poor access roads

Table 148. Gender activity profile in yam production - Ejura Sekyeredumasi Municipal

Activities	M	F	Y	Reasons
Land scouting	✓			The man is the head so he takes for his family. He also knows suitable land for each yam type. The females and youth always get from the head
Yam seeds search	✓			He is able to recognize true-to-type varieties and he manages the yam field
Land clearing and removal of stumps			✓	The male youth have the strength
Burning of weeds			✓	It requires a lot of energy and the male youth have the strength
Mounds making			✓	It requires a lot of energy and the male youth have the strength
Carrying of yam seeds		✓		Women are noted for carrying head-loads
Cutting of yam seeds	✓			It requires special skills, especially to detect where the 'eye' is.
Placing of yam seeds on mounds		✓		It is easy and the women do it to support the men
Planting the yam seeds	✓			It requires special skill as the placing has special orientation
Covering of yam with weeds/ soil (mulching)		✓		It is easy and the women do that to support the men
Burning of trees for stakes		✓	✓	Women are good at working with fire so it is their duty
Cutting and carrying of stakes		✓	✓	The male youth do the cutting and the women carry the stakes.
Putting the vines on the stakes	✓		✓	This requires special skills and is done in the evening after resting for some time. At this time the females will be at home, cooking.
Weeding (3times) and spraying			✓	The male youth have the strength and can carry the machine on their backs
Carrying of water for spraying		✓	✓	Women are noted for carrying head loads
Management of farm	✓	✓	✓	Once the farm has been established, anyone can visit and monitor
Harvesting and sorting	✓			Very laborious. It needs care so that it doesn't break. The adult male also knows the total operation cost so can sort into correct sizes to recoup his money invested
Selling at the farm gate	✓			The adult males know the total cost incurred and can therefore price and bargain well
Selling on the market	✓	✓	✓	It is based on trust; where the adult female or youth goes, he or she is given instructions from the head concerning the price but they can retail and get more
Cooking		✓		Traditionally females are in charge of cooking
Carrying of yams into tractor		✓	✓	Women are noted for carrying head loads
Construction of storage shed on-farm	✓		✓	The adult males know the total yams harvested and therefore the size of storage structure to put up. He is supported by the sons or hired male workers

Table 149. Access to and control of resources for yam production - Ejura Sekyeredumasi Municipal

Resources	Access	Control	Decision making
Land	Adult males	Adult males	Adult males
Labor	All gender groups	All gender groups	Adult males
Seed yam	Adult males	Adult males	Adult males
Other inputs	Adult males	Adult males	Adult males
Marketing	All gender groups	Adult males	Adult males
Capital for production	Adult males	Adult males	Adult males
Income	Adult males and females	Adult males	Adult males

Conclusion and Recommendation(s)

The workshop enabled participants to share their knowledge about the key gender concepts and appreciating them. The importance of yam production in these communities and the 'access to' and control over yam production resources and the constraints to yam cultivation have been documented. It is recommended that the CAY Seed project helps farmers to address the constraints that the community members outlined during the discussion.

Gender Monitoring of WAAPP Yam Activities

Research Team: J. Haleegoah, R. Sagoe, E. Otoo and P. Appiah Danquah.

Collaborating Institution: MoFA

Source of funding: WAAPP

Introduction

The WAAPP-Ghana gender action plan is organised under four thematic areas to ensure that gender is mainstreamed into all WAAPP activities. These areas are policy development; capacity building; technology development, dissemination and adoption; and monitoring and evaluation. The last two areas are the responsibility of CSIR-CRI (designated as the National Centre of Specialisation (NCoS) under WAAPP to ensure that beneficiaries have equal access to and benefit from technologies developed, disseminated and adopted. To address this, gender monitoring was undertaken by the Institute.

Objectives

To find out:

- how different genders (men, women and the youth) are involved in WAAPP activities
- how they have benefited from WAAPP with respect to access to production resource
- any improvements in their livelihood activities.

Materials and Methods

A checklist of questions was developed and used for individual or group discussions among project beneficiaries at the various locations where research scientists had worked with farmers on field trials, demonstrations as well as innovative platform (IP) activities. The questions covered respondents' involvement in WAAPP activities, their group or association activities, technologies they had learnt about and were using on their farms (as men and women farmers), the benefits of these technologies and how WAAPP could improve on its activities with farmers. Other questions related to how they had shared the knowledge gained with others and the challenges they faced in practising the knowledge gained. The locations were Ahotor (Atebubu-Amanten district); Frante (Ejura Sekyeredumasi municipal); Brahoho (Nkoranza South district); Dromankese (Nkoranza North district), Sogliboi and Baniantwe (Kintampo North district). The work was done in August 2015.

Results and Discussion

A total of 104 farmer beneficiaries of WAAPP made up of women (45%) and men (55%).were involved in the discussions. About 38% of the farmers were youth (age 18 – 35). WAAPP scientists had worked with these communities for 1 – 10 years.

The farmers (men and women as well as the youth) were able to mention all the different technologies learnt from the project for the period they had interacted with WAAPP scientists. These included: minisett technology; seed treatment; identification of diseased yam plants; planting at the recommended spacing; staking with fewer stakes and trellis; planting yam on ridges; vine technology for seed yam production; storage of yam; soil diagnosis of nematodes; yam nursery establishment and the identification of matured yams for harvesting.

Some of them indicated that they were practising some of the technologies on their farms. Others were not and gave varying reasons.
About ridging, they indicated it was good and explained "we do it because we get many plants from a small land area but it is expensive and difficult to do, we have to redo the ridges when it rains, adding to the labour cost". Some of the farmers, especially the women, expressed concern about the smaller tubers obtained from planting on ridges because the market gave premium price to larger tubers. Farmers used the ridges on smaller portions of their fields to generate the next season's planting materials.They complained about drought.and how it has adversely affected the trials and demonstrations that scientist planted in the communities. In some communities where women planted groundnuts on ridges, ridging had been well adopted.

They indicated that seed treatment was good and they practised it on their farm but not all of them did because they could not afford the chemicals all the time. They explained “it gives you good and healthy tubers for sale but we have no money sometimes to buy the chemical”. One group indicated they had been thought how to use wood ash for seed treatment but they had not practised it because the rains had not being reliable for planting.
Yam minisett technology was used on a smaller area of their lands. They practised it to produce seed yams. They would do it only when they needed more seeds or wanted to expand their yams farms. They had not adopted it as a business yet, due to risk of not getting buyers.
The vine technology impressed the farmers so much, but some of the women were doubtful about it. It required a lot of water at the nursery and this was a hindrance to its adoption because of the drought and in situations where they do not have any irrigation facilities for yam production.

Farmers were aware of the benefits to be derived from the technologies transferred to them despite their inability to practice some. The few who had practised some of them reported of gains - more income to take care of the children’s school fees and general well being of men, women and young farmers

The following are some things WAAPP could do to improve upon the adoption of technologies:

- Trials and demonstrations must come on time when they are also planting
- Provide them with irrigation facilities
- Bring them more of the improved yam seeds
- Provide the women and the youth with start up capital for yam cultivations because in most communities, gender roles assign yam production to men and not women.

Conclusion and Recommendation(s)

A significant number of women and the youth are involved in yam production, however, there is room to increase this number to ensure equal representation of men, women and the youth as beneficiaries of WAAPP activities and technologies. The ridging technology would benefit the women but the cost of labour for re-construction after rains had washed them off limits their acceptance of this technology. Its adoption is slow because it produces smaller tubers, which do not attract good prices on the market compared to the larger tubers from mounds. Drought also prevents some of the farmers (men and women) from adopting some of the technologies.

It is recommended that:

- Scientists should work continually for about three years with farmers and farmer groups to facilitate technology adoption.

- Following up on technologies transferred is very critical for adoption since farmers often give up just after a year’s interaction with them, despite the benefits to be derived from a particular technology.

- Other factors go into the adoption of technologies, by men and women, and should be considered when designing the technologies.

- WAAPP should release funds for field trials and demonstrations on time in order to get farmers’ involved to facilitate adoption.

Contractual Arrangements Development and Improving Rice Marketing Standards in Ghana

A. Contractual Arrangements Development

Research Team: B. Nsiah Frimpong, A. Adu-Appiah, L. Brobbey, R. Bam, S. Boadu, G. Afukaar, A. Arouna* and R. Fiamohe (*AfricaRice Center)

Collaborating Institutions: AfricaRice, (Cotonou, Benin), MOFA and GIDA

Source of funding: AfricaRice

Introduction

Agriculture is constrained by numerous challenges, notably declining farm incomes, as a result of low input use (due to high costs), insufficient access to agricultural credit and low adoption of improved technologies, among others. These result in low yields. In modern age, agricultural credit is very important for the development of the agricultural sector. Ghana's current agricultural policy framework and national development plan emphasize the importance of moving from a subsistence-based small-holder system, to a sector characterized by a stronger market-based orientation, based on a combination of productive small-holders alongside larger commercial enterprises engaged in agricultural production, agro-processing and other activities along the value chain. To maximize the impact of private investment in agriculture on development, a particular focus is to facilitate small-holder linkages with other commercial businesses through (for instance), contract farming. Contract farming has been practised for decades, especially for most of the cash crops and its popularity appears to be increasing in recent years. Contract farming helps to solve many of the problems associated with market access and input supply, faced by small holder farmers. In contract farming other actors of the value chain often agree to support the farmer through, for example, input supply, assisting in land preparation and other farm operations, providing technical advice and transportation of produce from the farm. It is against this background that it has become necessary to learn from past experiences of previous projects and develop workable models for the rice value chain actors in the hubs.

In order to reduce risks in the process, the following terms or specifications of existing contracts are worth noting:

- Date of delivery
- Quantities pre-determined
- Quality of product pre-defined
- Prices pre-fixed

Objectives

- Find out and evaluate existing contractual arrangements and marketing standards in Ghana
- Identify the best contractual arrangements to be tested
- Test different models between chain actors
- Propose new models

Methodology

The study was conducted in the rice sector development hubs created in the Ashanti and Volta regions during the AfricaRice baseline study. Rice farmers were sampled from the Atwima Nwabiagya district (Kumasi hub) and Ketu North district (Afife hub) i.e farmers on the irrigation scheme. Six communities were selected from each district and 10 rice farmers selected from each community making a total of 120 farmers. The study began with an informal survey involving reconnaissance and interview of key informants to gain first hand information about the existing contractual arrangements and marketing grades and standard. This was followed with a structured interview schedule involving 120 rice farmers. However 119 valid questionnaires were retrieved. Other actors interviewed included traders and millers. Both qualitative and quantitative data were collected from primary and secondary sources. Information collected included actors' characteristics, membership of associations, awareness of contract, participation in contract, its benefits and challenges and existing marketing standards. The analytical tool used was mainly descriptive such as frequencies, percentages and diagrams.

Results and Discussion

- **Sample description**

  Majority of the producers interviewed were males however, one- third of the sample was females implying that both sexes are actively involved in rice production (Table 150). This is consistent with studies by Addison *et al*., (2014) and Adekunle (2013) which have shown the dominance of the rice sector by males. The situation was the reverse for the traders as females dominated the rice trade. This affirms the different gender roles that exist in rice production which is worth noting so that interventions targeting each stage of the production will identify exactly the gender group to deal with. Majority of the respondents were married indicating that actors (in production and trading) receive support from their spouses. Both producers and traders were educated to the same level (Senior High school) indicating that they can understand issues better especially introduction of new technologies.

- **Farm level characteristics**

Rice the principal source of income for the both producers and traders and this shows that any marginal technological change can bring about a change in the livelihoods of the respondents. Majority of the producers belonged to an association, unlike the traders where only a handful had joined an association. The producers had joined the associations / groups in order to have access to inputs and credits. The traders on the other hand joined the group to have access to paddy and for welfare issues - Table 151.
The fertility status of their fields was assessed and measured on a five point likert scale as presented in Table 157. More than one-third (48%) of the respondents describe their soil fertility status as average and quite an appreciable number described theirs as poor. This shows that the fertility of the soils is declining and this can have serious implications on rice yields. A way out is to apply fertilizer, which most farmers cannot afford. Another option is to change the farming system by adopting, for example, shifting cultivation; but majority of the farmers decried that option knowing that land is becoming scarce due to illegal human activities such as "galamsey" and competition of land for non-farming purposes such as construction.

- **Participation in training programmes**

Producers' capacities in production practices have been improved through training programmes (Table 152), however, little has been done for them in post-production activities/techniques which are also essential. Training must be organized for rice value chain actors in the area of marketing so that they would appreciate the inefficiencies in the market system and take full advantage of it.

Table 150: Demographic characteristics (Qualitative variables) of interviewees

Variables	Producers		Traders	
	Frequency	Percentage	Frequency	Percentage
Sex				
Male	79	63.4	1	3.1
Female	40	33.6	31	96.9
Marital Status				
Married	97	81.5	25	78.0
Single	6	5.0	3	9.4
Divorced	9	7.6	2	6.3
Widowed	7	5.9	2	6.3
Educational level				
None	27	22.7	7	21.9
Basic	66	55.5	19	59.4
Senior High	19	16.0	6	18.8

Table 151: Farm level characteristics of interviewees

Variables	Producers		Traders	
	Frequency	Percentage	Frequency	Percentage
Principal Source of Income				
Farming/ Trading	110	92.4	31	96.9
Others	9	7.6	1	3.1
Main Crop (Income)				
Rice	110	92.4	31	96.9
Membership of Association	75	63.0	5	15.2
Motivation for joining				
Easy access to credit	35	29.0	-	-
Easy access to inputs/ paddy rice	26	21.8	3	9.1
Communal labour	6	5.0	-	-

Welfare issues	8	6.7	2	6.0
Nature of soil				
Very rich	13	10.9		
Rich	33	27.7		
Average	57	47.9		
Poor	15	12.6		
Very poor	1	0.8		
Availability of land	47	39.5		

Table 152: Training received by interviewees

Variables	Producers	
	Frequency	Percentage
Ever attended training in rice production		
Yes	57	47.9
Trainings attended		
Seed selection	21	17.6
Seed treatment	32	26.9
Fertilizer Application	54	45.4
Timely pesticide/herbicide application	44	37.0
Post harvest technologies	17	14.3
Marketing	7	5.9
Quality grains standards	4	3.4
Price negotiation	3	2.5
Development of different rice based products	1	0.8

Contract awareness and benefits

Table 153. Assessment of contractual arrangements in the study area

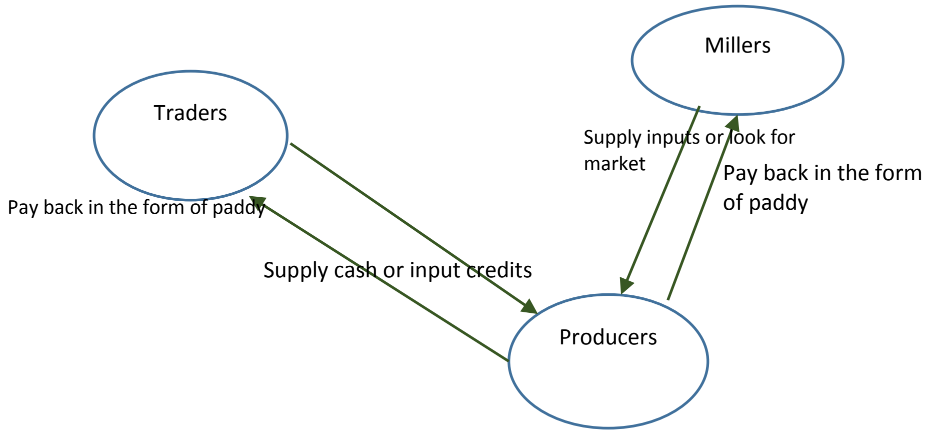
Variables	Producers		Traders	
	Frequency	Percentage	Frequency	Percentage
Knowledge (Awareness) of contract	97	81.5	24	75.0
Ever made contract	56	47.1	16	50.0
Agreement type				
Verbal	20	16.8		
Written	36	30.3		
Producers' contract with other rice actors				
Traders	11	9.2		
Input dealers	30	25.2		
Financial Institution	6	5.0		
Benefits gained from contract				
Seed	27	22.7		
Fertilizer	40	33.6		
Herbicide/pesticide	38	31.9		
Cash credit	15	12.6		
Field supervision	11	9.2		
Implements (eg. Spraying machine)	8	6.7		

- **Existing contractual arrangements in the study areas**

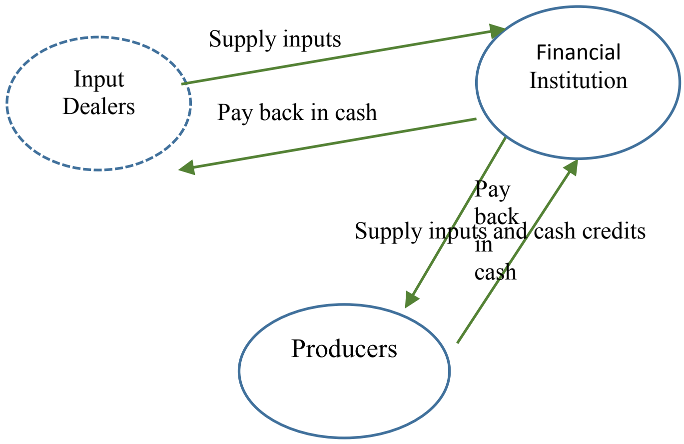
  Several contractual arrangements exist but in the study districts, the common ones per district are as presented in the diagrams below. In Atwima Nwabiagya, producers interact mostly with the traders, millers and financial institutions. In the Bi-partite model, involving two parties, a producer either deals with the traders by taking inputs or cash credit from them and pay back with paddy rice. The miller either provides inputs to producers or mills and sells the rice for the producer and takes his milling cost. The miller may also be the buyer himself and in most cases determine the price for producers.

  A tri-partite system also exists (in the districts) whereby the producers take cash or input credit from a financial institution (such as the Opportunity International Bank); the inputs are then provided by a wholesale input dealer (such as K. Badu Agro-chemical Co.). The producers pay back in cash.

Kumasi Hub- Atwima Nwabiagya District
Bi- Partite model

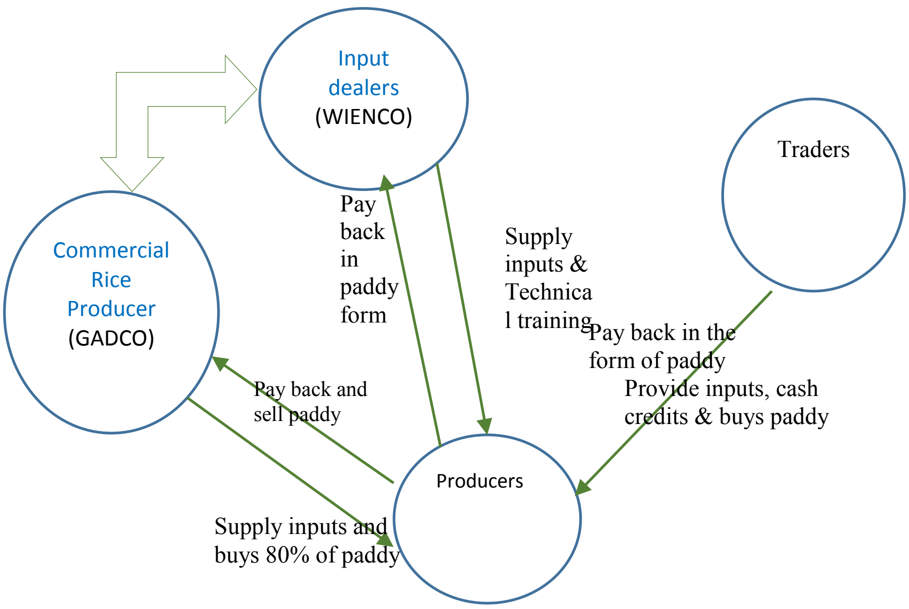


Tri-partite model



Ketu North District
Bi-Partite

Afife Hub- Keth North District
Bi- partite model (Different Forms)



- **Contract types identified and practised**

The forms of contracts identified in the districts were:

- Resource providing contract
- Production management contract
- Market- specification (very few practice)

- **Reasons for not being in a contract (in order of importance)**

- Fear of being cheated or being charged exorbitant interests
- The contractors may not be reliable
- Have no idea about the contract system
- Not interested
- Seasonal nature of farming (Yields not stable)

- **Advantages of Contractual Arrangements**

- Easy access to production inputs and timely delivery of inputs (impacts other farm operations)
- Easy access to credit to purchase needed inputs
- Increased income as a result of high yields (able to pay ward's fees)
- Receive technical training on input use
- Assured market
- Less or no manipulation as a measuring scale is used (by GADCO and WIENCO but not Traders)
- Capacity built in good farming practices
- Farmers presented with their cost budget
- Good customer services provided by staff of contracting company ***(Ketu North District)

- **Inconveniences encountered**

- Rice produced is bought on credit and payment delays
- High defaults in case of crop failure (sometimes seed supplied may not be viable)
- Contractors take all harvested produce in case of crop failure
- Stringent laws in contracts
- High interest rates charged by traders (sometimes 100%)
- High costs of inputs supplied
- Poor standardization (by traders)

- **Other production problems**

- Lack of harvesting machines
- High transportation cost

Conclusion and Recommendations

Contract farming is a promising concept that can help to manage the problems of input acquisition by farmers especially in rice production. This can boost production, improve the livelihoods of actors in the chain as well as ensure food security for the nation. Through contract farming, market imperfections which exist as a result of lack of information flow will be minimized. It is therefore recommended that farmer-based organizations should be strengthened to serve as a model for other individual farmers. Government policies on rice should be implemented and enforced to strengthen the weak local rice marketing system in Ghana.

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B. Improving Rice Marketing Standards in Ghana

Research Team: B. Nsiah Frimpong, A. Adu-Appiah, L. Brobbey, R. Bam, S. Boadu, G. Afukaar, A.
Arouna* and R. Fiamohe* (*AfricaRice Center)

Collaborating Institutions: AfricaRice, (Cotonou, Benin), MOFA and GIDA

Source of funding: AfricaRice

Introduction

Most agricultural development projects in Ghana traditionally address the supply side, focusing on crop productivity issues (increased use of improved seeds, fertilizers and improved agronomic practices). Few address the demand or marketing issues that ensure that the (increased) produce find its way to the markets without adverse effects on prices and incomes of farmers and other stakeholders in the value chain. Between 2010 and 2015, rice demand was projected to grow at a compound annual growth rate of 11.8 %. In Ghana, annual per capita rice consumption on the average increased from 17.5 kg during 1999-2001, to 22.6 kg during 2002-2004. Per capita rice consumption was estimated to increase to 63.0 kg in 2015 if the trend remained the same (MOFA-NRDS, 2009). Unreliable production and marketing arrangements resulting from lack of reliable market information have contributed to the situation where demand for rice outstrips supply due to population increase and improved standard of living for farmers at the base of the pyramid (Agricinghana, 2011). Producers lose out on their incomes due to poor post-harvest handling, processing and the low standards employed. This study investigated the existing rice grading system and standards in the study areas.

Objectives

- To find out existing grades and standards in the study areas
- Propose new market grades and standards
- Conduct experimental auction on consumers' willingness to pay for rice and rice based products

Materials and Methods

The study was conducted in the Atwima Nwabiagya and Ketu North districts of Ghana. A structured interview schedule was administered to 120 and other actors such as millers and traders. The areas sampled fall within the rice sector development hubs of Ghana. Both qualitative and quantitative data were collected.

Results and Discussion

The producers either sold their rice in the milled or paddy form. The results have been summarized in Table 154. Most farmers at Atwima Nwabigya sold in the milled state while farmers at Ketu North sold in paddy form. The rice was mostly sold at the milling site and since few mills had all the components to ensure quality rice, the standard of rice produced is sometimes affected. The main trait used by buyers is the appearance which depends mostly on the type of mill used. Majority of the producers relied on fellow farmers for price information during the season. Producers used all types of traditional measures (Makola size 5 and buckets) which are not standardized and this affects the incomes gained by producers.

Table 154: Summary of survey results

Variable	Frequency	Percentage
Form of rice sold		
Paddy	52	43.7
Milled	67	56.3
Markets for rice		
Milling site	67	56.3
Others	52	43.7
Mill has all components		
Yes	26	21.8
Traders concerned about quality		
Yes	112	94.1
Trait of importance		
Appearance	101	84.9
Steps to ensure high grain quality		
Harvest on time	19	16.0
Winnow after threshing	36	30.3
Source of price information		
Fellow farmers	53	44.6
Millers	29	19.3
Current measure used		
Buckets (size 5)	92	77.3
Weigh rice before selling		
No	97	81.6
Prefer to weigh the rice		
Yes	106	89.1

Few producers weigh their rice before selling though majority of them preferred that it is weighed and the price paid based on the weight but they are afraid that traders may not accept new strategies which will affect their access to rice markets.

Traders display local rice on the market in different ways and use all forms of measures to sell without knowing the exact weight of what they are selling. Some are, however, branding and packaging the local rice to compete with the imported rice (Plate 27). There is still room for improvement in the packaging and the whole processing process.

Plate 34. Bagged local rice on the market

Constraints in marketing

- Delay in payments by contracting companies
- Low prices offered by companies and traders
- Poor measuring standards used by traders
- Poor quality (Brokenness leads to low prices)
- Lack of good mills

Conclusion and Recommendation(s)

Though progress has been made in the Ghanaian local rice sector, there is still room for improvement in terms of quality and standards. Improving the quality of grains sold on the markets still remains a challenge in Ghana. Policies must be geared towards helping millers to upgrade their mills by acquiring all the necessary accessories for better performance. The existing standards must be improved. There is the need to improve on the local grain quality to meet the standards of the imported ones.

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Participatory field evaluation of seventeen cassava clones at CSIR-CRI Fumesua station

Research Team: B. Nsiah- Frimpong, A. Adu-Appiah, B. Peprah, O. Djan and E. Lotsu

Collaborating Institution: MoFA

Source of funding: BMGF (through the PEARL Project)

Introduction

Malnutrition remains a serious problem in Sub-saharan Africa (SSA) especially in children. One of the major nutritional problems facing developing countries is micronutrient deficiency, particularly vitamin A (West and Darnton-Hill, 2001) which predominantly affects low-income groups (Ruel, 2001). Humans require at least 49 nutrients to meet their metabolic needs. Inadequate consumption of even one of these nutrients will result in adverse metabolic disturbances leading to poor health, impaired development in children such as learning disabilities, increased morbidity and mortality rates, and large economic costs to society including lower worker productivity and high healthcare costs (Branca and Ferrari, 2002; Golden, 1991; Grantham-McGregor and Ani, 1999; Ramakrishnan *et al*., 1999).

Nutritional deficiencies (e.g. iron, zinc, vitamin A) account for almost two-thirds of the childhood deaths worldwide. The primary source of all nutrients for humans is agricultural products. Biofortification is a new public health intervention that seeks to improve the nutritional quality of staple foods consumed by poor people. With cassava being an important staple in Ghana, this technique has been introduced in the crop and clones developed are being tested on research stations in Ghana. The main objective of this study was to assess farmers' preferences of the new bred clones based on their characteristics in the field and after cooking.

Materials and Methods

The study was conducted at Fumesua station. The study employed participatory approaches such as field observations and individual evaluations (backed with reasons) and informal interactions through focus group discussions. Nineteen producers were sampled from farming communities in Ejisu and its environs. They were brought to the research field where 17 cassava clones had been planted. The cassava clones were made up of 15 with yellow flesh and two with white flesh (as checks). After a briefing by the research scientists each participant was made to select their best five plants based on the physical characteristics. After the field assessment, samples of boiled roots were also presented to them to evaluate based on traits such as colour, taste, texture and mealiness.

Results and Discussion

Majority (63%) of the participants were females. This may be because cassava is inexpensive to produce and require less inputs compared with other crops like yam and rice so both men and women can equally go into its production. Most (80%) of them have had basic education and were married (73%) with farming experience of about 23 years. Farming was their main occupation (90%) and served as the main source of livelihood for them. Their mean age was 48 years (which falls within the active group) with a household size of seven members per household. This could be a source of labour to support farming actives since most farmers rely on this source of labour due to the high cost of hired labour. Out of the average of six acres cultivated; two acres were under cassava (Table 155).

Table 155: Characteristics of participants

Variables	**Frequency**	**Percentage**
Sex		
Male	7	37.0
Female	12	63.0
Educational level		
None	1	5.0
Basic (Up to JHS/MSLC)	15	80.0
Secondary	2	10.0
Tertiary	1	5.0
Marital status		
Married	14	
Single	4	
Widowed	1	
Main occupation		
Farming	17	90.0
Artisan	1	5.0
Transporter	1	5.0

- **Field Assessment**

  The five clones that came top in descending order were 104, 105, 116, 107 and 113. These were chosen due to their unique traits such as high yielding, big tuber sizes and appealing skin colour (pink) which makes them have high marketability. The pink skin colour also often implies poundability.

- **Sensory Evaluation**

  The five clones that came top in descending order were 113, 105, 111, 114 and 101. The selection was based on colour, taste, texture, mealiness and overall acceptability of the sample. Sample 113 which was selected fifth on the field came first during the sensory evaluation. Other clones which were high yielding (on the field) fell out completely during the sensory evaluation probably due to their unacceptable cooking qualities.

Conclusion and Recommendation

It was noted that the physical characteristics on the field less correlated with the cooking qualities. Those rejected after the sensory evaluation which have high β-carotene levels may however be considered for other uses (apart from fufu). The dynamics in terms of field and sensory qualities are therefore critical and must be considered by breeder. The results obtained are not conclusive. There is the need to test the clones multi-locationally and farmers' preferences assessed across the various locations backed with laboratory results of their total beta-carotenoid levels.

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Potential Adoption of Improved Sweetpotato Varieties in Ghana

Research Team: N.E. Amengor, K, Adofo, J. Osei Adu and A. Adu Appiah

Collaborating Institution: MOFA

Source of funding: WAAPP

Introduction

In a study on agricultural technology, Beale and Bolen (1955) emphasized that awareness of a technology was premier in adoption and it was a period in which the existence of a technology is made known to the farmer. Nowak and Korsching (1998) also stated that ignoring the creation of awareness was responsible for poor predictive power in binary analytical models in adoption studies. The primary stage in new technology introduction is to make farmers aware of the technology through demonstrations and workshops, among others, for farmers to adopt if they find it productive, technically and economically. Diagne and Demont (2007) concluded that in determining potential adoption rates if technology awareness is left out, then the end result would be inconclusive. The first phase of WAAPP ended with the released of four improved sweetpotato varieties (*Ligri, Bohye, Dadanyuie* and *Patron*) with higher yields compared to other varieties in existence. It is essential to undertake an adoption study of the four varieties as an aid to dissemination of the varieties.

Objective
To identify farmer preferences of new improved sweetpotato varieties.

Materials and Methods
Participatory Rural Appraisals (PRA) of improved sweetpotato varieties were conducted at three locations as summarized in Table 156.

Table 156. Participants in PRA at three locations

Location	Participants (Farmers)	% Males	% Females	% Youth
Komenda	32	65.6	34.4	43.8
Ohawu	27	65.3	34.6	42.3
Asempanaye	32	35	65	40.0

Results and Discussion

Other commodities produced by farmers' aside sweetpotato were cassava, watermelon, maize, tomatoes, pepper, okro, garden eggs, onion, cowpea, cucumber, beans and groundnut. .Sweetpotato production provided farmers with employment, income, food security and nutritional improvement. Sweetpotato is cultivated in both major and minor rainy seasons. During the major season planting is done in April by few farmers on the highlands because excessive rains make the lowlands waterlogged and unworkable. In the minor season which starts from August, there is less rain so more land is available for cultivation by more farmers. In Komenda and Asempanaye, females constitute 20% of sweetpotato farmers during the major season. However the percentage increases to about 40% during the minor season. At Ohawu, the ratio is 70% males and 30% females. The average farm size across locations is about 1.5 acres. Farmers plant mostly on mounds, compared to ridges, because they believe that the space on ridges is very small. They apply pesticides when the need arises. Some pests mentioned by farmers (and the estimated yield losses they cause) are grasshopper (30%), caterpillar (20%) and *Cylas* (50%). Damage caused by Cylas was more sevre during the minor season. Farmers control pests mostly by chemicals though they believe that excessive use of chemicals cause the tubers to rot. The cost of production (per hectare) and price of tubers per bag are summarized as Table 157.

Table 157. Cost of production (per hectare) and price of sweetpotato tubers per bag

Location	Cost of production/ha (GH₵)		Price per bag of tubers (GH₵)	
	Major season	Minor season	Major season	Minor season
Komenda	800.00	1000.00	70.00	100.00
Ohawu	900.00	1200.00	70.00	120.00
Asempanaye	700.00	1200.00	60.00	100.00

Farmers' awareness about improved varieties at the various locations were:

- Komenda - *Apomuden* and *Sauti*
- Ohawu - *Faara, Apomuden* and *Santompona*
- Asempanaye - None of the farmers knew the name of the variety they were growing

Some farmers were not growing the improved varieties because of lack of planting materials and high cost of agro-chemicals. The characteristics of sweetpotato required by farmers to warrant growing of new varieties were early maturity, high yield, disease resistant, good taste, good colour and marketability

Farmers' varietal preferences were:

Komenda - *Dadanyuie* (85%) and *Patron* (62%);
Ohawu - *Bohye* (85%) and *Dadanyuie* (76%)
Asempanaye - *Patron* (76%) and *Bohye* (70%).

Farmers explained that, the characteristics of the varieties made them ideal for their farming conditions and could help to increase output and income.

Conclusion and Recommendations

For the adoption of every variety to be successful, it is important that stakeholders are fully aware of the variety and its traits. Researcher knowing the potential adoption of their varieties would help in it dissemination. For the four varieties to be adopted it is essential that specific varieties are promoted in the different locations according to famers/consumers' preference. For example *Dadanyuie* and *Patron* should be promoted in the Central Region, *Bohye* and *Dadanyuie* in the Volta Region and *Patron* and *Bohye* in the Eastern Region.

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Systems of Rice Intensification Innovation Platform Sensitization meeting

Research Team: N.E. Amengor, G.K. Acheampong and W. Dogbe Wilson

Collaborating Institution: MOFA and GIDA

Source of funding: WAAPP

Introduction

The Linear transfer of technology is one model introduced to address problems in agriculture. This evolved through the farming systems perspective and farmer participatory approach. The latter recognized the importance of farmer involvement in the knowledge development process with less consideration for implementation and administrative constraints, and the usefulness of multiple actors besides the necessity to engage all key stakeholders. This gave room for the emergence of the Innovation Systems Approach using the Innovation Platform as a key tool. (Hounkonnou *et al.*, 2012). Innovation platform is a coalition of actors along the value chain, formed to address particular constraints to upgrade the value chain through the use of knowledge and mutual learning. It can be applied in all aspects of agriculture and for technologies that are either simple, complex, integrated or composite.

Objectives

- To identify the various actors in the rice value chain available in the communities.
- To sensitize actors identified on the operations and importance of an Innovation Platform.
- To identify constraints at the various levels in the rice value chain.
- To identify the entry points in the formation of the IP.

Methodology

Innovation Platform (IP) formation was an integral part of the System of Rice Intensification (SRI) Project. Two Innovation Platforms were established Jasikan and Weta. Membership is made up of farmers (15), traders (5), processors (5), food vendors (5), consumers (5), input dealers (5), agric. extension agents (2) and researchers (2). Information is presented either on individual IP bases or collectively as may be appropriate. A sensitization meeting was held on 21st August, 2015, at Jasikan and attended by actors from Jasikan, Kadjebi and Worawora.

Results and Discussion

Participants validated the need to form an IP and agreed that the IP was necessary to address some of the challenges that actors encountered in the rice value chain. Participants were grouped according to their roles to discuss the challenges in their operations.

Challenges presented by the groups are:

Farmers

- High cost of agro chemicals including fertilizer.
- Unreliable rainfall patterns.
- Lack of irrigational facilities.
- Low farm gate price of produce/Exploitation by traders
- High incidence of weeds on rice farms.
- Low yielding varieties.

Traders

- High cost of paddy rice at farm gate.
- Paddy rice purchased at farm gate contains chaff hence after winnowing the quantity and weight reduces.
- High cost of milling.
- Poor milling quality.
- Low volumes of paddy rice available for purchase.

Millers

- Less efficient milling machines.
- Low service charges.
- Stones in paddy rice destroy the milling machines hence frequent repair works at high cost.
- No alternative source of power aside that of the national electric grid.

Food vendors

- Milled rice bought from local market is not well dried.
- High cost of local rice.
- Stones in rice
- Low quality of milled rice (not aromatic, unpolished and ungraded)

Consumers

- High cost of processed and unprocessed rice
- Stones in rice
- Poor cooking quality (either becomes soggy or hardens a few minutes after boiling)
- Non-aromatic rice.

Input dealers

- High cost of chemicals at wholesale points.
- Non compliance of farmers to required rates of chemical application.

The issues raised were discussed and it came to light that the issues had chain effects. The main entry points identified were the input dealing and production issues. Dealing with challenges at these level would set up a ripple effect on all the other actors within the rice value chain.

Conclusion

It became evident that there were challenges, in the rice value chain in Jasikan and Worawora, which needed to be addressed with urgency. There is the need to strengthen the rice value chain to ensure increased productivity which would also lead to increase in the total production of rice in Ghana.

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Economic analysis of the SARD-SC maize minikits demonstrations

Research Team: A**.** Adu-Appiah, K. Obeng-Antwi, K. Agyeman and L.M. Tengan

Collaborating Institution: MOFA

Source of funding: AfDB/IITA

Introduction

A stakeholder analysis conducted in 2013 on the innovation platforms (IPs) of SARD-SC maize identified a number of challenges among the various actors along the value chain at Mampong. Farmers' challenges included the poor measuring standards (use of over-sized sacks) by traders, low productivity, low technology adoption and adverse effect of climate change. The issue of over-sized sacks was resolved through policy advocacy in the form of enactment and enforcement of bye-laws through the District Assembly. Scientists on the IPs attempted to address the remaining challenges through the introduction of mini-kits demonstrations on farmers' fields. Under the mini-kit demonstration drought tolerant quality protein maize varieties were given to farmers. The seeds were planted simultaneously with farmers' seed on farmers' maize fields to enable them to manage, observe and make their own judgment based on the results from their fields. All these were done in collaboration with the Agricultural Extension Agents of MOFA.

Objectives

- To assess the performance of the mini-kits demonstrations in addressing the issues of climate change, low productivity, and low technology adoption.

Specifically, the study seeks to:

- Examine the gains associated with changing from farmers' varieties to researchers' (improved) variety.
- Determine the feasibility of adopting researchers' variety on farmers' field.

Materials and methods

Each collaborating farmer from two districts each in the forest and transition zones (Table 1) was given 1kg of drought tolerant maize (*Abontem*) seed from the researchers, to plant on a demarcated area - 100m^2 (10m x 10m) - on the farmers' field which has been cropped with farmers' variety of maize; this was to allow for observation and comparison. All the recommended practices for maize production were followed. At maturity, a 25m^2 (5m x 5m) area was demarcated within the 100m^2 of the *Abontem* plot planted by each farmer. A similar area (25m^2) of the farmers' field planted with farmers' maize variety was also demarcated. Maize was harvested from the demarcated areas of the two different maize varieties. These were weighed and compared. Averages of the yields were estimated across the locations. Using Crawford and Kamuanga (1988), and Dugje, (2015) partial budget analysis, the data collected were analysed. Partial budgets indicate the net gain attributable to changing from current practices to recommended practices. Additional benefits are compared with their associated costs for a decision to be made using marginal analysis.

Some basic concept of the partial budget

- Average grain yield (Kg/ha)
- Adjusted grain yield = 90% of grain yield
- Gross benefit (GB) = Adjusted grain yield X price/ Kg of maize
- Total Variable cost (TVC)= summation of all variable costs
- Net benefit (NB) = GB – TVC
- Marginal Cost (MC) – TVC_1-TVC_0
- Marginal Benefit (MB) = NB_1-NB_0
- Marginal Rate of return = (MB/MC) x 100

Results and Discussion

A total of 498 farmers (made up of 163 from two districts in the forest zone and 335 also from two districts in the transition zone) participated in the mini-kit demonstration (Table 158). This number represents over 80% of the targeted 600 farmers from the two IPs for the year.

Table 158: Number of participants in mini-kit demonstration

IP/Location	District	No. of farmers
Forest	Sekyere Central	83
	Mampong	80
Sub-Total		163
Transition	Nkoranza	220
	Kintampo	115
Sub-Total		335
Grand-Total		498

The average yields of the researchers' variety (*Abontem*) and farmers' variety across the two IPs (four districts) are presented as Table 159.

Table 159: Average yield of maize (t/ha) from Researchers' and Farmers' varieties

District	Researcher	Farmer
Mampong	7.4	2.8
Sekyere Central	4.9	3.9
Nkoransa	6.9	4.8
Kintampo	2.1	1.5
Average	5.3	3.3

Economic Analysis

Following the yield differences between the drought tolerant variety "*Abontem*" and farmers' varieties, economic analysis using partial budget was done (Table 160). A gross benefit of GH₵ 5889.17 with a total variable cost of GH₵1685 resulting in a net benefit of GH₵ 4204.43 was realized from the researchers' variety (*Abontem*). On the other hand, farmers' varieties gave a gross benefit of GH₵ 3611.56, a total variable cost of GH₵ 882.5 and a net benefit of GH₵ 2729.01. A marginal benefit of GH₵ 1475.82 was recorded considering a marginal cost of GH₵ 802.5, the marginal rate of returns (MRR) was estimated as 184%. The positive marginal benefit is an indication of the profitability of the proposed change; farmers stand to earn a profit of GHC 1475.82 by changing from their varieties and adopting Researchers' improved variety. Furthermore, The MRR of 184% implies that any extra GHC1 invested by changing to the researchers improved (drought tolerant) maize would be recovered by farmers with an additional GHC 0.84.

Table 160: Partial Budget Analysis of mini-kit demonstration

	Abontem	Farmer Variety
Average grain yield (kg/ha)	5320.17	3262.5
Adjusted grain yield (kg/ha)	4788.15	2936.25
Gross Benefit (GH₵)	5889.43	3611.56
VARIABLE COST (GH₵)		
Harrowing/double ploughing	175.5	0
Basal fertilizer	600	300
Nicogan (weedicide)	50	25
Gramozone (weedicide)	37.5	200
Top dressing	250	0
Shelling	308	192.5
Sacks	132	82.5
Bagging	132	82.5
TOTAL VARIABLE COST (GH₵)	1685	882.5
Net Benefit (GH₵)/ha	4204.43	2729.01
Marginal Benefit	1475.82	
Marginal Cost	802.5	
MRR	184%	

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Tomato post-harvest studies in Ghana: the participatory rural methodology approach

Research Team: A. Adu-Appiah, E. Adu-Kwarteng, H. Mireku Bortey and A. Aidoo

Collaborating Institutions: MOFA and KNUST

Source of funding: KAFACI Horticulture Project

Introduction

Tomato is one of the most important vegetables grown in Ghana. The area under cultivation is over 46,000 ha with an average yield of 7.5mt/ha (MOFA-SRID, 2014), and an estimated value of GH₵ 374,000 (GSS, 2014). The crop contributes to the nutritional needs of Ghanaians. Despite its importance, challenges such as short shelf life and lack of postharvest systems bring about fast deterioration of the product quality and economic value as tomato moves down the supply chain (Kwami et, al, 2014). According to Hodges et, al, (2010), postharvest system comprises all the after-harvest activities involved when an agricultural produce moves along the food supply chain from farm to the point of consumption. This implies that the management of the crop by both producers and marketing intermediaries can contribute to postharvest losses (Sharma and Sigh, 2011). According to Kwami et, al (2014) two main methods have been used to estimate postharvest losses - the direct method which involves tracking and indirect method which involves surveys. While the use of surveys has the advantage of larger sample size, it may lead to inaccurate estimation. The tracking method is tedious and only smaller sample sizes can be tracked but it also focuses on discarded fruits /quantitative. Irrespective of the method used, the involvement of local people along the supply chain provides useful information as in the participatory rural appraisal (PRA) approach. This is due to the fact that, they are creative and capable, and can do their own investigations, analysis, and planning. Chambers (1994) has defined PRA as an approach and method for learning about rural life and conditions from, with and by rural people. He further stated that PRA extends into analysis, planning and action. PRA closely involves villagers and local officials in the process.

Objective

To get a general understanding of post-harvest losses as tomatoes move along the supply chain from harvest until it gets to the final consumers through the marketing intermediaries.

Methodology

Three tomato producing communities were selected from three agro-ecological zones in Ghana - Agogo (Forest), Atebubu (Transition), and Ada Kasei (Coastal savanna). In each community, a group of 10-30 members made up of farmers, traders and transporters were met for discussions. Following Cavestro (2003) and Chambers (1994), the PRA method was used to solicit for and analyze information from the groups. Informal interviews, using prepared check lists, were organised to help the local people conduct their own analysis. This was done in order to get information which would provide direction for a major study, where methodologies would be developed for postharvest estimation.

Results

The information collected is summarized as Table 161.

Table 161: Summary of tomato production and marketing activities.

PRACTICES	AGOGO (FOREST ZONE)	ATEBUBU (TRANSITION)	ADA-KASEI (COASTAL SAVANNA)	
Land and input acquisition	Land is usually rented and other inputs such as fertilizer, insecticides, and herbicides are acquired in the same manner across the agro-ecologies.			
Land preparation	Slash and burn and allow weeds to grow before applying herbicides. Stumping is also done.	Herbicide application follows land clearing after which ploughing is done.	Land is either ploughed and harrowed or doubly ploughed at non-irrigated sites. Irrigated sites make ridges after ploughing using machines	
Nursery/transplanting	Farmers in all three locations nursed their seeds on beds after which transplanting is done on the fields and earthen-up.			
Fertilization	Between 1.5 and 2 bags/acre of basal fertilizer are used followed by 1 bag of Sulphate of ammonia to top dress	2 bags/ acre each of NPK are used as basal and top dressing respectively	Non-irrigated sites used 1.5 bags each /acre of NPK as basal and top dressing. While irrigated sites use 2 bags /acre each as basal and top dressing	
Weeding	Is done two times per season in both forest and transition zones		Weeding is done 3 times per season	
Chemical usage	Chemicals such as insecticides and fungicides are mixed together in tanks and sprayed on the crop.			
Harvesting	Harvesting is done when the fruit is partially or fully ripe. Fresh fruits are picked with bare hands into smaller containers which are in turn poured into larger ones placed along road sides. They are then packed into wooden crates (boxes) and transported to the marketing centres; this practice also cuts across the three locations.			
Peak seasons	Harvesting is at peak during May, September, and December implying three seasons.	Harvesting peaks in July and December (two seasons).	Harvesting is at peak in July/ August in the non-irrigated areas while the irrigated sites have their peak in November/ December	
Yield	55 crates /acre	35 crates/ acre	33-35 crates/ acre at the non irrigated fields. Irrigated fields get 40 crates / acre	
Marketing	Traders arrange their own transport as they purchase at the farm-gate to the urban centres through other marketing intermediaries. Farmers in all the zones sell to traders from Kumasi, Accra and the Volta Region, and sometimes from Togo. Tomato is also imported from Burkina Faso around January to these production areas.			
Pricing	Pricing is usually through negotiations; however, traders are able to dictate in cases where there is glut or where they have pre-financed the production. Farmers are able to dictate the price where there is scarcity.			
Challenges	Extreme weather (prolonged drought), diseases, adulterated varieties, wrong chemical labeling, high production cost, low prices during glut, unfaithfulness on the part of producers when given credit and on the part of traders and when goods are bought on credit.			
Estimated losses	15%	30%	10%	
Institutions	Agricultural extension agents and input dealers provide technical support		In addition to extension workers and input dealers, banks provide credit to farmers at the rate of 40% per annum. Some individuals lend money to farmers at the rate of 100% per season of 4 months; this amounts to 300% per annum.	
Estimated Price (GH ₵)	275	80	90 (non irrigated)	90 (Irrigated)
Gross Income (GH ₵)	15,125	2,800	3,150	3,600
Total Variable Cost (GH ₵)	5,415	1,580	1,521	1,530
Gross Margin per acre (GH ₵)	9,710	1,220	1,629	2,270

Conclusion

The study revealed that certain practices such as land acquisition, nursing and transplanting, chemical usage, harvesting, marketing and pricing are virtually the same across the study locations. However, differences exist in how farmers prepare their lands, fertilizer usage as well as yields from the farmers' fields. Tomato cultivation seemed to be more profitable in Agogo than the other places- a case which needs more investigation. The various groups estimated tomato post-harvest losses of 10% - 30%.

Way Forward

This information would be used to develop alternative methodologies for the estimation of post-harvest losses.

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Postharvest studies of citrus in Bantama and Ejisu markets, Ashanti Region

Research Team: A. Adu-Appiah, E. Adu-Kwarteng, H. M. Bortey, A. Aidoo and P. Mintah

Collaborating Institutions: MOFA and KNUST

Introduction

Citrus is one of the important horticultural crops in Ghana, with an annual production of 55,000 mt on about 15,700 ha of land (MOFA-SRID, 2009). As food citrus is a source of vitamins, minerals and dietary fibre (MOFA, 2010). Producers derive income from the crop on both local and international markets. The 100g daily consumption of fruits and vegetables by Ghanaians is far below the recommended intake of 400g/ person per day by the FAO and WHO. This has been partially attributed to post-harvest losses (PHL) at various stages of marketing (FAO, 1981). Apart from reducing the availability, PHL increases the unit cost of transportation and marketing (Subrahamanyam, 1986) and this adversely affects both producers (reduction of in income) and consumers (reduced availability and higher prices).

Objectives

To estimate PHL of citrus at the Ejisu and Bantama markets.
Specifically the study sought to:

- Estimate the losses by tracking.
- Compare post-harvest losses at the two markets.

Materials and Methods

Following an informal survey of citrus farmers in the Ashanti and Central Regions of Ghana, two markets were chosen for an in-depth study into post-harvest losses at the markets, using wholesalers. The purpose of the study was explained to their leaders who in turn assisted in the selection of three traders who collaborated in each market study. Upon the arrival of the citrus fruits at the market (in vehicles), each trader's consignment was weighed before they were sold. Traders were asked to keep the rejected fruits in special containers and these were weighed at the close of sales each day until the whole consignment was sold out. Two methods of estimating PHL - direct and indirect- (Kwami et, all, 2014) were used during the study. The indirect method was used during the informal survey while the market study used the direct method.

Results and Discussion

The three traders engaged as collaborators during the study at each market were labeled as A, B, C and X, Y, Z respectively (Table 162). The citrus consignments received by the traders were recorded as total and the losses indicated as rejected. The ratio of losses to the total for each trader was given as % rejected (in the last column). Table 6 shows the losses incurred by the traders, on daily basis, at each market. In all, the study recorded about 1.24 mt and 4.84 mt of citrus at Ejisu and Bantama markets respectively. A total of 29.58kg and 405kg were rejected at both markets representing losses of 2.39% and 8.36% respectively within a week. Table 164 shows that, while most of the citrus were sold within 24 hours at Ejisu, those at Bantama were sold within one week and this might have accounted for the differences in the losses between the two markets.

Traders at Bantama seem to experience more losses than those at Ejisu as indicated in Table 163, and this could be due to the fact that, the Ejisu consignments are in smaller quantitites, and are sold out within 24 hours. Proportionately the losses at Ejisu would have been higher or comparable to that of Bantama as indicated in Table 164.

Table 162: Post-harvest losses of citrus fruits at two markets

Market	Trader	Total (kg)	Rejected (kg)	% Rejected
Ejisu	A	242.10	1.54	0.64
	B	656.22	15.10	2.30
	C	340.34	12.94	3.80
	Total	1238.66	29.58	2.39
Bantama	X	2090.00	205.00	9.8
	Y	2310.00	158.00	6.83
	Z	442.00	42.00	9.50
	Total	4842.00	405.00	8.36

Table 163: Fruit losses per day at the two markets

Market	Trader	Rejection in days (kg)							Total rejected (kg)	%
Ejisu		1	2	3	4	5	6	7		
	A	1.54	-	-	-	-	-	-	1.54	0.64
	B	5.60	-	-	9.50	-	-	-	15.10	2.30
	C	12.94	-	-	-	-	-	-	12.94	3.80
	Total	20.04	-	-	9.50	-	-	-	29.58	2.39
Bantama	A	7.00	4.00	9.00	35.00	80.00	50.00	20.00	205.00	9.8
	B	18.00	9.00	21.00	30.00	55.00	25.00	-	158.00	6.83
	C	42.00	-	-	-	-	-	-	42.00	9.50
	Total	67.00	13.00	30.0	65	135	75	20.00	405.00	8.36

Table 164: Comparison of fruit losses within 24 hours

Market	Total	Rejected	%
Ejisu	1238.66	20.04	1.6
Bantama	4842.00	67.00	1.3

Conclusion and recommendation

The study should be repeated for a valid conclusion to be drawn.

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Assessing the Information Seeking Behaviour of Rice Farmers in Ghana: Case study of Rice Farmers in Ejisu/Juaben Municipal; Ashanti Region, Ghana

Research Team: L.D. Acheampong, M.D. Asante, A. Adu-Appiah and B. Nsiah Frimpong

Collaborating Institutions: MOFA and Ejisu Juaben Municipal

Source of funding: KAFACI Project

Introduction

In the agricultural environment, relevant and timely information helps farming communities to take right decisions to sustain their agricultural activities. Information on weather trends, best practices in farming, improved varieties developed by scientists and timely access to market information, helps farmers to improve productivity. Despite the volumes and variety of agricultural information available, knowing the sources and accessing these information is a major challenge to farmers in Africa including Ghana. There is a gap between information needs of farmers, where to locate available information and how to evaluate the information. These have severely limited farmers' ability to increase their productivity and income. Babu *et al*. (2011) indicated that a better understanding of farmers' agricultural information needs and information sources could help guide extension and other agricultural programs to better target specific groups of farmers. This study seeks to assess the situation of rice farmers in the Ejisu Municipal and make recommendations for improvement.

Objectives

- To find the information needs of the rice farmers
- To find out the source(s) of information used by the rice farmers
- To examine the challenges faced by rice farmers in meeting their information needs
- Recommend measures to improve delivery of information services to the farming communities for better rice productivity in the study area

Methodology

Sampling technique

The study was conducted in the Ejisu Juaben Municipal, because of its contribution to rice production in the Ashanti Region of Ghana. Five communities namely Achinakrom, Nobewam, Duampopo, Bomfa and Donaso, were randomly selected from a list of communities involved in rice production in the municipality. Proportional sampling was employed to select the farm households to be interviewed. In places where there are more rice farmers in the communities, a lot of them were sampled from there compared with the others.

Data collection

Primary and secondary information were collected during the study. The secondary information included desk reviews, searching the internet and libraries for similar works in the area. The primary information was collected through a formal survey involving individual interviews using a structured questionnaire. The type of information collected included characteristics of the rice farmers, their information needs, the type of information they access, sources of the information, and their willingness to pay for the information they need.

Results and Discussion

Socio-demographic Characteristics

Table 165 shows the demographic characteristics of the respondents. Results indicate that 67% are males while 33% were females, implying that rice farming is dominated by males. About 91% of the respondents are married. Twenty-seven farmers, representing 24.8% had no formal education. The remaining 75.2% have had 6-18 years of formal education. On the whole, more than 50 % of the respondents have had up to basic school level education. All things being equal, the level of formal education is expected to affect rice farmer's level of access to sources of extension information as well as their knowledge about rice production technologies, trade and marketing information.

Table 165: Demographic characteristics of respondents

Variables	**Frequency**	**Percentage**
Sex		
Male	73	67
Female	36	33
Marital status		
Married	99	90.8
Single	4	3.7
Widowed	3	2.8
Divorced	3	2.8
Educational level		
None	27	24.8
Basic	68	62.4
Secondary	14	12.8

Characteristics of the farmers

The average respondent has about two years of rice farming experience (Table 166). Their ages ranged between 20 and 72 years with 42 as the mean age. More than six persons constitute a household; with about two persons actively assisting the household head on the rice farm. The farmers operate on a small scale of about 3 acres per person; with a mean yield of about 23 bags. This translates into a mean yield of about 6.4 bags per acre.

Table 166: Farmers' characteristics

Characteristics	**Minimum**	**Maximum**	**Mean**	**Standard Deviation**
Age	20	72	42	11.8
Years in rice farming	1	12	1.8	1.7
Years of Education	0	12	5.7	4.6
Household Size	1	15	6.4	2.9
Active household members in rice production	1	12	1.8	8.5
Farm Sizes (acres)	0.5	25	3.1	3.1
Yield (total) in bags	1	100	23.4	16.4

Over 20% of the respondents belong to farmers' association with only about 15% belonging to rice-based farmers' association. Farmers belonging to associations indicated that they can easily access credits from banks as the group serve as the social capital needed as collateral. They also have easy access to production inputs such as fertilizers, pesticides, etc. at a subsidized price.

Information Usage

Over 60% of respondents receive information on fertilizer, weeds and disease control (Table 167). About 29% and 25% of respondents receive information on planting materials and irrigation respectively; however, only 16%

and 8.3% always use the information on planting materials and irrigation. The low usage of irrigation information is due to the absence of irrigation facilities in most of the communities.

Table 167: Information receivers and users

Type of Information	Recipients (%)	Users of information (%)
Marketing	43	32
Credit	37	15
Fertilizer	73	55
Pesticide	76	56
Weed control	76	57
Disease control	68	46
Storage	44	27
Land preparation	49	28
Irrigation	25	8.3
Planting materials	29	16

Information Sources

Most farmers (62%) relied on their own experience as the source of information. Other sources were friends (53%), family members (49%) and Extension/ Research (48%). Radio was the least source of information.

Information seeking behavior

Respondents rely on their experience, family members and friends who are farmers on daily basis for their information needs. As time goes by, extension/ research becomes more important in their quest to satisfy the information need as the percentage increases from 10 on daily basis to 27 on monthly basis. Seasonally, 24% of farmers seek information from extension/ research. Table 168 shows that extension/ research is the most preferred source of information by farmers as indicated by 54% of the respondents. This is followed by friends (49%), family members (44%) and radio stations in that order. The results seem to suggest that the optimal time for meeting farmers' information needs is between monthly and seasonally. Farmers in the study area seem to have a lot of confidence in extension and research. Farmers' information needs range from pre-production to post-harvest issues such as sources of credit for input acquisition, subsidized inputs, improved seeds, information on land and water management, planting methods, the use of nets to scare birds, fertilizer application and optimal harvesting time.

Table 168: Information seeking behavior among rice farmers

Source	Preference				
	Daily	Monthly	Seasonally	Yearly	Preferred
Family	28	10	13	0	44
Radio	24	10	9	0	39
Experience	46	6	6	1	32
Friends	27	12	26	2	49
Extension/ Research	11	27	24	1	54

Willingness to pay for information

Table 169 indicates how much farmers are willing to pay for information; on the average, respondents are willing to pay at least GH₵ 43 for information.

Table 169: Rice farmers' willingness to pay for information

	Mean	Standard Deviation
The least price willing to pay	42.95	79.72
Maximum price willing to pay	85.62	148.60

Conclusion and Recommendation

Majority of rice farmers (in the study area) rely on their own sources of information. This severely limits their ability to increase their productivity and income. It is therefore recommended that, knowledge sharing should go beyond the formal public-sector extension system and utilize the various agents and intermediaries who interact with farmers and other stakeholders in the rice value chain so that the knowledge and information required by farmers to innovate can be accessed.

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TECHNOLOGY TRANSFER ACTIVITITES

Research Extension Linkage Committee (RELC) Activities, Ashanti Region

Team: J. N. Berchie and E. Nasarah* (*MOFA)

The RELC was formed to ensure that research activities are designed to address farmers' constraints. RELC activities are funded by WAAPP. The Ashanti regional RELC is led by Dr. Berchie, as the Regional Coordinator. Activities undertaken during the year included planning sessions in the various districts and at the regional level to present farmers' constraints identified in the field, prioritize the constraints and develop strategies to address the constraints and also a feedback mechanism. Members also visited the no-till practice centre at Amanchia and CSIR-CRI research fields at Fumesua. They organised monitoring tours, technical review meetings and training in improved practices for poultry, livestock and non-traditional crops production as well as training in the safe use of pesticides (with vegetable farmers from Kentinkrono, a suburb of Kumasi). A Regional Steering Committee meeting was held on November, 24, 2015. These activities promoted good working relationship between CSIR-CRI research scientists and staff of MOFA, especially the extension officers. Farmers also gained knowledge in good agricultural practices.

Recommendations

- Adequate support should be given to enhance RELC activities at the district levels.
- There should be exchange of RELC coordinators to other regions so that the coordinators can learn from the activities in the other regions.

Training of Trainers on Positive Selection

Under the auspices of the CAY-SEED project a training-of-trainers workshop on positive selection was organized by CSIR- CRI and facilitated by IITA on July, 13 – 14, 2015. Nine technical staff from CSIR-CRI and 32 Extension workers participated in the workshop, which was organized to increase and improve participants' knowledge in plant health through the concept of positive selection so that they would facilitate the transfer of skills to other project beneficiaries. The workshop focused on:

- Diseases and pests that affect seed quality (mainly viral diseases, nematodes and some fungal pathogens)
- Identification of symptoms of viral and fungal diseases
- Rating severity of symptoms
- Selection and labelling of healthy-looking plants (or severely symptomatic plants)
- Data collection, analysis and interpretation
- Seed tuber selection

Demonstration and dissemination of improved agronomic practices

Improved agronomic practices, consisting of a package of mechanized ridging for seed bed preparation, use of trellis staking and fertilizer application at a recommended rate of 45-45-60 Kg/ha N-P_2O_5-K_2O, were used to set up a demonstration plot alongside a plot where farmers used their traditional practices - mounding for seedbed preparation, staking and no fertilizer application for yam production. The locations were Ejura and Atebubu. The improved agronomic fields produced a yield increase of 95 – 115% over the farmers' practice plots at both locations.

Field Days

Field days were organised with farmers at various locations such as:

Ejura and Atebubu during the demonstration and dissemination of improved agronomic practices. Five field days were organized with attendance ranging from 22 to 50 made up of males and females. The farmers were excited about the use of ridging for yam production.

- Ejura, on the use of biochar as a soil amendment for increased productivity. There were 35 yam farmers. They expressed their willingness to adopt the technology.
- Nkonsia and Amponsakrom as part of the on-farm work on the management of speargrass with herbicides. There were 58 participating farmers (34 males and 24 females).
- Bipoa and Abrakaso (Ashanti region) with taro farmers, during the harvest of on-farm trials established in 2014 to evaluate five elite taro lines, alongside farmers' varieties. There were 30 participants (20 males and 10 females) at Bipoa and 29 (20 males and 9 females) at Abrakaso.
- Fumesua, Ejura, Kintampo and Atebubu during the vegetative and harvesting stages of microtubers and macrosetts generated using the vine multiplication and minisett techniques respectively. The field day was used as part of the training process for stakeholders. Sixty-one seed yam growers were trained at Fumesua in the yam vine multiplication technique.

Introducing Basic Biotechnology Teaching Techniques in High Schools

In collaboration with Tuskegee University and GES, Ashanti Region, awareness creation campaigns in schools, quiz competition, training sessions, career guidance sessions and industrial visits were carried out.

The specific objectives are to:

- introduce more Senior High School teachers, heads of schools and/science departments to the project
- encourage constructive debates and competition on Modern Biotechnology among high school students
- introduce teaching models to enhance teaching of elementary molecular biology and related topics
- train teachers to train other teachers

At least 10 schools were targeted in the Kumasi metropolis to introduce to the teachers paper models and wet and dry labs to enhance their understanding and delivery of plant biology with emphasis on biotechnology.

Achievements

- **Quiz competition**

  A quiz competition on Modern Biotechnology and Genetically Modified Organisms (GMOs) was organized on 5th March, 2015, at CSIR-CRI, for six High Schools in Kumasi namely Opoku Ware School, Prempeh College, T.I. Ahmadiyya SHS, Kumasi Anglican SHS, Armed Forces SHS and Kumasi High School. The competing schools answered questions on general knowledge of the CSIR, general overview of biotechnology, tissue culture, molecular biology and genetically modified organisms (GMOs). T.I. Ahmadiyya SHS emerged as winners. There were cash prizes in addition to plaques. All participating schools received general prizes of Biotechnology books, T-Shirts, pens and mugs. An organization, based in South Africa, (Inqaba) that supplies biotechnology laboratory items provided sponsorship in the form of souvenirs and prizes.

Plate 28. Participants and audience at the quiz

- **Train-the-trainer workshop**

  A train-the-trainer workshop was organized on June 23 - 26, 2015, for 16 teachers from eight high schools in the Ashanti Region. One post-graduate student from the University of Ghana also participated in the programme. The opening ceremony was attended by about 70 invitees comprising Heads of Science Departments, Teachers, Media men, Scientists and Technicians. The programme included lectures on introduction to biotechnology and its application, genomics and its relevance in the educational system, DNA and plant transformations, among other topics. There were practical demonstrations on DNA to protein and protein folding modeling activities, PCR paper modeling, transformation with green and blue fluorescent proteins and DNA extraction, Mendelian Genetics on independent assortment and agarose gel electrophoresis. On the last day each teacher came along with one student from their schools to train the students on what they had learnt. All participants, facilitators and supporting staff were presented with certificates.

A similar programme was organized for 27 teachers and 30 students from 13 schools in the Ashanti Region on October, 20TH – 23RD 2015.

Plate 35. Some sessions during the training

Training and awareness creation activities on Biotechnology carried out during the year and the beneficiaries are presented as Table 170.

	Activity and Beneficiaries	**Date**	**No. of beneficiaries**
1	Study tour at CSIR – CRI by Presbyterian Girls Senior High School final year students	Feb., 2015	145
2	Biotechnology and GMO quiz for six SHS in Kumasi	March, 2015	90
3	Awareness creation for Ghana Association for Science Teachers, Ashanti region camp meeting.	March, 2015	105
4	Study tour at CSIR-CRI by GIS and ICS	April, 2015	49
5	Awareness creation for first and second year students of Presby Girls' Senior High	April, 2015	300
6	Train the trainer session	June, 2015	43
7	Awareness creation during Science and Math Camp in Koforidua for High school students from all over Ghana	July, 2015	600
8	Hosting students from Ashanti region in Science and Math camp at CSIR-CRI		650
9	Trained teachers training new set of teachers	Oct., 2015	47
10	Hosting students from Enas Hybrid School	Nov., 2015	72
11	Career guidance at Ejisuman Senior High School	Nov., 2015	80
	Total number of beneficiaries		2181

Table 170. Training and awareness creation activities on Biotechnology and beneficiaries

COMMERCIALIZATION

Production of Planting Materials

Team: E. Adjei Asamoah, P. Mintah, K. Offei Bonsu, B.M. Dzomeku, E. N. Tetteh, S. Darkey, V. Amankwah, M. Osei Bonsu, J. Owusu, A.J.A Awazam, A. Bediako and M. Anti

Collaborating Institutions / Clients: GREL, EDAIF, Croplands Ltd, WIENCO

Source of funding: CSIR-CRI

Introduction

CSIR – Crops Research Institute has identified the production of planting materials as one of its income generation activities. The Institute has therefore signed Memoranda of Understanding with some private organizations to produce and supply to them, planting materials. Production of plantain suckers, rubber seedlings, lime seedlings, mango seedlings and pepper seeds were the major activities carried out during the year.

Objectives

- To generate income for the Institute through the sale of planting materials.
- To make available to farmers quality planting materials of the Institute's mandate crops.

Production of Plantain Suckers

A total of 19,144 suckers were collected from farmers' fields at Nkoranza and transported to the Institute's station at Aiyinasi, where they were pared and nursed, for multiplication using the tissue manipulation technique. Some (3,170) of the initial materials were rejected because they were infested with pests and some showed disease symptoms. Humidity chambers (170 of them) were constructed for the nursing of the ex-plants from the mother suckers. The chambers were watered every other day to make the growing media moist. After two weeks, the sprouted suckers were further manipulated (secondary manipulation) to produce more plantlets. The sprouted plantlets (after the secondary manipulation) were transplanted into polybags filled with black soil and kept under a shed constructed with bamboo and roofed with palm fronds. The plantlets were watered and cared for until they were ready for supply to farmers. A number of the plantlets died in the nursery **a**fter the secondary manipulation. A total of 48,252 plantlets were supplied to farmers.

Challenges

- A lot of the suckers supplied were not good enough and this affected the sprouting of the plantlets in the chamber.
- It took the farmers (at Nkoranza) who supplied the initial mother suckers more than a week to obtain a truck-load of materials required per trip (of about 300km) - five trips were made in all.
- The workers to do the paring (after the arrival of the mother suckers) were not enough, and this adversely affected progress of work.
- The distance between the source of mother suckers (Nkoranza) and the nursery site (Aiyinase) - (300km)- was long.

Recommendations

i. Selection and harvesting of mother suckers for paring should be supervised to reduce the inclusion of diseased and pest infested suckers.

ii. Sucker quality is very important for the tissue manipulation technique. Sword suckers are preferred. Harvesters should avoid water suckers, peepers, suckers with short pseudostems, and those with mechanical defects as well as suckers from very old farms.

iii. Mother suckers should be pared on time and nursed to avoid deterioration

iv. As much as possible nurseries for commercial production of plantlets should be sited close to the farm/plantation site in order to reduce cost and length of time for transporting the planting materials.

v. The sawdust and black soil for nursery activities should be sterilized to avoid infection of the plantlets
vi. Workers capacity should be built in planting material production to improve their efficiency and to speed up the process.
vii. The promotion criteria for Scientists working on commercialisation projects should be reviewed to enable them to devote adequate time to commercial activities beside their core research work.

Rubber Seedlings Production

GREL, as the sole provider of rubber seedlings to its out-grower farmers, has not been able to meet this obligation. GREL has therefore sub-contracted the production of rubber seedlings to CSIR-CRI from 2014 to 2016. The commercial production of rubber seedlings GREL has since become one of the flagship projects of CSIR-CRI, leading to the establishment of a nursery, at its Aiyinasi Station, to produce rubber seedlings. The Institute has provided an interim irrigation system (made up of a bore hole, 10 stand pipes and water hoses) to supply water to the rubber seedlings that had been nursed at the station. Thinning, fungicide application, weeding and fertilizer application were carried out as scheduled. About 100,000 grafted materials had been produced by June 2015. The second round of grafting began in July 2015 and it is expected that by March 2016, about 20,000 more grafted materials would be added for collection by GREL between April and August, 2016.
GREL has already paid GH₵20,000.00 to CSIR-CRI (in September 2015). The remaining amount would be paid by GREL when all the seedlings have been collected from the nursery.
The production of rubber seedlings appears to be more lucrative than plantain sucker production.

Challenge

Collection of rubber budwood from GREL's nursery at Abura has been a very difficult task because it has to be done at 3.00am in order to return to the station around 5.00am for grafting to begin at 6.00am (on the same day). It is also costly and labour intensive.

Recommendation

The provision of a reliable irrigation facility is very essential for future work.

Mango Seedling Production

It had been arranged to supply of 80,000 mango seedlings to EDAIF. A target of 100,000 seedlings was therefore set to be produced in 2015 for sale in 2016. All materials - mango stones, black soil, polybags – were assembled and labour mobilized, and by the end of December, 2015, a total of 63,000 root stocks had been raised at Fumesua, Kwadaso and Ejura. A prolonged drought, however caused high seedling mortality at Ejura. Consequently 59,845 seedlings were supplied to EDAIF as at the end of December, 2015. It is planned that at the onset of the rains in 2016, pre-germinated rootstocks will be sourced and nursed.
It is recommended that until a borehole is provided, raising of mango seedlings at Ejura should cease.

Lime Seedlings Production

CSIR-CRI was contracted to produce 660,000 quality lime seedlings for Croplands Ltd, within three years (2015-2017), to establish 6,000 acres of lime plantation. Two nurseries were therefore set up at Kwadaso and Fumesua. The two nurseries had in stock over 340,000 seedlings of rough lemon rootstocks to be budded with lime in September 2015. However, the parent stocks (at Asebu and other areas) from which the lime bud woods were to be taken for grafting, were in flower at the time so work had to be suspended until fruiting (and harvesting) was over.
Large quantities of rough lemon seeds have been acquired and nursed at Kwadaso and Fumesua to begin production of seedlings for 2017 (alongside the 2015 production). The seeds have germinated and would be transplanted into polybags in early 2016.

Challenges

Irrigation of the two batches of seedlings would demand more labour during the dry months from December 2015 to March 2016.

Pepper Seed Production

The Institute was contracted by WIENCO Ghana Limited to produce 2,500kg of certified seeds of the Institute's released pepper variety called *Shito Adope*. Two hectares of pepper field were established at the Akomadan Irrigation Field. Just as harvesting begun the rains ceased and the Irrigation Development Authority (IDA) workers stopped irrigating the fields, explaining that tomato production, which covered most of the irrigated fields, was over and the pepper field alone, will be too expensive to irrigate. This led to crop failure and only 2667 kg of fruits were harvested. This yielded 290 kg of seed after processing. About 202 kg of dried pulp was also obtained which was processed into pepper powder.

Maize Grain Production

Ten acres of maize was planted in the major season of 2015, and it yielded 12.50mt of grain. In the minor season five acres was planted to reduce losses associated with poor rainfall distribution. The field has been harvested and an estimated yield of 13 mini-bags is anticipated.

Challenges

- Unfavourable rainfall distribution adversely affected grain yield.
- High cost of inputs increased production cost.
- Adulteration of agro-chemicals on the market also posed a great challenge as most of them were ineffective.

Recommendations

- Major season production should be increased as rainfall distribution seems to be better than in the minor season.
- Production of early-maturing legumes could be considered for the minor season as rainfall distribution does not favour maize production at the Kwadaso location. Rotating maize with legumes will also improve the soil fertility through nitrogen fixation.

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FINANCIAL REPORT

Income and Expenditre

	2014	2015
	GH¢ M	GH¢ M
GoG-GRANTS	19.72	17.40
IGF	1.33	1.23
Total Fund	21.05	18.63
EXPENDITURE	20.95	18.82
SURPLUS / (DEFICIT)	0.10	(0.19)

Total Externally Funded Projects

	2014	2015
	GH¢ M	GH¢ M
BALANCE	5.12	11.51
INFLOWS	13.76	13.38
OUTFLOWS	7.37	16.71
BALANCE C/D	11.51	8.18

PUBLIC RELATIONS

Public Relations

Team: Mr. S. Gyasi-Boakye and Ms. Linda Agyeman

The Public Relations Unit of the Institute organized the following activities to support the Institute's outreach programmes:

- **Media coverage of Variety release**

  The National Variety Release Committee approved of the release of 12 improved crop varieties that have been developed by the Institute. The varieties were maize (7), cowpea (4), rice (1) and cassava (6). The PR Unit organized media coverage of the event and monitored the media reportage on the release.

- **Research-Media meeting**

  The Unit organized a meeting of research scientists (of CSIR-CRI) and representatives of media houses in the Kumasi metropolis. The objectives of the meeting were to:

- help the journalists to update their knowledge about CSIR-CRI and to better understand and appreciate the research activities and achievements of the Institute for adequate and accurate reporting about the Institute.

- enable the research scientists to become more conversant with the media and to better understand how to work with the media to get research results across to society.

There were presentations on '*Dissemination of Agricultural Research Information: The Role of the Media* (by a Research scientist) and '*Engaging the Media to better Communicate Science*' (by a media representative). The presentations were followed by discussions during which each group suggested ways to improve working relations.

Research-Industry Dialogue

A meeting was organized between research scientists of the Institute and some agribusinessmen. Participants included seed producers, agro-processors, agro-input dealers and commercial farmers. The objective was to present to participants' research outputs of the Institute, facilities and specialized manpower available at the Institute, services that the Institute can offer to support agri-business as well as opportunities for public – private partnership with the identified groups.
There were presentations on improved technologies developed through breeding and post-harvest research. The agribusiness participants also outlined their research needs.

'Biotech series'

Two editions of the 'Biotech Series' were prepared/edited by the Biotechnology research team for publication in the newspapers. Editors of the Daily Graphic and Ghanaian Times were contacted to get the series published in their newspapers. It was proposed to have a monthly publication. Other Head of Divisions were consulted to prepare other articles for publication.

Records of Media reports on CSIR-CRI activities

TITLE OF PUBLICATION	MEDIA ORGANIZATION	DATE
CSIR harvests fourth batch of genetically modified rice	www.graphic.com.gh	21st Jan., 2015
Ghanaian scientists edge up GM rice trial	Luv News/ myjoyonline.com	24th Jan., 2015
CAYSEED: Agriculturists meet on yam development	www.graphic.com.gh/news/general.news	11th Mar., 2015
Kofi Annan promotes consumption of sweet potatoes	www.graphic.com.gh	13th Mar., 2015
CRI hit by high staff attrition	Luv News/ myjoyonline.com	7th May, 2015
CRI loses 100 workers in 4 years; Tells government to lift embargo on employment	www.graphic.com.gh	8th May, 2015
Poor land use exposes Ghana to possible food and water scarcity	Luv News/ myjoyonline.com/ modernghanaonline.com	June 2015
Crop scientists in Ghana grow "seed yams in the air"	Luv News/ myjoyonline.com/ modernghanaonline.com	23rd July, 2015
West African scientists join forces to fight viral diseases in crops	Luv News/ myjoyonline.com	6th Aug, 2015
CRI spearheads national campaign to overcome food insecurity	GNA/ modernghanaonline.com	Aug.2015
CRI-CSIR to release three new high-protein maize varieties	Luv News/ myjoyonline.com	17th Aug., 2015
Agricultural Researchers brainstorm to improve cassava production	GNA/ modernghanaonline.com	28th Aug., 2015
CSIR-Crops Research Institute releases 12 crop varieties to address climate change and malnutrition	Luv News/ www.myjoyonline.com	15th Sept., 2015
CRI releases improved varieties of crops	Daily Graphic/ www.graphic.com.gh	16th Sept., 2015
CRI releases seven new maize varieties	Ghana News Agency	29th Sept., 2015
CSIR-CRI to run post-graduate programmes in Science	Luv News/ www.myjoyonline.com	1st Oct., 2015
Crops researchers engage Industry in commercialization of products	Luv News/ myjoyonline.com	2nd Oct., 2015
Ghana develops 12 high yielding crops to boost food production	tv3network.com/Ghana	4th Oct., 2015
'Scientists, Journalists need each other'	The Chronicle	6th Oct., 2015
Management of groundnut rosette disease in farmers' fields (TV documentary)	Modern African Productions	8th/15th Nov., 2015
CSIR-CRI releases new cassava varieties	Daily Graphic/ www.graphic.com.gh	16th Nov., 2015
Crops Research Institute launches six cassava varieties	The Spectator	5th Dec., 2015
Health Benefits of Cassava – Bits and pieces about cassava	The Spectator	5th Dec., 2015

ADMINISTRATIVE REPORT

STAFF MATTERS

- **Promotions**

The CSIR Head Office approved of the promotions of the under-listed members of staff:

Senior Members

Name	From	To	Effective date
1. Dr. Joe Manu-Aduening	Sen. Res. Sci.	Prin. Res. Sci.	July 1, 2013
2. Mr. P. Osei-Bonsu	Res. Sci.	Sen. Res. Sci.	July 1, 2013
3. Dr. K. Obeng-Antwi	S.R.S.	P.R.S	Jan. 1, 2014
4. Dr. M. B. Mochiah	S.R.S	P.R.S	Jan. 1, 2014
5. Dr. J. N. Berchie	S.R.S.	P.R.S	July 1, 2014
6. Mr. K. Offei-Bonsu	R.S	S.R.S.	July 1, 2014
7. Dr. Maxwell D. Asante	R. S	SRS	Jan. 1, 2015

- **Senior Staff**

The promotions of the under-listed were approved with effect from January 1, 2015:

Name	From	To
1. Daniel Kingsley Cudjoe	Sen. Tech. Officer (STO)	Prin. Tech. Officer (PTO)
2. Agnes Nimo Bosompem	STO	PTO
3. Esther Agyemang Marfo	STO	PTO
4. Maxwell Lamptey	STO	PTO
5. Matilda Frimpong	STO	PTO
6. Agnes Achiaa Aboagye	STO	PTO
7. Wiiliam Lelabi Kota	STO	PTO
8. Samuel Tandoh	STO	PTO
9. Afua Gyaama Gyimah	STO	PTO
10. Lily N.A. Allotey	STO	PTO
11. Gertrude Osei Diko	STO	PTO
12. Aisha Karim	STO	PTO
13. Maxwell Kodane	Tech. Officer (TO)	STO
14. Elizabeth Nakor Nartey	TO	STO
15. Richard Yeboah	TO	STO
16. Emmanuel Owusu	TO	STO
17. Alberta Nsenkyire	TO	STO
18. Prince Opoku	TO	STO
19. Henry Antwi-Bofah	TO	STO
20. Alhassan Kwadwo	TO	STO
21. Franklin D. Bosompem	TO	STO
22. Eric Baffoe	TO	STO
23. Abigail Amoah-Owusu	TO	STO
24. Bismark Abugri	TO	STO
25. Foster Boateng	Assist. Farm Manager (AFM)	Sen. Asst. Farm Manger (SAFM)
26. Justice Lotsu	AFM	SAFM
27. Samuel K. Agbenyega	AFM	SAFM
28. Samuel Toroson Millah	AFM	SAFM
29. Kwame Twum Barima	Asst. Transport Officer	Sen. Asst. Transport Officer

- **Upgrading**

The under-listed members of staff were up-graded:

Name	From	To	Effective Date
1. Mr. Yaw Dwumfour-Berchie	STA	T.O	June 30, 2012
2. Ms. Dora Aninakwa	Snr. Clerk	Admin. Asst.	May 23, 2014
3. Mr. Alex Adu-Appiah	CTO	R.S	June 1, 2015
4. Mr. Felix Frimpong	PTO	R.S	July 1, 2015
5. Mrs. Z. Appiah-Kubi	CTO	R.S	October 1, 2015

- **Award**

  Dr. J. Manu-Aduening, a Principal Research Scientist and a Cassava Breeder and a team of other scientists won the 2015 National Best Agricultural Researcher award. The award was presented to him during the National Farmers' Day celebration, at Bolgatanga on 4th December, 2015.

- **Conferences and Workshops**

Some members of staff attended various meetings during the year as presented below:

International

Drs. J. Manu-Aduening and G. Bolfrey-Arku: WAAPP study tour on "Technology Transfer and Adoption", Nigeria, 25th January -7th February, 2015

Mr. I.S. Baning: WAAPP study tour on "Cross Border Technology Transfer", Niger, 8th- 14th February, 2015

Dr. M. B. Mochiah: West Africa Virus Epidemic (WAVE) of Root and Tuber Crops, Abidjan, Cote d'Ivoire, 15th-18th March, 2015

Dr. M. Asante and Ms. B. Nsiah Friompong: CNS-Rice Regional Programming Workshop, Bamako, Mali, 27th -30th April, 2015

Mr. E. N. Tetteh: International training course on "Renewal Energy as a catalyst for Regional Development", Arava Institute for Environmental Studies, Kibbutz Ketura, Israel, 5th -20th May, 2015

Dr. A. Oppong: Annual Review and Planning of the Cassava Disease Diagnostic Project, Lilonge, Malawi, 9th -14th May, 2015

Mr. K. Adofo: Annual Sweetpotato Breeders Meeting, Colline Hotel, Mukono, Uganda, 1st -6th June, 2015

Rev. (Dr.) H. Adu-Dapaah: African Regional Intellectual Property Organization Diplomatic Conference, Arusha, Tanzania, 29th June-7th July, 2015

Local

Dr. E. Moses and Mrs. Z. Appiah-Kubi: Workshop on Plantwise Ghana Stakeholders Analysis, Erata Hotel, Accra, 9th-10th February, 2015

Mr. L. Mensah: Orientation seminar towards Job Re-evaluation, Hephzibah Christian Ltd., Aburi, 25th February, 2015

Drs. R. Sagoe and G. Bolfrey-Arku: Workshop on "Web-based M& E System", Maxlot Hotel, Accra, 26th-27th March, 2015.

Dr. E. Annan Afful: Workshop on Ghana Soil Information Service Project under Africa Soil Information Service Project. (AfSISII), Accra, 22nd-23rd April, 2015

Mr. G. Sefa-Anane: "e-Capacities Demand-Side training workshop", FARA Secretariat, Accra, 17th-19th August, 2015

Mr. E. Sosu and Mrs. L. D. Acheampong: ADLSN Digital Library Policy and Management Training, Accra, 21st-23rd September, 2015,

Mr. K. Agyeman: Workshop on Ghana's Intended Nationally Determined Contribution (INDCI) to United Nations Framework Convention on Climate Change Miklin Hotel, Kumasi, 16th October, 2015

Dr. M. Asante: Technical Review workshop on AGRA rice production, Takoradi and Sefwi Wiawso, 24th & 26th November, 2015, respectively.

- **Institutional Transfers**

The under-listed members of staff were transferred to other CSIR Institutes:

	Name	Position	From	To
1.	Mr. Samuel Adu	Accountant	CSIR-CRI	CSIR-SRI
2.	Mr. Emmanuel Sosu	Res. Sci.	CSIR CRI	CSIR-OPRI
3.	Ms. Ruth Fosu	PTO	CSIR-CRI	CSIR-FRI

Mr. Konadu Yiadom, an Accountant, was transferred from CSIR-SRI to the Institute.

- **Staff on Study Leave with Pay**

Name	Programme	Institution
1. Mr. B. M. Dzomeku	PhD (Crop Physiology)	KNUST
2. Mr. C. Afriyie-Debrah	PhD (Crop Physiology)	KNUST
3. Mr. H. Okyere	PhD (Environmental Chemistry)	KNUST
4. Mrs. E. Adu-Kwarteng	PhD (Food Sci. Tech.)	KNUST
5. Mr. J. Kwaku Addo	PhD (Food Sci. and Tech.)	KNUST
6. Mr. M. Akuamoah Boateng	PhD (Food Sci. and Tech.)	KNUST
7. Mr. Y. Danso	PhD (Plant Nematology)	KNUST
8. Mr. M. B. Ewool	PhD (Plant Breeding)	KNUST
9. Mr. B. Boakye Peprah	PhD (Plant Breeding)	Univ. of Free State, S. Africa
10. Mrs. J. Haleegoah	PhD (Soc. Sciences)	Wageningen, Netherlands
11. Mrs. L. Agyeman	MPhil (French)	KNUST
12. Ms. L. Abrokwah	MPhil (Crop Science)	KNUST
13. Mr. F. Coffie Danso	MSc (Plant Breeding)	KNUST
14. Mrs. V. Larweh	MSc (Plant Breeding)	KNUST
15. Mrs. F. Okyere	MSc (Biochemistry)	KNUST

16. Mr. F. Sumaila	BSc (Agriculture)	UEW, Mampong
17. Mr. D. Antwi	BSc (Agriculture)	Meth. Univ., Wenchi
18. Mr. Y. Huss Cole	BSc (Agriculture)	KNUST
19. Mr. A. Agyekum Darkwa	BSc (Agriculture)	Meth. Univ., Wenchi
20. Mr. I.N. Boakye-Mensah	BSc (Agriculture)	UoG
21. Ms. S. Baah Sakyi	BSc (Info. Tech.)	Blue Crest College
22. Mr. J. Naa Dong	BSc (Construction)	UCEW
23. Ms. P. Adusei Sarkodie	BBA (Admin.)	CSU
24. Ms. C. Atta Boateng	BBA (Secretary)	UCEW
25. Ms. E. Dwomoh	BBA (Mgmt)	UCEW
26. Ms. V. Amuzu	Diploma (Gen. Agric)	UCC

- **Resumption of Duty**

The under-listed members of staff resumed duty after completing their training programmes:

Name	Programme
1. Mrs. Priscilla F. Ribeiro	PhD (Plant Breeding)
2. Ms. Mavis Akom	MSc (Agroforestry)
3. Ms. Harriet A. Dwamena	MPhil. (Applied Mathematics)
4. Mr. Michael T. Odamtten	MSc (Water Resource Engineering)
5. Ms. Monica Ode Adu-Gyamfi	BSc (Biotechnology)
6. Mr. Richard Peprah	BSc (Agriculture)
7. Augustine D. Agyekum	BSc (Agriculture)

Dr. P.K.A. Dartey, a Senior Research Scientist and Mrs. Grace Acheampong, an Assistant Farm Manager, resumed work from Sabbatical leave and "Leave without pay" respectively.

- **Resignations**

The under-listed members of staff resigned from the services of the CSIR:

Name	Grade	Effective Date
1. Ms. Victoria Agyare	Supervisor II	March 1, 2015
2. Mr. Patrick Tuffour	Labourer	May 30, 2015
3. Mr. Godfried Nkasia Zewu	Artisan	November 1, 2015

- **Voluntary Retirement**

  Mr. Hamidu Sulemana, a Security Assistant, retired voluntarily on September 30, 2015.

- **Compulsory Retirements**

The under-listed members of staff proceeded on compulsory retirement:

Senior Members

Name	Grade	Effective Date
1. Mr. E. Lanor Omenyo	Res. Sci.	Feb. 28, 2015
2. Mr. I.O. O. Ansah	R.S	Sept. 30, 2015
3. Dr. Emmanuel Moses	R.S	Dec. 31, 2015

Senior Staff

Name	Grade	Effective Date
1. Lucianus Kuweiner	Asst. Farm Manager	January 22, 2015
2. Joseph Donkor	CTO	March 4, 2015
3. Cosmos Boafo	Asst. Farm Manager	May 5, 2015

4.	Titus K. Gbarinaa	CTO	May 5, 2015
5.	Robert Afrim Darko	Snr. Asst. T'port. Officer	May 22, 2015
6.	Kassim Donson	Asst. Farm Manager	May 22, 2015
7.	Haruna Adam	CTO	June 18, 201
8.	Alice Addo	Asst. Farm Manager	August. 15, 2015
9.	John K. Ali	Snr. Asst. Farm Manager	October 9, 201
10.	Lord E. Ohemeng-Appiah	CTO	October 17, 2015
11.	Yaw Osei	Security Officer	November 4, 2015
12.	Beethoven Ameho	PTO	Dec. 11, 2015

- **Deaths**

The following members of staff passed away:

Name	Grade	Station	Date
1. Haruna Kusasi	Snr. Headman	Fumesua	April 10, 2015
2. Joseph Kutame	Asst. F/M	Kwadaso	June 25, 2015
3. Felicia Ampofo	Overseer	Fumesua	July 27, 2015
4. Cyperano Tieruwe	Overseer	Fumesua	August 18, 2015

VISITORS

- About 63 distinguished persons visited the Institute during the year. They included H.E. Kofi Annan and his wife Nane Annan, Hon. Mr. Mahama Ayariga (Minister for Environ. Science, Tech. and Innovation) and Dr. Victor Agyeman (Director-General, CSIR).

- Students from 12 tertiary and second cycle Institutions visited the Institute to acquaint themselves with research activities in the Institute.
- Ms Lisa Burgel, from the University of Honenheim, Germany, was on an exchange programme, at the Biotechnology, Seed and Food Science Division of the Institute, from August 8 to December 14, 2015.

Vacation Training

One hundred and four (104) students from various tertiary Institutions in the country undertook their practical vacation training at the Institute.

National Service

Thirty-five National Service Personnel were posted to the Institute during the 2015/2016 service period.

STAFF PUBLICATIONS

Refereed Journal Papers

1. **Adama, I**., **H. Braimah** and **B. W. Amoabeng** (Accepted) Efficacy of Super neemol® granules for the control of cowpea (*Vigna unguiculata* L. Walp.) insect pests in the forest region of Ghana. *International Journal of Agriculture Innovations and Research.*

2. **Addo, J. K., Osei, M. K., Mochiah, M. B., Bonsu, K. O.**, Choi, H. S. and Kim, J. G. (2015). Assessment of Farmer Level Postharvest Losses along the Tomato Value Chain in three Agro-Ecological Zones of Ghana. *International Journal of Research in Agriculture and Food Sciences*. Vol. 2 (9) pp. 15-23.

3. **Agyeman, A**. and Nsowah-Nuamah, N.N.N. (2015). Demographic and Socio-Economic Characteristics of Monozygotic and Dizygotic Twins in the Labour Market. *Journal of Social and Economic Statistics 4(2):19-41*.

4. **Agyeman, A., Parkes, E** and **Peprah, B.B** (2015). AMMI and GGE biplot analysis of root yield performance of cassava genotypes in the forest and coastal ecologies. *International Journal of Agriculture Policy and Research* Vol. 3 (3), pp. 222- 232.

5. **Agyeman, K.** E. Gaisie, A. Sadick, T. Adjei-Gyapong, G. Quansah (2016). Leaf Decomposition and the Nutrients Release from Multipurpose Trees for Crop Production. *International Journal of Scientific Research in Science, Engineering and Technology*. Vol 2 Issue 1. Pp 345-352. Online ISSN: 2394-4099.

6. **Aidoo, A. K, Appiah-Kubi Z, Bam, R. K**. (2015). Mycoflora associated with seeds of five rice (*Oryza sativa*) varieties in Ghana. *Greener Journal of Plant Breeding and Crop Science*. ISSN: 2354-2292 Vol. 3 (1), pp. 014-019, May 2015.

7. **Aidoo, K.A.** (2015). Bioactivity of *Zingiber officinale* and *Piper nigrum* plant extracts in controlling postharvest white yam (*Dioscorea rotundata*) tuber rot fungi. *AJMR.* Vol. 9(22), pp. 1499-1503.

8. **Aidoo, K.A.** (2015). Improving Pit Storage Systems to Reduce Rots of White yam (*Dioscorea rotundata*) in *Ghana. Sci. Jr. of Agri. Res. & Mgt.* Vol. 2015. 4 Pages.

9. **Amponsah**, S. K., J. O. Akowuah, **E. Adu-Kwarteng** and E. Bessah (2015). Design and Construction of Improved Yam Storage Structure using Locally-Available Materials. *International Journal of Research in Agriculture and Forestry* Vol. 2 Issue 10.

10. **Appiah-Kubi, Z**., Apetorgbor A.K.**, Moses, E., Quian, M., Thompson, R., Appiah-Kubi, D., Abrokwa, L**. (2015.) Genetic variability in *Colletotrichum gloeosporioides* (Penz.) isolated from cassava and yam from four agro-ecological zones of Ghana. *Greener Journal of Agricultural Sciences Vol. 5* (4), pp. 132-140.

11. **Asante, M.D., Bam, R.K., Amoako-Andoh, F.** and **Annan-Afful, E**. (2015). Grain quality characteristics of imported rice in Ghana: Implications for breeding for consumer-preferred varieties. *Ghana Journal of Agricultural Science* (Accepted).

12. **Baafi E,** Gracen, V. E., Blay, E. T, Ofori, K, Manu-Aduening, J. and Carey, E. E. (2015). Evaluation of Sweetpotato Accessions for End-user Preferred Traits Improvement. *African Journal of Agricultural Research* 10(50), 4632-4645. DOI: 10.5897/AJAR2015.9953.

13. **Baafi, E. Osei, M.K.**, **Agyeman, A**. and Afriyie, J. (2015). Diversity studies on sugarloaf pineapple variety. *International Journal of Science and Knowledge, 4(1): 14-25*.

14. **Baafi, E.,** Manu-Aduening, J., Carey, E. E., Ofori, K., Blay, E. T. and Gracen, V. E. (2015). Constraints and Breeding Priorities for Increased Sweetpotato Utilization in Ghana. *Sustainable Agriculture Research 4(4), 1 - 16. ISSN 1927-050X E-ISSN 1927-0518. doi:10.5539/sar.v4n4p1 URL: http://dx.doi.org/10.5539/sar.v4n4p1.*

15. Baah, F. A, Osekre, E. A., **Mochiah M. B.** and Logah, V. (2015). Effect of Different Levels of Nitrogen in Liquid Fertilizer on the Population Dynamics and within Plant Distribution of *Aphis gossypii* and *Thrips palmi* and Yield of Eggplant. *American Journal of Experimental Agriculture* Vol. 9 (1) pp. 1-10.

16. Enoch Sapey, **Bright Boakye Peprah**, Kwasi Adusei-Fosu and Dan Agyei-Dwarko (2015). Genetic Variability of Fresh Fruit Bunch Yield (FFB) Yield in Some Dura X Pisifera Breeding Populations of Oil Palm (Elaeis guineensis Jacq.). *American-Eurasian J. Agric. & Environ. Sci.*, 15 (8): 1637-1640.

17. Fening, K.O., **I. Adama**, **M. B. Mochiah,** M. K. Billah, **H. Braimah**, M. Owusu-Akyaw and **J. A. Manu-Aduening**. (*Accepted*). Quantifying millipede (Diplopoda) damage on cassava (*Manihot esculenta Crantz*) and cocoyam (*Xanthosoma Sagittifolium* (L.) Schott) in the Western region of Ghana: A preliminary study. *Ghana Journal of Agricultural Science.*

18. **Frimpong, F., Amponsah, S., K. Agyeman**, K.O. Amoah, H. Dankwa and **J. Osei-Adu**. (2015) Aquaponics based food system project. Interdisciplinary AGEP Winter School, University of Hohenheim - A World without Hunger Conference. DOI: 10.13140/RG.2.1.1605.5127.

19. Gaikpa, D. S., Akromah, R., **Asibuo, J. Y.,** Nyadanu, D. (2015). Studies on Molecular Variation in Commercially Cultivated Groundnuts (*Arachis hypogaea* L.) using SSR markers. *The International Journal of Science and Technology*. 3(2):80-85.

20. Gaikpa, D.S., Akromah, R., **Asibuo, J. Y., Appiak-Kubi**, Z.**,** Nyadanu, D. (2015). Evaluation of Yield Components of Groundnut Genotypes Under Cercospora Leaf Spots Disease Pressure. 2015. *International Journal of Agronomy and Agricultural Research.* 7(3):66-75.

21. Gongolee, G.A.K., **Osei, M.K.,** Akromah, R., Nyadanu, D. and Aboagye, L.M. (2015). Evaluation of Some Introduced Tomato Cultivars. *Horizon Journal of Agriculture and Food Science, Vol. 1(1) pp. 001-004.*

22. **Haleegoah, J.,** Ruivenkamp, G., Essegbey, G., Frempong, G., and Jongerden, J. (2015). Street Vended Local Food Systems Actors Perceptions on Safety in Urban Ghana: The Case of *Hausa Koko*, *Waakye* and Ga *Kenkey*. *Advances in Applied Sociology, 5,* 134-145.

23. Marquez-Garcia, B., D Shaw, J.W Cooper, B. Karpinska, **M.D. Quain**, E.M. Makgopa, K. Kunert and C.H. Foyer (2015). Redox markers for drought-induced nodule senescence, a process occurring after drought-induced senescence of the lowest leaves in soybean (*Glycine max*). *Ann Bot* first published online April 7, 2015 doi:10.1093/aob/mcv030.

24. **Moses, E.**, **Oppong, A** and **Lamptey, J.N.L**. (2015) Reaction of local accessions of cassava to diseases in southern Ghana. *African Crop Science Journal* Vol 23, No 1. Pp: 27-34.

25. Ofori, A.P., Ofori, K., **Obeng-Antwi, K**., **Tengan, K.M.L**. and Badu-Apraku, B. 15a. Combining ability and heterosis estimate of extra-early quality protein maize (QPM) single cross hybrids. *Journal of Plant Breeding and Crop Science* Vol. 7(4), pp 87-93.

26. Ofori, A.P., Ofori, K., **Obeng-Antwi, K., Tengan, K.M.L.**, **Agyeman, A**., and Badu-Apraku, B. (2015). Genetic analysis of single cross Quality Protein Maize (QPM) hybrids. *Journal of Plant Breeding and Crop Science, 7(8): 251-255.*

27. Ofori, J., **Asante, M. D.**, Narh, S., MacCarthy, D. S. and Godson-Amamoo, S. (2015). Validation of System of Rice Intensification on Vertisol in Coastal Savannah Ecological Zone of Ghana. *Ghana Journal of Agricultural Science* (*Accepted*).

28. **Oppong, A**., Offei, S., Ofori, K., Adu-Dapaah, H., Lamptey, J L., Kurenbach, B., Walters, M., Shepherd, D., Martin, DP. and Varsani, A. (2015). Mapping the distribution of maize streak virus genotypes across the forest and transition zones of Ghana. *Archives of Virology*, Vol. 159:1-10 ISSN 0304-8608 DOI 10.1007/s00705-014-2260-7.

29. **Oppong, L.A., Quain, M.D., Oppong, A., Doku, H.A., Agyemang, A.** and **Offei-Bonsu**, E. (2015). Molecular Characterization of *Solanum* Species Using EST-SSRs and Analysis of Their Zinc and Iron Contents. *American Journal of Experimental Agriculture 6 (1): 30-44, 2015, Article no. AJEA.2015.062 ISSN: 2231-0606.*

30. **Osei Bonsu** (2015). Effect of planting device and seed sorting on yield of maize. *International Journal of Scientific and Technology Research* Volume 4, Issue 01.

31. **Osei Bonsu** (2015). Evaluation of two jab planters for planting maize in the forest zone of Ghana. *International Journal of Innovation and Applied Studies* Volume 10. No 1.

32. **Osei, K., Danso, Y., Otoo, E., Adomako, J., Sackey-Asante, J**. and Abugri, B. (2015). Evaluation of yam varieties for resistance to plant parasitic nematodes infestation in three agro-ecologies of Ghana. *Academic Research Journal of Agricultural Science and Research* 7**:** 201-206.

33. **Osei, K., S. A. Ennin, Y. Danso, E. Owusu Danquah** and **J. Adomako.** (2015). Management of plant parasitic nematodes with fulan in mechanized yam production. *African Journal of Plant Science*. Vol. 9(9), pp. 346-351, September 2015 DOI: 10.5897/AJPS2015.1275 Article Number: 52EC05B55506 ISSN 1996-0824. www.academicjournals.org/AJPS.

34. **Osei, M.K., Bonsu, K.O., Adu-Gyamfi, K., Frimpong, M.** (2015) Development of high yielding and uniform tomato fruits using pure line selection. *Direct Research Journal of Agriculture and Food Science, Vol. 3 (1) pp. 10-16.*

35. **Osei, M.K., M.B. Mochiah, J.N. Berchie, K. Osei, J.N. Lamptey** and R.L. Gilbertson (2015) Performance of tomato varieties: IPM versus farmer practice in different agro-ecologies of Ghana. *Journal of Integrative Agriculture* (JIA-2015-1390) pp 2-31.

36. **Osei-Adu J., Ennin, E.A., Asante, B.O.,** Adegbidi, A., Mendy, M. and Kergna, A. (2015). Gender Issues in Crop-Small Ruminant Integration in West Africa, I*nternational Journal of Agricultural Extension*, 3(2), 137-147.

37. **Osei-Bonsu, I., Dzomeku, B.M., Bonsu, K. O., Osei, M.K., Agyeman**, **K. Ekyem, S.O and Berchie, J.N**. (2015). Assessing Flood Tolerance Potential of Papaya Germplasm at the Juvenile Stage. *International Journal of Plant & Soil Science* 9(6): 1-14, 2016; Article No. IJPSS.20191.

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52. **Tetteh, E.N.,** V. Logah, K. Twum-Ampofo and S.T. Partey (2015). Effects of duration of reclamation on soil quality indicators of a surface-mined acid forest oxisol in South-Western Ghana. *West Africa Journal of Applied Ecology.* Volume 23(2), 2015: 63 – 72.

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Conference Papers / Technical Reports

1. **Acheampong, P. P.** and Owusu V. (2015). Impact of improved cassava varieties adoption on farmers' incomes in Rural Ghana: A propensity score matching analysis. *International Conference of Agricultural Economists, August 8-14, 2015, Milan, Italy.*

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8. **Asante, M.D**. (2015). Characterization of diverse rice accessions for protein content and its correlation with starch properties. *Proceedings of 4th International Conference and Exhibition on Food Processing & Technology.* August 10-12, 2015, London, UK. J. Food Process Technol. DOI: 10.4172/2157-7110.S1.023.

9. **Asante, M.D., P.K.Y. Dartey**, W. Dogbe, **G.K. Acheampong**, S. Abebrese, **R.K. Bam, E. Annan-Afful, A. Oppong, P. Acheampong, E. Asamoah,** R. Quaye and M. Mensah (2015). Release of Arize 6444 Gold hybrid rice. *Presentation to National Variety Release Committee, Ghana* at CSIR-CRI, Kumasi, 11th September, 2015.

10. **Benedicta Nsiah Frimpong**, **Grace Bolfrey-Arku**, Afiavi R. Agboh-Noameshie, and **Jonas Osei-Adu** (2015). Improving Incomes of Rural Women through Better Parboiling Processes in Ghana. *Book of*

Abstracts; Tropentag Conference 2015 on Management of Land use systems for enhanced food security-conflicts, controversies and resolutions. September 16-18, 2015, Humboldt-Universatat zu Berlin, Germany.

11. Frimpong, F., Amponsah, S., **Agyeman**, **K.** Owusu Amoah, K., Dankwa, H., Osei-Adu, J. (2015) Aquaponics based food system project. Interdisciplinary AGEP Winter School, University of Hohenheim - *A World without Hunger Conference*. DOI: 10.13140/RG.2.1.1605.5127.

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Book Chapter

Quain, M.D., M.O. Adu-Gyamfi, R.N. Prempeh, D. Appiah-Kubi, A. Agyeman and **V. Amankwaah** (2015). Molecular Fingerprinting and Selection of Appropriate Media for Rapid Multiplication of Three Released Yam Varieties in Vitro in Ghana. *Biotechnology*, ISBN 978-953-51-4157-0. Edited by Deniz Ekinci, Publisher: InTech. *Book Chapter 2* Pp 33 – 57.

LIST OF SENIOR MEMBERS AND SENIOR STAFF AS AT DECEMBER 2015

DIRECTOR

Stella Ama Ennin	PhD (Agronomy), Univ. of Nebraska, USA, 1997	- CRS

DEPUTY DIRECTOR

Emmanuel Otoo	PhD (Plant Breeding), KNUST, Ghana, 2009	- PRS

ROOT AND TUBER CROPS

Joseph Manu-Aduening	PhD (Plant Breeding), Univ. of Greenwich, UK, 2005	- PRS
Regina Sagoe	PhD (Population Studies), Univ. of Ghana. 2010	- SRS
*Kwadwo Adofo	MSc. (Agronomy), UCC, Ghana. 2004	- RS
Peter Appiah Danquah	MPhil. (Crop Science), UoG, Ghana, 2011	- RS
*Bright Boakye Peprah	M. Phil (Plant Breeding), Univ. of Ghana, 2011	- RS
Ernest Baafi	PhD. (Plant Breeding), KNUST, Ghana, 2005	- RS
Asamoah Obeng Nyarko	Dip. (Gen. Agric), Univ. of Ghana, 1991	- CTO
Joseph Esuman K. Awoodzie	Dip. (Gen. Agric.), Univ. of Ghana, 1993	- CTO
Edem Lotsu	Dip. (Gen. Agric.), Univ. of Sci. & Tech. Ghana, 1996	- CTO
Oswald Ohene Gyan	Dip. (Gen. Agric.), Univ. of Ghana, 1993	- CTO
Nanaebo Blankson	Dip. (Gen. Agric.), Univ. of Ghana, 1995	- PTO
Cynthia Oppong Darko	B.Ed. (Agric), Uni.of Edu. Wineba (Mampong), 2011	- PTO
Habbibah Aggrey	BSc (Agriculture), KNUST, 2013	- PTO
Irene Dufie	Cert. in Agric (ATC). 2004	- TO
Prince Opoku	Dip. (Gen. Agric.), Kwadaso Agric. College, 2011	- TO
Kwadwo Alhassan	Dip. (Gen. Agric.), Kwadaso Agric. College, 2011	- TO

CEREALS

Maize Programme

Kwadwo Obeng Antwi	PhD. (Plant Breeding), Univ. of Reading, UK, 2008	- PRS
*Manfred B. Ewool	MSc. (Plant Breeding), KNUST, Ghana, 2004,	- RS
Martin Luther Tengan	MSc. (Agronomy), KNUST, Ghana, 2010	- RS
*Frank Coffie Danso	BSc. (Agric.) , KNUST, Ghana, 1999	- ARS
Joseph K. Amponsah	BSc. (Agric), KNUST, Ghana. 2008	- PTO
C.K.A. Adaabre	Cert. in Agric (ATC), CIMMYT Cert.	- PTO
E. Abugbila	Cert. in Agric. (ATC)	- PTO
Stephen Oware Kunkumah	Dip. (Gen. Agric.), Methodist Univ. College, 2011	- TO
Eric Baffoe	Dip. (Gen. Agric.), Kwadaso Agric. College, 2011	- TO

Rice Programme

Raphael K. Bam	M.Phil. (Agronomy), Univ. of Ghana, 1996	- SRS
Paul Kofi A. Dartey	Ph.D (Plant Breeding), Liverpool Univ., UK. 1993	- SRS
Ebenezer Annan-Afful	PhD (Soil Fert. and Plant Nutrition), Tottori Univ., Japan, 2004.	- SRS
George Kwasi Acheampong	M.Phil (Weed Sci.), KNUST, Ghana. 2001	- RS
Maxwell Darko Asante	Ph.D (Plant Breeding), Univ. of Ghana, 2012	- RS
William Lelabi Kota	BSc. (General Agric.), UCC, Ghana, 2008	- STO
Samuel Tandoh	BSc. (Gen. Agric.), KNUST, Ghana, 2011	- STO
Sober E. Boadu	Dip. (Tropical Agric.), KITA/MoFA, 1995	- STO
Vida Amuzu	Cert. in Agric. (ATC), 1998	- STO
Isaac Owusu Konadu	Cert. in Agric. (ATC) 1997	- STO
Phyllis Aculey	BSc (Agriculture), KNUST, 2013	- PTO
Elizabeth Norkor Lartey	Dip. (Gen. Agric.) Kwadaso Agric. Coll., 2011	- TO

LEGUMES AND OIL SEEDS

James Yaw Asibuo	PhD. (Agronomy), KNUST, Ghana, 2008	- RS
Hans Adu-Dapaah	PhD (Plant Breeding), Univ. of Ibadan Nigeria, 1989	- CRS
Stephen Amoah	PhD (Plant Sciences), Rothamsted Research & Univ. of Reading UK, 2010	- RS
Sylvester Addy	MSc. (Plant, Soil & Environmental Science), North Carolina State Univ., USA, 2007.	- RS
K. Adjei-Bediako	BSc. (Agric), KNUST, Ghana, 1999	- ARS
Michael Adu	Dip. Agric – 1987	- CTO
*Victoria Larweh	BSc. (Agric) UCC, Ghana. 2010	- PTO
Paul Manor	B.Ed. (Agric), 2011	- PTO
Maxwell Lamptey	BSc (Agric), UCC, 2009	- STO
Afua Gyaamah Gyima	BSc (Agric), KNUST, 2011	- STO
Seth Odjerh	Cert. in Agric., 1993	- TO
Franklin Bosompem Denkyira	Dip. (Gen. Agric.), Kwadaso Agric. College, 2010	- TO

HORTICULTURE

Plantain Programme

*Beloved Mensah Dzomeku	M.Phil (Crop Physiology), Univ. of Ghana. 1994	- SRS
Alberta Nsenkyire	Dip. (Gen. Agric.), Kwadaso Agric. College, 2011	- TO

Tropical Fruits

Paul Mintah	M.Phil. (Agronomy), UCC, Ghana, 1995	- RS
*Isaac Osei Bonsu	M. Phil. (Botany), Univ. of Ghana, 2011	- RS

Vegetables

K. Offei Bonsu	M.Phil. (Plant Breeding), UCC, Ghana, 1995	- SRS
Seth Obosu-Ekyem	M. Phil. (Weed Science), UCC, Ghana. 1993	- RS
*Michael Osei Kwabena	MSc (Agron./ Pl. Breeding), KNUST, Ghana, 2010	- RS
Adama Haruna	Cert. in Agric. (ATC) 1986	- PTO

RESOURCE and CROP MANAGEMENT and SOCIO- ECONOMICS

Resource and Crop Management

- **On-station Research**

Joseph Nketiah Berchie	PhD. (Crop Physiology), KNUST, 2010	- PRS
Patterson Osei-Bonsu	MSc. (Agronomy), Kishiner Agric. Inst., USSR, 1988	- SRS
*Patricia Oteng Darko	MSc (Soil & Water Engineering), KNUST, 2011	- RS
*Shadrack K. Amponsah	MSc (Agric. Mech. Engineering), KNUST, 2011	- RS
*Stephen Yeboah	M. Phil (Crop Physiology), KNUST, 2010	- RS
Eric Owusu Danquah	M.Phil (Agroforestry), KNUST, 2011	- RS
Kennedy Agyeman	MSc. (Agroforestry), KNUST, 2011	- RS
Erasmus Narteh Tetteh	MSc. (Agroforestry), KNUST, 2011	- RS
Felix Frimpong	MSc. (Agric Sci. & Res. Mgmt. in Tropics & Sub-tropics) Univ. of Bonn, Germany, 2014	- RS
Mavis Numafo	MSc (Agroforestry), KNUST, Ghana, 2015	- PTO
Michael T. Odamtten	MSc. (Water Res. Engineering) KNUST, 2015	- PTO
S. Obeng Antwi	Gen. Cert. of Educ. (Adv. Level), 1976	- PTO
Aisha Karim	BSc. (Agric. Tech.), UDS, 2011	- STO
John K. Fordjour	Cert. in Agric. (ATC), 2004	- PTO

- **On-Farm Research**

Offei Micah Apraku	Dip. (Post harvest Tech.) Univ. of Ghana, 2002	- PTO
P.E. Amoa-Darko	Dip. in Agric. - 1980	- PTO
Beethoven Ameho	Cert. in Agric. (ATC) 1991	- PTO
Joseph B. O. Antwi	Cert. in Agric. (ATC) 1993	- STO
Zakaria Atohulo	Cert. in Agric. (ATC) 1991	- STO

Socio-Economics

*Joyce A.S. Haleegoah	M.A (Rural Sociology), Univ. of Guelph, Canada, 1996	- RS
* Bright Owusu Asante	M.Phil (Agric. Econs), Univ. of Ghana, 2009	- RS
Jonas Osei-Adu	M.Phil (Agric. Econs.), KNUST, 2010	- RS
Patricia P. Acheampong	PhD. (Agric. Economics) KNUST, 2015	- RS
Natson Eyram Amengor	M.A. (Economics), KNUST, 2012	- RS
Alexander Adu-Appiah	MPhil (Agribusiness), Univ. of Ghana, 2012	- RS
Benedicta Nsiah Frimpong	MPhil (Agric. Econs), KNUST, 2013	- RS
Lydia Brobbey	BSc (Agriculture), KNUST, 2013	- PTO
Harriet Yeboah	Cert. in Agric. (ATC) 1998	- TO

PLANT HEALTH

Biological Control

Haruna Braimah	PhD. (Entomology), Univ. of Reading, U.K. 1997	- PRS

Entomology

Moses Mochiah	PhD (Entomology), (UCC) 2002	- PRS
Adama Ibrahim	MSc (Crop Protection/ Entomolgy),2011 - RS	
Umar Sanda Issah	MSc (Crop Protection/ Entomology), KNUST, 2010	- RS
*W. Amoabeng Blankson	MPhil (Ento.), C/Sturt University, Australia, 2014	- RS
Anthony Gyimah - PTO	BSc. (Gen. Agric.), KNUST, 2008	
Adama Amadu	Cert. (Gen Agric.) ATC, 2009	- STO
Matilda Frimpong	BSc. (Entomology & Wildlife), UCC, 2009	- STO

Weed Science

Grace E.K. Bolfrey-Arku	PhD (Weed Science), UCC, 2004	- SRS
Stephen Arthur	B.Ed. (Gen. Agric), UCC, 2011	- STO

Plant Pathology/Virology/Nematology

Kingsley Osei	PhD. (Nematology), Univ. of Reading, UK, 2007	- SRS
Allen Oppong	MSc. (Virology), KNUST 2006, UK, 2006	- RS
Joseph Adomako	MSc. (Crop Protection/ Nematology), 2010	- RS
Atta Kwasi Aidoo Snr.	MSc. (Plant Pathology), KNUST, 2011	- RS
Zippora Appiah-Kubi	MSc (Plant Pathology), KNUST, 2012	- RS
*Yaw Danso	MSc (Agronomy/ Pl. Breeding), KNUST, Ghana, 2010	- RS
J. Sackey Asante	Cert in Agric. (ATC), 1986	- CTO
Francis Ayueboteng	Cert. in Agric. (ATC), 1991	- PTO
*Esther Agyemang Marfo	BSc. (Gen. Agric.), KNUST, 2009	- STO
Bismark Abugri	Dip. (Gen. Agric.) Kwadaso, Agric. College, 2011	- TO

TECHNICAL SERVICES

Biotechnology/ Biochemistry / Tissue Culture/ Food Science /Seed Technology

Marian Dorcas Quain	PhD (Botany), Univ. of Ghana, 2007	- SRS
*Evelyn Adu-Kwarteng	M.Phil. (Biochemistry), KNUST, Ghana, 1999	- SRS
Michael Akuamoah Boateng	MSc. (Food Science & Technology), KNUST, Ghana, 2006	- RS
*John Kwadwo Addo	MSc. (Food Sci. and Tech.), KNUST, Ghana, 2004	- RS
Albert Aubyn	M.Phil (Horticulture), Wye College, U.K. 1998	- RS
Francis O. Amoako-Andoh	PhD (Food Sci.), Katholieke Univ., Leuven, Belgium, 2013	- RS
Ruth Thompson	M.Phil (Biological Science), KNUST, Ghana, 2008	- RS
*Charles Afriyie Debrah	MSc. (Environmental Science), KNUST, Ghana, 2009	- RS
Priscilla F. Ribeiro	MSc. (Agron./Plant Breeding), KNUST, Ghana, 2010	- RS
*Harry Okyere	MSc. (Analytical Chemistry), KNUST, Ghana, 2010	- RS
Hillary Mireku Bortey	MSc. (Seed Science & Tech.), KNUST, 2010	- RS
*Victor Acheampong Amankwaah	MSc. (Agronomy/ Plant Breeding), KNUST, Ghana, 2012	- RS
Henry Akrofi Doku	M.Phil. (Nuclear Agriculture), Univ .of Ghana, 2011	- RS
David Appiah Kubi	MSc (Agronomy/Plant Breeding), KNUST, 2012	- RS
*Linda A. Abrokwah	BSc. (Mol. Biology & Biotech.), U.C.C. 200	-Technologist
*Belinda Akomeah	BSc. (Laboratory Technology), U.C.C. 2008	-Technologist
*Faustina Okyere	BSc. (Chemistry), KNUST, Ghana, 2010	-Technologist
*Theodora A. Mensah	Dip. (Agric. Econs. & Extn.), UCC.	- PTO
Stanley Asare	Dip. (Crop Production) Univ. of Ghana. 2009	- STO
Agnes Achiaa Aboagye	BSc. (Biochemistry), KNUST, 2011	- STO
Gertrude Osei-Diko	BSc. (Biochemistry), UDS, 2011	- STO
Daniel K. Cudjoe	BSc. (Biochemistry), UCC, 2011	- STO
Lily Naa Adoley Allotey	BSc. (Biol. Sci.), KNUST, 2011	- STO
Agnes Nimo Bosompem	BSc. (Biochemistry), UDS, 2011	- STO
Monica Ode Adu-Gyamfi	Dip. (Nat. Res. Mgt.), KNUST, Ghana, 2008	- TO
*Sylvia Kafui Artcher	HND (Chem. Eng.), Kumasi Polytech, 2009	- TO
Joyce M. Gbarimaa	Dip. (Gen. Agric.), Kwadaso Agric. College	- TO
Abigail Amoa-Owusu	HND (Chem. Eng.), Kumasi Poly, 2010	- TO
Mary Arthur	Cert. (Gen Agric.), Ejura Agric. College, 2010	- TO

Seed Technology

Hillary Mireku Bortey	MSc. (Seed Science & Tech.), KNUST, 2010	- RS
Sadia Osuman Alimatu	MSc (Seed Technology), KNUST, 2012	- RS

COMMERCIALIZATION AND SCIENTIFIC SUPPORT SERVICES

Isaac Stewart Baning	MSc. (Info. Sci.), City Univ., London, U.K. 1995	- Prin. Sci. Sec.
Lynda G. S. Nsafoah	M.A. (Info. Studies), Univ. of Ghana, 2013	- Sci. Info. Officer

Training and Communication

Solomon Gyasi Boakye	M.A. (Comm. Studies), Univ. of Ghana, 2004	- Sci. Info. Officer
Solomon K. Darkey	M.Phil. (Agric. Extn) UCC, Ghana. 2011	- RS
Dora Aninakwa	BA (Comm. Studies), CSUC, 2014	- Admin. Asst.

Biometrics/Info. Tech.

Adelaide Agyeman	PhD (Statistics), UCC, Ghana, 2013	- SRS
Harriet A. Dwamena	BSc (Mathematics), Univ. of Mines & Tech. 2010	- PTO
David Kow Amo	Hon. Dip. (Network Engineering), NIIT, 2005	- STO
George Sefa-Anane	Hon. Dip (Networking Engineering), NIIT, 2009	- STO

Enock Osei Tutu	Dip. (Hardware and Software Engineering), IPMC, 2013	- TO
William F. K. Aidoo	Dip. (Software Engineering), IPMC, 2014	- TO

Library

Lawrencia D. Acheampong	M.A. (Library Studies), Univ. of Ghana, 2009	- Librarian

Commercialization

Emmanuel Agyei Asamoah	MSc. (Agroforestry), KNUST, 2007	- Res. Sci
Martin Osei Bonsu	B Ed. (Accounting), Univ. of Educ. Winneba, 2004	- Asst. Acct.
Joseph Owusu	GCE Ord. Level. 1972	- CTO
Mark Anti	BA (Busn. Management), UCC, 2007	- PTO

ACCOUNTS (FINANCE)

Konadu Yiadom	Assoc. of Cert. Project Accountants (ACCA) (Fellow) 2013	- Accountant
Isaac Donkor	BSc. (Accounting), UEW – Kumasi, 2007	- Asst. Accountant
Samuel Sakyi Darko	Inst. of Chart. Acct. I - 1996	- Chief Acct. Asst.
Abraham Walden	Inst. of Chart. Acct. - 2014	- Chief Acct. Asst.
Anthony Ofori	Inst. of Chart. Acct. II – 2004	- Chief Acct. Asst.
Isaac Osei Mensah	HND (Accounting), K'si. Poly, 2004,	- Chief Acct. Asst.
Peter Amoah	BSc (Business Admin - Acct.) KNUST, 2012	- Chief Acct. Asst.
Emmanuel Manu	BSc. (Marketing), UCC, 2012	- Chief Acct. Asst.
Daniel Tetteh	B. Com (Accounting), UCC, Ghana, 2008	- Prin. Acct. Asst.
James Nyag	BSc. (Busn. Admin./Acct.), KNUST, 2011	- Prin. Acct. Asst.
Fredrick Owusu	BSc. (Busn. Admin./Acct), UCEW, 2011	- Prin. Acct. Asst.
Esther Boakye	BSc. (Accounting), GBUC, 2014	- Prin. Acct. Asst.
Robert Adu-Gyamfi	BBA (Accounting), CSUC, 2010	- Prin. Acct. Asst.
John Amihere Mensah	Inst. of Chart. Acct. I - 2000	- Prin. Acct. Asst.
Hayford Asiedu Boateng	GCE A/L, 1994	- Prin. Acct. Asst.
Mawusi Lotsu	BSc (Busn. Admin./Accounting) 1999	- Prin. Acct. Asst.
Thomas Konadu Yiadom	RSA III (1980)	- Snr. Acct. Asst.
Olivia Opoku	DBS (Accounting), K. Poly, 2009	- Acct. Asst.
Prince O. Agyeman	GCE 'O' Level, 1985	- Acct. Asst.
Naomi Agyebeng	GCE 'A' Level, 1994	- Acct. Asst.

ADMINISTRATION

Lawrence K. Mensah	M.A. (Pub. Admin), Univ. of Ghana, 2000	-Snr. Admin. Officer
Emmanuel Afriyie	MPA, (Pub. Admin), KNUST, Ghana, 2012	-Admin. Officer
Hagar Assan	MBA (Busn. Admin.) U.E.W., Kumasi. 2013	-Admin. Officer
David Denu	B.Ed. (Soc. Science), U.C.C., Ghana, 2003	-Asst Admin. Officer
Luke Opoku Amankwah	Dip. (Gen. Agric.), Univ. of Ghana, 2006	- PTO
*Linda Agyeman	B.A (French), KNUST, Ghana, 2008	- Prin. Admin.
Asst.Christina Ivy Tetteh	B.A. (Busn. Admin.), Christian Service Univ. Coll. 2008	- P.A.A.
Joyce Larbi-Siaw	B.A. (Busn. Admin.), Christian Service Univ. Coll. 2009	- P.A.A.
Mary Gyapong	BSc (Busn. Admin.) GBUC, 2014	- PAA
*Paulina A. Sarkodie	DBS (Secretaryship & Mgmt Studies) K'Poly	- SAA
Emmanuel Dadzie	GCE Ord. Level, 1980	- SAA
Martina Sikinya	Com. Dip., Garden City Comm. College	- SAA
Charlotte Agyapong	Snr. Typist Cert. Gov't Secretariat, 1980	- SAA
Linda Kumah	DBS (Secretarial), Kumasi Polytech., 2001	- SAA
Elizabeth Nyarko	Comm. Dip. 'O' Level, 1983	- SAA

Joshua Atisu	Cert. in Agric. (ATC) 1986	- TO
Vida Antwi /Telephonist	Ghana Telecom Trg. Sch., 1996	-Snr.Sup.
Ophelia Nketiah /Telephonist	Ghana Telecom Trg. Sch., 1996	-Snr.Sup.
Christiana Nti	MSLC, 1976	- Admin. Asst.
Bridget Adjei	City & Guilds (Institutional Management), 1987	- A.A
*Sandra Baah-Sakyi	GCE ‘A’ Level, 2009	- A.A
Vera Fosua Yeboah	BSc (Business Admin), GBUC, 2014	- A.A
Paulina Asieduaa	Dip. (Business Studies), Kumasi Polytech. (2012)	- A.A
Maxwell Kwodane	Dip. (Gen. Agric.) Kwadaso Agric. College, 2011	- TO

POKOASE STATION

James Konadu Boafo	Dip. Agric Univ. of Ghana, 2002	- CTO
Edwin Odame Darko	Dip. Agric. Univ. of Ghana, 1997	- PTO

*Study Leave ** Sabbatical Leave *** Leave without pay