ANNUAL REPORT 2016

CSIR-CROPS RESEARCH INSTITUTE

RESEARCH FOR DEVELOPMENT

CSIR–CRI IN 2016

CSIR-CROPS RESEARCH INSTITUTE

For more information please contact:

Dr. Stella A. Ennin
The Director
CSIR-Crops Research Institute
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: Bernard Sakyiamah, Joseph Manu-Aduening, Solomon Gyasi Boakye and Linda G. Nsafoah

Edited by: Bernard Sakyiamah, Joe-Manu Aduening, Stella A. Ennin

Layout and Design: Francis K.N. Nunoo (+233 (24) 2318792)

Contents

List of Figures

Board Members

Dr. James Kwasi Owusu- Ampofo, Country Manager, AGRA	Chairman
Dr. Stella A. Ennin, Director, CSIR-CRI	Member
Dr. J. O. Fening,Director, CSIR-SRI	Member
Dr. Barfour Osei,CEO, EDAIF	Member
Mr. Emmanuel Brako,Director of Finance,CSIR	Member
Mr. Tom Gambrah, CEO,Premium Foods Ltd	Member
Nana Adjei Mensah,Commercial Farmer&Business Man	Member

List of Acronyms

AA	Administrative Assistant
ACMV	African Cassava Mosaic Virus
APTC	Agricultural Productivity Technology Centre
ARS	Assistant Research Scientist
CMD	Cassava Mosaic Disease
CRI	Crops Research Institute
CRS	Chief Research Scientist
CSIR	Council for Scientific and Industrial Research
CTO	Chief Technical Officer
FFS	Farmer field School
GAP	Good agricultural practices
GM	Genetically modified
GPC	Good Processing Centre
ICT	Information, Communication and Technology
IGF	Internally Generated Funds
IITA	International Institute of Tropical Agriculture
INEA	International Network for Edible Aroids
IP	Innovation platform
IPM	Integrated pest management
MAS	Marker Assisted Selection
MoU	Memoranda of Understanding
NCoS	National Centre of Specialization
PAA	Principal Administrative Assistant
PPD	Postharvest Physiological Deterioration
PRS	Principal Research Scientist
PTO	Principal Technical Officer
QTL	Quantitative Trait Loci
RELC	Research Extension Farmer Linkage Committee

RS	Research Scientist
SAA	Senior Administrative Assistant
SANAS	South African National Accreditation System
SOP	Standard Operating Procedures
SRS	Senior Research Scientist
SSR	Simple Sequence Repeats
STO	Senior Technical Officer
TEEAL	The Essential Electronic Agricultural Library
TLBD	Taro Leaf Blight Disease
TO	Technical Officer
WAAPP	West Africa Agricultural Productivity Programme
YIIFSWA	Yam Improvement for Income and Food Security in West Africa
YMV	Yam mosaic virus

FOREWORD

Dear friends

We are excited to present an overview of our activities for the past year. As we continue to strive towards becoming a Centre of Excellence for agricultural research, we engaged in a number of research activities in 2016. Despite the numerous challenges that are evident in agricultural research, we are happy to report on a few "success stories".

As an institute under the Council for Scientific and Industrial Research (CSIR), CRI identifies with four of the seven thematic areas of research developed by the council. These are Food Security/Poverty Reduction, Climate Change/Environmental Conservation/Green Technology, Biomedical/Public Health and Science/People. Hence a conscious effort was made to guide a number of research activities undertaken by the institute this year towards these thematic areas.

The institute continues to deliver on its target areas such as acquiring new projects yearly, improving management systems and procedures, building human capacity and infrastructure as well as increasing commercialization activities

In everything we do, we recognize that success is founded on partnership. We will like to appreciate our sponsors, donors and collaborators who have all contributed in diverse ways to ensure that we have remained a key research institute in Ghana. Without them there would be no "success stories" to tell.

On behalf of the management, I would like to thank our entire staff for their hard work and dedication. CRI took a great step forward in 2016 and in the years ahead, change will demand a lot from us as an institute. We hope to continue to work even harder and seize every opportunity presented to us and secure our success.

Thank You

Dr. Stella A. Ennin
Director

Dr. James Kwasi Owusu- Ampofo
CSIR-CRI Board Chairman

ACKNOWLEDGEMENTS

We express our heartfelt acknowledgement to all our stakeholders for their support and participation in our activities in 2016. Our stakeholders include sister research institutions, national governments, universities, non-governmental organisations (NGOs), civil society organisations, farmers, ministries and international research institutions.

The institute appreciates the contributions made by our donors and funding agencies in financing and supporting its activities: the International Institute of Tropical Agriculture (IITA), the Bill and Melinda Gates Foundation (BMGF), the Alliance for a Green Revolution in Africa (AGRA), the Council for Technical and Vocational Education and Training (COTVET), the Korea-Africa Food and Agriculture Cooperation Initiative (KAFACI), YARA-Ghana, CALLI-Ghana, SEEDCO International, USAID, the World Bank and many others.

We also acknowledge CSIR-CRI's Board of Directors, for providing guidance and oversight to the institute.

Finally, we thank all our scientists and other members of staff whose relentless efforts have culminated in all the activities reported here.

About CSIR-Crops Research Institute

CSIR-Crops Research Institute (CSIR-CRI) is one of the 13 institutes of the Council for Scientific and Industrial Research (CSIR) of Ghana. It was established in 1964.

Vision

To be a Centre of Excellence for innovative and quality agricultural research for development.

Mission

To develop and disseminate appropriate technologies for high and sustainable food and industrial crop production.

Core Values

Our core values are Excellence; Fairness; Commitment; Transparency and Accountability and Teamwork

Goals

- To develop and disseminate appropriate technologies that are demand driven and acceptable to end users
- To promote and strengthen strategic partnerships with relevant stakeholders to enhance the generation of solutions to challenges in agricultural research, technology development and transfer
- To improve institutional capability to undertake effective research and service delivery to enhance agricultural productivity
- To enhance research and technology delivery through efficient mobilization and management of funds
- To improve the management and operating procedures and systems as a means of ensuring efficiency in research delivery

Mandate Crops

- Cereals (maize and rice)
- Legumes and Oil Seeds (cowpea, soybean, groundnut, bambara groundnut & canning beans)
- Roots and tubers (cassava cocoyam, sweet potato, yam and Taro)
- Horticultural crops

- Plantain and banana
- Tropical fruits (citrus, mango, avocado, pineapple, pawpaw)
- Vegetables (pepper, garden eggs, tomato, onion and leafy vegetables)

- Industrial crops (rubber and sugar cane).

Service to Clients

CSIR-CRI offers the following services:

- Production of breeder seeds for the National Seed Industry
- Supply of healthy planting materials of citrus, avocado, mango, plantain and banana.
- Development of crop varieties for food and industrial uses
- Establishment of farms (tree crop plantations)
- Integrated management of crop diseases and pests (including weeds)
- Production of extension materials
- Advise on the use of appropriate experimental designs for field studies

EXECUTIVE SUMMARY

The 2016 Annual Report has been developed to reflect 4 of the 7 thematic areas of research developed by the Council for Scientific and Industrial Research (CSIR). These are Food Security/Poverty Reduction, Biomedical/Public Health, Climate Change/Environmental and People/Science. The institute's achievements in the various thematic areas have been captured.

Under Food Security/Poverty Reduction, the institute multiplied six improved cassava varieties which were released the previous year. This is expected to produce at least 500 acres in 2017.

Very high yielding improved soybean varieties were also released by the institute in 2016 for both human consumption and industrial use. The varieties are locally named as *Toondana, Latara, Gyedie* and *Anigye* and are available to farmers. In addition to the soybean, three common bean varieties were also released for both domestic and commercial uses. These projects were sponsored by the West Africa Agricultural Productivity Programme (WAAPP).

The CAY-seed project which is aimed at improving the quality of farmer-saved seed yam and yam productivity of small holder farmers at community levels continued in 2016. In a project to produce secondary seed yams of *Mankrong Pona* from tissue culture, seed yam tubers have been harvested and are being stored for dormancy to break.

Brazilian Agriculture Institute for Research, EMBRAPA, has sponsored an aqua-ponics based food production system at the institute. The objective of this project is to increase smallholder food production through implementation of water conserving aquaponics-based food systems. The project has trained 150 persons on the technology with 20 beneficiaries adopting and setting up the system across the country.

The institute also undertook research under the Biomedical/Public Health thematic area. A novel research by our Molecular Biology Laboratory using Marker Assisted Selection (MAS) was successful in reducing the breeding cycle of improved cassava varieties to 5 years. The cycle hitherto was between 10 and 15 years. Subsequently, six improved varieties were certified by the National Variety Release Committee and released

With support from HarvestPlus, "orange" maize was released and introduced to farmers. Farmers accepted this new variety due to its very high yields and 110-day maturity period.

The need to package and brand developed technologies by the institute so that they are available to end users was envisioned some years ago. In order to bring this vision to fruition, the Agricultural Productivity Technology Centre (APTC) was set up with support from the Council for Technical and Vocational Education and Training (COTVET).

The institute continued its commercialization activities throughout 2016. A number of lime and mango seedlings were produced and sold to stakeholders. Overall, the commercialization

division made a 57.10 percent profit from the sale of materials. The division projects a 60 percent profit in 2017.

Ninety-five (95) members of staff of the institute were promoted across various divisions in 2016. These comprised 5 in the research category, 18 and 43 in the senior and junior staff categories respectively as well as 29 monthly rated staff promotions.

The year 2016 also saw a 13 percent increase in the number of scientific publications by the institute. These included 62 refereed journal publications, 34 conference papers, 49 technical reports, 2 books, 2 book chapters and 14 manuals and production guides. There were also 4 video documentaries produced.

Research Themes and Support Functions

The institute's five strategic thrust areas fall under four of the seven thematic research areas of the CSIR. These are the key areas selected to drive the institute's focus in achieving its vision of becoming a Centre of Excellence for agricultural research, innovation and capacity building for development.

The thematic areas inter-relate to achieve the desired results which will satisfy its mission of developing and disseminating demand-driven technologies and build capacity for sustainable food and industrial crops productivity to enhance livelihoods for development in Ghana.

The support functions which involved the non-core research activities provide the needed anchor for effective delivery of the research activities.

RT 1: Food Security and Poverty Reduction

Food security is defined in its most basic form as access by all people at all times to the food needed for a healthy life. The first Millennium Development Goal (MDG) is dedicated to eradicating extreme poverty and hunger globally. Key issues addressed under this research theme include:

- Cereals and Legumes
- Roots, Tubers, Horticultural (Vegetables & Fruits) and Industrial Crops
- Forest, Trees and Plant Resources (Natural Products)
- Livestock and Poultry
- Fisheries and Aqua-culture
- Soils, Mechanization, Agro-food processing
- Biotechnology (Genetics, Germplasm Conservation, Bio-prospecting and Bio-processing)

Highlights of achievements

Output 1: ***Influence of Fertilizer Application on Postharvest Storage of White Yam Tubers in Ghana***

Ghana, the leading exporter of yam in Africa is currently threatened by poor tuber storability. Some actors along the food value chain attribute most storage rots to the application of

fertilizer by farmers. Yam growers across major growing areas are being encouraged to increase harvest yield through the application of fertilizer at the recommended rates and time. It was therefore important to investigate the claim that fertilizer application has effect on the shelf life of most white yams. Experiments were conducted on three white yam varieties: *Serwa, TDr 95/19177* and *Dente* to test the effects of five recommended fertilizer application models on the deterioration of stored yam tubers. The effect of fertilizer application on postharvest deterioration of white yam was found to be insignificant implying that the rate of deterioration of yam produced from fertilized plots was not different from those produced from unfertilized plots. It was recommended that further research, using different storage systems practiced by farmers be undertaken.

White yams in storage

Rotten yams in storage

Output 2: ***Improved cassava varieties for food and industrial uses***

The importance of cassava as a food staple in terms of calories consumed, as a cheap raw material for starch-based industries and Africa's food insurance continues to increase. In Ghana, cassava is now seen as a crop capable of changing the livelihoods of millions of stakeholders along the value chain. The cassava value chain is faced with several challenges which have prevented the crop from gaining the prominence it requires in changing livelihoods of many who depend on the crop either directly or indirectly as well as improving the economy of Ghana.

The most pressing challenges include; the availability and accessibility of clean and healthy planting materials, pests and diseases incidence, declining soil fertility, non-adoption of good production practices, limited value addition, poor markets and cyclical gluts resulting in high post-harvest losses.

Currently, over 60% of cassava produced is consumed locally in different forms. However, its importance as an industrial crop is gaining prominence through the emerging markets. Ghana has the capacity to transform her cassava industry into a major economic enterprise. Cassava

starch, in either native or modified form, has varied uses in the paper, lumber (plywood) textile, pharmaceutical and petrochemical industries. Currently cassava is being processed into industrial starch, high quality cassava flour (HQCF), adhesives for the wood industry, alcoholic beverages and feed for livestock.

CRI Abrabopa variety

CRI Duade Kpakpa variety

Scientist engages farmer on the field

Six improved cassava varieties which were developed from farmer-preferred landraces and released in 2015 were multiplied at eight locations in three agro-ecological zones. Over 43 acres of multiplication fields were established and this is expected to produce at least 500 acres in 2017. In addition to the multiplication fields, demonstration fields using Innovation Platforms (IPs) were established in 6 different locations to sensitize key stakeholders along the cassava value chain on the importance and different uses of the new varieties. This approach was to provide farmers and other stakeholders access to the new varieties and help address some important challenges identified. The six varieties (*CRI-Duade Kpakpa, CRI-Amansan bankye, CRI- AGRA, CRI-Dudzi, CRI Abrabopa and CRI-Lamesese*) are mostly high yielding (yield range: 45-60T/ha), high dry matter content (35-40%), resistant to Cassava Mosaic Disease (CMD), early maturing, very vigorous and produce dense canopy very early in their growing cycle making them able to control weeds. Two of the varieties are poundable all year round and one is yellow-fleshed (contains β-carotene).

Generally, the new varieties are superior to the existing varieties such as *Afisiafi, Dokuduade, Essam bankye, Agbelifia* and *Bankye hemaa* in terms of yield, dry matter content, tolerance to CMD and adaptability to wider ecological environments. The cultivars have very low cyanide levels (i.e. < 50mg/kg of fresh root) which make them safe for fresh consumption.

Business opportunities using the new cassava varieties

- *Sustainable supply of raw materials to the cassava industry.*
- *Increase levels of rural employment, improved income for the rural poor through cassava cultivation.*
- *Diversification of cassava products by promoting competitive commercial cassava farming*
- *Attraction of small scale industries to the districts/communities*
- *Public-private-partnerships*
- *Links among stakeholders along the crop value chain*

Output 3: ***Adoption and Impact of Improved Root &Tuber Technologies (Cassava, Yam, Cocoyam)***

The Government of Ghana and donor agencies have over the years adopted policy programmes and strategies to help achieve a sustainable increase in the productivity of root and tuber crops. However, yields have continuously fallen below potential amounts. This huge gap in yield has been attributed mainly to the poor uptake of improved technologies by farmers. Since 2008, the West Africa Agricultural Productivity Programme (WAAPP) has increased efforts at improving root and tuber productivity by introducing new varieties and new agronomic practices. The Socioeconomics team of the CSIR- Crops Research Institute was tasked to track the progress made by this intervention, eight years on.

Cassava (*Manihot esculenta*)

Afisiafi-One of the varieties introduced to farmers

The overall rate of adoption of improved cassava variety was 41% with the most widely adopted improved cassava variety being *Afisiafi* which was cultivated by 16% of all households. This was followed by *Bankyehemaa* which had an 11% adoption rate. Furthermore, the results depicted that adoption of improved cassava varieties increased incomes from all households by GHC 603.

Cocoyam (*Colocasia esculenta*)

Akyede-One of the cocoyam varieties introduced to farmers

Cocoyam enjoyed an overall adoption rate of 21% among households. The three main improved cocoyam varieties cultivated in Ghana are *Akyede, Gyimidi* and *M'ayeyie* yet the adoption rates of these varieties are very low. (8%, 6% and 3% were obtained for *Akyede, Gyimidi* and *M'ayeyie* respectively). Despite the low adoption rates, the results showed an average increase of GH¢ 3514 per hectare in the incomes of farming households that adopted the technology.

Yam (*Dioscorea spp.*)

A number of technologies and improved varieties were introduced to yam farmers as well. These included the Minisett technology (which was adopted by 17% of households), Ridging (adopted by 21%), Trellis (adopted by 32%) and the Vine technology. The improved varieties introduced were *Makron-Pona* and *CRI-Pona*. The rates of adoption were generally low with an overall adoption rate of just 6%. There was an adoption rate of four percent (4%) for *Makron-Pona* and three percent (3%) for *CRI-Pona*. Nonetheless an increase of GH¢ 839 per hectare was observed in the income levels of households that adopted these varieties. The impacts of adoption of improved root and tuber varieties on yield have positive implications for enhancing food security and reducing poverty in Ghana. In addition to documenting the uptake and diffusion of these technologies, this study provided valuable insights about the many factors that can affect the adoption of agricultural technologies.

Makron-Pona yam variety

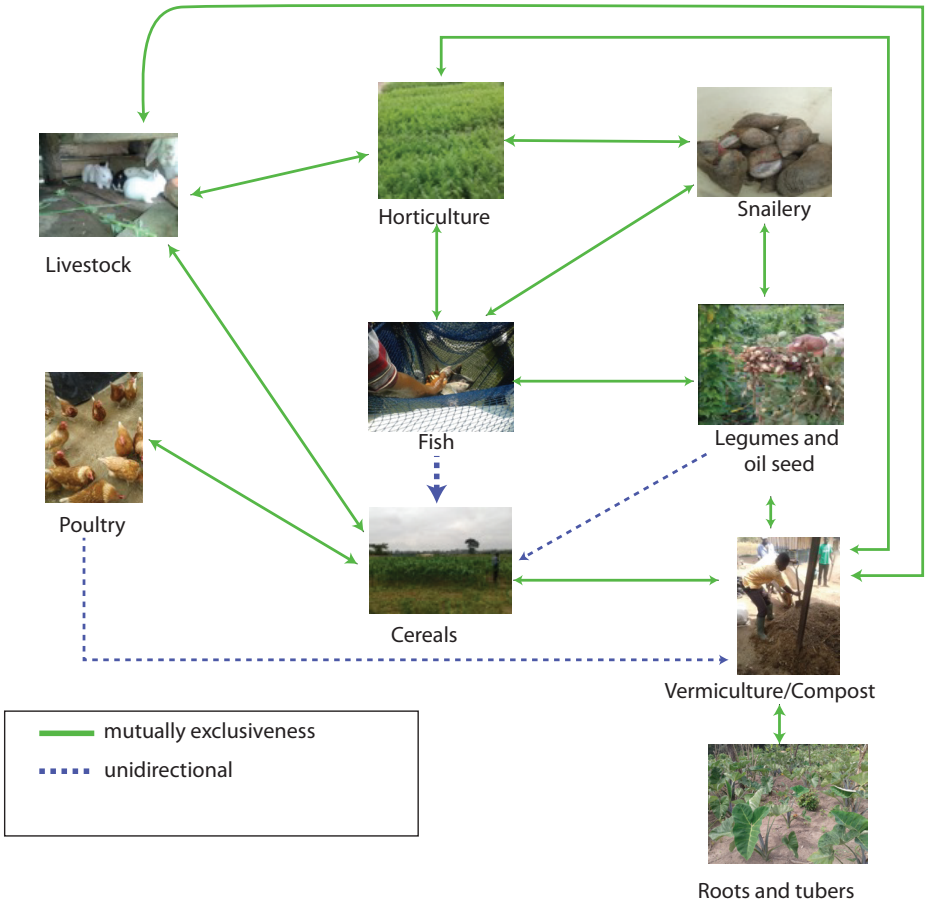
Sweet Potato *(Ipomoea batatas)*

Overall, 59% of farmers across the country adopted improved sweetpotato varieties. *Sauti* was the most popular variety cultivated by all farmers. It was cultivated by about 17% of the population. The next popular improved varieties were *Apomuden* and *Faara* with 13% and 12% adoption rates respectively.

Apomuden sweet potato variety introduced to famers

Output 4: ***Increasing Small-Holder Food Production Through an Aquaponics-Based Food System***

An aquaponics-based food system is a coined name for a technology that integrates fish farming, crops and/or animal production such as small ruminants, grass cutters, rabbits, sheep, goats etc. as a comprehensive unit usually on a hectare of land. It is a closed system which may involve several units such as aquaculture, compost unit, livestock/poultry, vegetables, worms rearing, and crop production. The output or effluent from one of these components becomes an input for another.



The Aquaponics Process

The objective of this project, which was sponsored by the Brazilian Agriculture Institute for Research, EMBRAPA was to increase smallholder food production through implementation of water conserving aquaponics-based food systems ensuring all-year-round food production. The Crops Research Institute has therefore established an on-station demonstration at Fumesua.

An aquaponics system established by CRI on its premises

The system has been established with rabbits, broilers/layers, tilapia/ cat fish, vemiculture, compost and fish effluent and about ¼ acre of degraded land fertilized with the composted manure. Integrated food crops (maize, plantain, Tania and taro, yam) gained a yield increment of 23% over achievable yields of the MoFA mainly because of the use of improved varieties, effluents fertilization & good husbandry. Hands-on training has been given to more than 150 persons (including fish farmers, extension and fisheries department staff) on the fish pond construction as part of the knowledge transfer and dissemination to the general public. The project has more than 20 direct beneficiaries/adopters having the set-up across five agro-ecological zones of Ghana.

Output 5: ***Improved Legume Varieties Released for Food and Industrial Uses***

Soybean

Soybean is a highly nutritious grain legume that contains high amounts of protein (40%) and essential fatty acids. Vegetable oil extracted from soybean has no cholesterol. Regular consumption of soybean has proven to reduce cardiovascular diseases and various kinds of cancer. The soybean plant is also able to fix atmospheric nitrogen into soils, thereby improving the fertility levels of soils where they are grown. Four improved soybean varieties with potential yields ranging from

3.2t/ha to 3.5t/ha were released in 2016 both for human consumption and industrial use. These yields are 20-25% higher than the best improved varieties available to farmers. Whereas the protein contents (38-42%) were comparable to that of the best existing varieties, the micro mineral contents particularly Iron (Fe) and Zinc (Zn) were 26.3% and 16% higher than that of existing varieties. The varieties are locally named as *Toondana, Latara, Gyedie* and *Anigye* and are available to farmers.

Common Beans (Baked Beans)

In addition to the soybean, three common bean varieties were also released for both domestic and commercial uses. Common bean (*Phaseolus vulgaris*) is a leguminous crop commonly grown in Eastern and Southern Africa. The grain has very high levels of Iron and Zinc and is commonly used in local food preparations. The dry beans may be boiled in water and eaten or used in food preparations such as stews, soups, paste, cakes, chips, salads, baked beans and other products.

"Baked beans" is one of the major ingredients in the fast foods enterprise in Ghana, needless to say that the demand for common bean in Ghana is expanding. It is strongly envisaged that the release of the three varieties which were released through participatory breeding with farmers, processors and other stakeholders, would help reduce the deficit created by importing baked beans into the country. Many farmers and some industrialists have expressed interest in the production and processing of the crop. It therefore behooves on all major stakeholders including, local assemblies, government agencies, researchers, processors and farmers to create awareness on the nutritional benefits of the crop in order to promote it.

RT 2: Biomedical and Public Health

Research under the Biomedical and Public Health thematic area focuses on human and animal epidemiology (including research into infectious diseases, clinical epidemiology and in the field of risk evaluation), Biostatistics, Health Communication, Health Policy and Nutrition. Other research programmes under this theme include:

- Plant and Animal Health (Pathology, Virology, Entomology, Micro-Biology, Molecular Biology, Cell Biology)
- Genetics, Germplasm Conservation, Bio-prospecting and Bio-processing
- Bio-Informatics, Bio-Physics and Bio-Chemistry
- Biomedical, Biosafety and Public Health Ethics

Highlights of achievements

*Output 1**: A new yam leaf blight disease:** Incidence and Severity of Disease in Major Yam Growing Areas in the Brong Ahafo Region of Ghana**.***

Disease surveys were conducted from July to September, 2016 to establish the extent of disease spread and infection in eight (8) selected communities in 2 districts (Atebubu-Amantin and Kintampo North districts) of the Brong Ahafo Region.

In each community, 15 farms were randomly selected and assessed for disease presence. The average disease incidence was 40.8% and severity of 2 (1-20% infected leaf area) was recorded. However, Ahontor in the Atebubu-Amantin district recorded the highest incidence of 48.1% while Suronoase (Kintampo North) recorded the lowest with 28.8%. There is no doubt that yam leaf blight disease reduces yield since greater part of the leaf surface is covered with lesion. There is the need for significant efforts to control the spread of this disease. It is now suspected to be a leaf blight type of anthracnose disease.

A plant affected by New Leaf Blight Disease

A plant affected by New Leaf Blight Disease

Output 2: ***Development of Aeroponics for Seed Yam Production***

Seed yams have for a long time been a cost impediment in the expansion of the area put under yam production. Research into new and efficient methods of seed yam production has been undertaken. Among these methods is the aeroponics technology. Aeroponics production has been defined by the International Society for Soilless Culture as a system where roots are continuously or discontinuously grown in an environment saturated with fine drops (a mist or aerosol) of nutrient solution (Carruthers, 1992). Plants grown using aeroponics often show signs of accelerated growth and early maturity (Mirza *et al.*, 1998). These abilities have made the technology a popular research tool for studying root growth and nutrient uptake (Barak *et al.*, 1998). Aeroponics, if successfully disseminated and adopted in the propagation of seed yams, can improve access to quality seed yams all year round (and make it more accessible and affordable to commercial growers and small scale farmers), improve timeliness of planting operations, increase yields, thus improving farmers' livelihoods and also enhancing food security in the country. The technology has been investigated at the CSIR-CRI through the support of the West African Agricultural Productivity Programme (WAAPP) and the BMGF Africa Yam project. Two systems were developed; a power-dependent system and a power-independent system. The most significant achievement in using aeroponics to develop the two systems for seed yam production was the increase in multiplication ratio. Mean seed yam multiplication ratio of the power-dependent aeroponics system for all the varieties was 1035 mini-tubers/explant. The mean seed yam propagation ratio using the power-independent system was 587 seed yams/explant.

Plants on an aeroponic system

Multiple mini-tubers at a node

The system has ten boxes each with four tables and a powerhouse with two polytanks and two water pumps and is powered by a 3.5KVA solar system. Yam seedlings planted in the system are generated from the tissue culture laboratory and these are certified as clean planting materials using molecular biology diagnostics tools. The first planting in the system generated vigorous shoot developments. Single nodal cuttings were harvested from the growing vines and planted in seed trays to generate yam seedlings. Yam seedlings generated have been planted on the field for the production of seed yam. The CSIR – CRI yam aeroponics system can hold approximately 1800 seedlings at a time. After 6 months of growth under aeroponics, each seedling can generate at least 50 single nodes, which are planted to generate seedlings. This generates about 90,000 seedlings for field establishment. Seedlings are planted on the field at a density of 16,188 per

acre for the production of seed yam with an average weight of at least 1.5kg. The seed yam produced serves as a ready source of planting material from a certified clean source.

The aeroponics system also generates tubers with average fresh weight of approximately 200g yielding 2 or 3 tubers per seedling, and this also serves as a source of clean planting material. This schematic approach of using cutting edge tissue culture technology and aeroponics to facilitate the availability of yam planting materials is novel is this country.

Yam growing in aeroponics in a screen house

Yam tubers growing in aeroponics boxes

Output 3: ***Use of Marker Assisted Selection (MAS) For Development of Improved Cassava Varieties Resistant to CMD***

Conventional breeding is a dynamic area of applied science which relies on genetic variation and uses selection to gradually improve plants for traits and characteristics that are of interest to both farmers and consumers. Although, this has been very successful in producing a continuous range of improved varieties, recent developments in the field of molecular biology have been employed to enhance plant breeding efforts and to speed up cultivar development. In addition, this tool is both time and cost effective and able to make accurate and useful selections in breeding populations.

For the first time in the history of Ghana, our Molecular Biology Laboratory was successful in using Marker Assisted Selection (MAS) in the improvement of farmer-preferred cultivars developed through introgression of genes for Cassava Mosaic Disease (CMD) resistance. The long growing cycle of cassava (≥ 12 months) makes the use of MAS in this project very apt. Conventional breeding for cassava is not attractive because it takes about 10-15years to develop a variety.

The cassava genetic improvement was therefore made more efficient through the use of MAS which enabled the precise identification of genotypes without the confounding effect of the environment, thereby enhancing heritability. MAS also contributed to the efficient reduction of large populations at the seedling stage.

The breeding programme using genetic hybridisation, Marker Assisted Selection and field evaluation was initiated in 2008 and by 2013, we had completed the various evaluation stages and had identified and selected six improved farmer-preferred cassava varieties with CMD

resistance. Coupling conventional breeding with MAS was therefore able to reduce the long breeding cycle for developing improved cassava varieties to 5 years. Subsequently, these six improved varieties were certified by the National Variety Release Committee and released.

Output 4: ***Curbing the Taro Leaf Blight Disease (TLBD) in Ghana***

In spite of taro's adaptability and its role in the national economy and the livelihood of the rural poor as a staple crop in Ghana, the crop has been bedeviled with taro leaf blight disease (TLBD) which has drastically reduced its productivity. The disease which is caused by *Phytophthora colocasiae*, takes just about 14 days to completely attack an entire taro farm, resulting in extensive defoliation and plant die-back. The economic importance of TLBD is its potential to cause total crop failure, which poses great threat to food security and income generation of farmers as well as depletion of the already narrow genetic diversity of the crop.

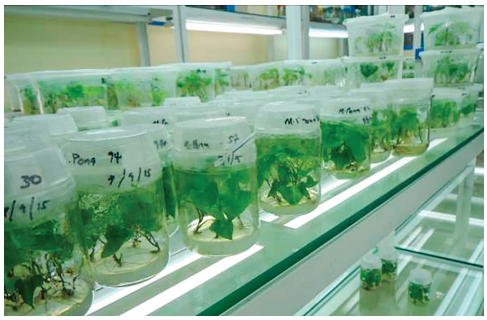
Since all attempts to find a resistance to TLBD in Ghana has proved increasingly difficult, there was the need to adjust our breeding and selection procedures to develop cultivars that confer resistance and are also preferred by the farmers. As a result, germplasm was sourced from the International Network for Edible Aroids (INEA) and screened for resistance to TLBD and adaptability. Five superior taro lines **(BL/SM 158, CE/IND 12, BL/SM 151, BL/SM 115, BL/SM 16)** which were selected from the taro leaf blight tolerant germplasm introduced from the International Network for Edible Aroids (INEA) were tested multilocationally on-farm along with farmers' variety as check. Three of the taro lines **(BL/SM 157, BL/SM 115 and BL/SM 16)** have shown outstanding performance in yield and dry matter content. They were also highly preferred by farmers and consumers, and therefore, will be proposed for release in 2018 after further testing in 2017.

Output 5: ***Production of Disease-Free High Quality Planting Materials Using Tissue Culture Technique***

Production of Clean Plantain Planting (cv Apantu) Materials using Tissue Techniques

Plant tissue culture techniques offer great potential in regeneration of cleaned, healthy and true-to-type vegetative propagated crops such as the root and tuber crops. These vegetative clones are susceptible to the destruction of epidemics, pests and diseases; and inadvertently carry with them these pathogens, which are used as "seeds" in ensuing farming seasons.

The use of these diseased cloned materials as "seeds" tend to reduce yield output and ultimately, the income of the farmer. Plants produced are virus-tested using both molecular and serological diagnostic tools to confirm their virus-free status. This has been successfully demonstrated in sweetpotato, yam and cassava where released varieties have been cleaned and virus tested; and distributed for field establishment.



In vitro Yam Plantlets

Microtubers for seed Yam Production

Output 6: ***Managing Spear Grass Infestation to Reduce Incidence of Root Rot in Root and Tuber Crops***

Over 20 farmers were introduced to one of the causal agents of cassava root rot as well as good spear grass management interventions. The incidence of pierced cassava roots by spear grass rhizomes was significantly reduced through appropriate mechanized or pre chemical land preparation coupled with timely hoe weeding or post herbicide application.

RT 3: People and Science

This thematic area is in line with the research agenda of the CSIR which has been aligned with the development priorities of government and development partners by putting research in the context of socio- economic development and sustainable resource utilization. It recognizes national priorities as outlined in the Ghana Agenda for Shared Growth and Development (GASGD) which focuses on research on social protection, and has the potential to reduce the vulnerability of poor people to the extent that they can manage moderate risks without external support. The priority areas under this thematic area include:

- Policy and Governance
- Statistical, Social and Economic Research
- Culture, Indigenous Knowledge and Community Improvement
- Technology for Livelihood and Wealth Creation

Highlight of achievements

Output 1: ***Orange Maize hits Ghanaian market***

Amanase, a town close to Suhum in the Eastern region of Ghana is a marketing center that serves several communities around. Traders saw a "wonder maize" and its products one market day. It was amazing because the colour of the maize was orange. Curious to know more, Akosua Benewa, a local trader and her sister shared their experiences. Akosua Benewa and her sister are among petty traders in this community who tasted this orange maize and realized that its food preparations such as "banku", kenkey and "Tuosafi", etc. were very palatable and these products from the orange maize were in high demand and preferable to the white varieties.

Farmers in this community, grow local maize generating yields less than 1 ton/ha. The local variety is late to mature (120-130 days), very tall and susceptible to lodging, streak, drought and is less nutritious in terms of vitamin "A". A team of scientists from CSIR-Crops Research Institute (CSIR-CRI) visited this community and introduced the farmers to the recently released orange maize varieties of CRI which mature in 110 days and is tolerant to the stresses mentioned above with adequate levels of vitamin "A". Yields of up to 3 tons/ha (about 3 times their normal yields) were obtained from their fields. Farmers gladly accepted these new varieties because of the good attributes mentioned above and a premium price over the white varieties (10-20%). Farmers testified that the premium price was an incentive for them to grow more of the orange maize. It is amazing that the introduction of the orange maize in this community has made such a great impact in the lives of these dwellers. Orange maize and its products are progressively spreading throughout the country. In addition, most poultry farmers in several of the areas where the orange maize has been introduced were glad to have this new orange maize because it improved the colour of the egg yolk and increased egg production as well as improved the health of the birds due to the adequate levels of pro-vitamin "A" in the orange

maize. Government of Ghana annually imports close to US$200 million worth of yellow maize and this amount could be saved when we step up production of these orange maize varieties.

Food products prepared from "orange maize"

Output 2: ***Introduction of Basic Biotechnology to Senior High School Teachers in Sub-Saharan Africa***

There are several fields of science under Modern Biotechnology. However, in developing countries such as Ghana, the application, understanding and relevance of molecular and related sciences in the field of Biotechnology is limited. A look at the current curricula for Senior High Schools, would reveal an obvious gap between emerging state-of-the-art science, its understanding, application, and awareness by students and teachers in sub-Saharan Africa.

The project *"Introducing Basic Biotechnology Teaching Techniques in High Schools in Sub-Saharan Africa"* funded by the American Society for Plant Biologists, BLOOME between September 2013 and December 2015 impacted tremendously on participants.

A 4-Day Train the Trainer Session organized for SHS students

This project sought to introduce modern biotechnology in an applicable way to educate teachers and students alike. Specific gaps in the teaching of Biotechnology and Genomics in Ghanaian high schools were identified. Teaching models for high school teachers to implement modern agriculture biotechnology were communicated through hands-on workshops. 14 Biology, Agricultural and related sciences teachers from various senior high schools benefited from a 4-day intensive hands-on training utilizing paper models and dry labs to enhance their understanding and delivery of plant biology with emphasis in biotechnology. Ten months into the project, about 1500 participants had benefited from the introduction to Modern Biotechnology. By December 2016, the program had reached approximately 5800 persons.

Output 3: ***Recognition and award of certificate during National Farmers' Day***


Republic of Ghana

MINISTRY OF FOOD AND AGRICULTURE

32nd NATIONAL FARMERS' DAY

Metro/Municipal/ District Award

Certificate of Merit

Awarded to

DAGOMBA GROUNDNUTS FARMERS ASSOCIATION

of DAGOMBA [BEST F B 0]

in recognition of the outstanding contribution towards

THE DEVELOPMENT OF AGRICULTURE IN GHANA

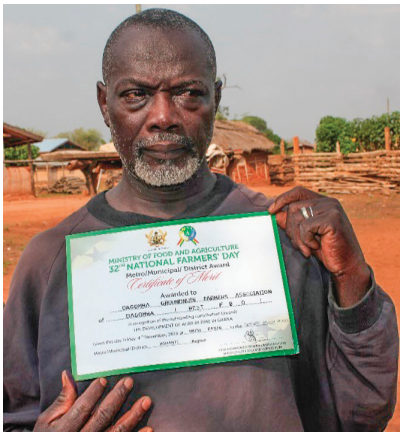
Given this day Friday, 4th November, 2016 at MOSI PANIN in the SEKYERE AFRAM PLAINS

Metro/Municipal/District, ASHANTI Region.

HON. MOHAMMED-MUNIRU LIMUNA (ALHAJI)

MINISTER FOR FOOD AND AGRICULTURE

Certificate Awarded



Leader of farmers' group with his certificate

Twelve farmers from Dagomba village, in the Drobonso District of Ashanti region were respectably awarded during the National Farmers' Day celebration on 4th November 2016. Each farmer received a pair of Wellington boot, a cutlass, a knapsack spraying machine and a certificate. These groups of farmers are groundnut growers who had basically little or no knowledge in the processes leading to aflatoxin contamination in groundnuts and how to reduce such contaminations to acceptable ppb levels. The farmers were selected for training in 2013 under the project *Feed the Future Mycotoxin Innovation Lab*.

They were taken through farmer field School (FFS) by Crops Research Institute (CRI). The farmers now equipped with how to grow groundnuts by selecting good groundnut seeds for planting. They also able to practice weed management, apply oyster shells (which contains 40% of calcium) to strengthen the pods thereby preventing mycotoxin infestation. After harvest, farmers are able to dry their pods using tarpaulin (off the bare ground) to the required moisture content below 10% and package the groundnuts in special bags on pallets for storage. The farmers have gone through all these training described as best management practices (BMPs) for 3 years and currently serve as lead farmers training other farmers in the communities and making positive impact in groundnut production.

Data generated by researchers from CRI so far suggest that even though the BMPs increased costs of production and pest management, increased yield (revenue) was realized. Research during 2016 confirmed these findings and demonstrated the variation in response to the BMPs introduced to farmers.

Output 4: ***Radio gets results***

Radio is acknowledged as the most important medium for communicating with the rural populations of developing countries. In Ghana, radio has proven to be an effective medium through which agricultural information is communicated across long distances, in languages familiar to rural people. The Public Relations Unit of CRI has over the years, coordinated the participation of CSIR-CRI scientists in farmers' radio programmes to share the institute's research results with farmers, and ultimately promote crop productivity. The radio programmes have also strengthened linkages between research, extension, farmers and other value chain actors. Through radio broadcasting, CRI scientists have communicated agricultural information to farmers and their organizations about improved crop varieties and their production technologies. Crop production techniques on cereals, legumes, roots and tubers, as well as such technologies as plantain rapid multiplication techniques, yam vine technique, cassava two-node technique (all for the generation of planting materials); safe use of pesticides, and information on biotechnology have all been shared with farmers and other value chain actors on radio.

CSIR-CRI Scientists on a radio programme at the Ghana Broadcasting Corporation

RT 4: Climate change, environmental conservation and green technology

The climate change, environmental conservation and green technology research programme focuses on the following:

- Soil, Water and Biodiversity Conservation
- Climate Change Mitigation (Including REDD+)
- Climate Change adaptation and Social Development
- Pollution and Waste Management, (Including Bio-Remediation)
- Green Technologies for Sustainable Development

Highlight of achievements

Output 1: ***Protected cultivation in Ghana no more a jinx: Thanks to the Ghana (CSIR-CRI) /Indian (MEA through NRDC) collaboration on tomato production.***

With the increasing uncertainty of the weather due to the effect of climate change, vegetable production is becoming increasingly difficult. This has been compounded by the incidence of pests in vegetable production which invariably leads to pesticide abuse. One sure way of producing healthy vegetables for the Ghanaian table is through protected cultivation. Protected cultivation started intensively some few years ago but is dying out despite support from the World Bank via WAAPP and also through other NGOs like GHANAVEG. This is mainly due to the low yields realized by farmers hence making production under the polyhouses uneconomical.

Hitherto yields obtained for tomato under polyhouse production has averaged **25-50 MT/ha**. However, using the same variety used by farmers, the Crops Research Institute realized **106.9 MT/ha.** The institute was able to achieve this by observing good agronomic practices in the polyhouse.

Tomato crop growing in a saw toothed model polyhouse at CSIR-CRI Kumasi – Kwadaso station

A saw toothed polyhouse which is fitted with foggers and to manage heat

Output 2: ***Smart Yam Technologies Increases Farmers' Resilience to Climate Change***

Yam farmers in parts of Ghana have been exposed to smart technologies required to build a resilient cropping system in order to increase yields by at least 30 per cent. With climate change thwarting efforts of yam farmers, researchers have underscored the need to have a technology packaged with fertilization, seed treatment, minimum staking and ridging to make farmers competitive to meet yam export standards and reduce production costs.

Ghana's Crops Research Institute of the Council for Scientific and Industrial Research (CSIR-CRI), in collaboration with the Ministry of Food and Agriculture(MoFA) and the International Institute of Tropical Agriculture (IITA), Nigeria, trained and disseminated good agronomic practices to more than 250 yam farmers from Ejura, Atebubu and Kintampo between 2014 and 2016. This is under the 5-year Yam Improvement for Income and Food Security in West Africa (YIIFSWA) project funded by the Bill and Melinda Gates Foundation

The project has helped to increase yam production and raised income levels of yam farmers through participatory demonstrations, on-farm trials and farmers' field days. The improved technology builds up farmers' resilience because the ridging helps in moisture conservation while the use of trellis staking reduces farmers' contribution to deforestation. The technology promotes intensification on the given area because of the high population density and arrangements it accommodates. Sprouting which is also key for yam production is assured because seeds are pre-treated thereby reducing pest incidence and rot. When adopted, the technology ensures better living standards compared to the traditional methods.

Yam harvested from a farmer who benefitted from the improved technology dissemination

Output 3: ***Monitoring Sun Ultraviolet ray (UV) Index on plantain production***

Monitoring the UV index from January to May 2016, the data showed that from 9.00GMT to 17.00Hours GMT, the UV index was always between 11 and 13. After May the index was between 7 and 9 daily from 1100Hours to 1400 hours GMT. Our study on plantains in pots during January to May revealed that the photosynthetic system was adversely affected as a result of the high UV levels. The situation remained the same irrespective of the amount of nutrient and water applied the crop. When the same plants were relocated to under 60% shade the photosynthetic apparatus was restored without any nutrient application. Fruit analysis also showed that the proVitamin A content was lower when fruits were harvested during the period of high level of UV compared to those harvested during the period of low UV levels. Our conclusion is that all crops may be affected by the high level of UV index. Therefore, scientists must develop an approach that can remedy the situation. Other studies on induced water stress also revealed that plant growth and development is adversely affected by climate variability. There is an urgent need for critical thinking to develop an approach for smart agriculture.

Research for Development (IAR4D)

The Integrated Agricultural Research for Development (IAR4D) concept was developed to overcome the shortcomings of the linear approaches for implementing agricultural research and development. The IAR4D concept appraises agriculture as a system that is made of many sub-systems that must work together to foster development. This concept sets up the Innovation Platform (IP) as its operational instrument. The IP is a forum for group of relevant actors selected along the value chain of specific commodity or system of production. The actors include farmers, researchers, extension agents, traders, processors, financial institutions, policy makers, regulators, output market operators, consumers and others. They interact to jointly identify problems, investigate solutions leading to generation of innovations and its accompanying socio-economic benefits.

Highlights of Achievements

Output 1: DONATA IP Activities

The low adoption rates of improved cassava varieties is attributable to factors such as limited knowledge on the attributes of the varieties, minimal access to market information, inefficient production practices and value addition for higher premium. An innovation platform (IP) on the cassava value chain – Dissemination of New Agricultural Technology for Adoption in Africa (DONATA) was initiated in the Wenchi Municipal to transfer, share and disseminate improved technologies and indigenous knowledge to actors along the cassava chain on three priority entry points:

- Access to improved cassava varieties and enhanced soil fertility management.
- Use of herbicides to control perennial weeds in cassava.
- Cassava product development and market access.

External factors such as market opportunities, the Research Extension Farmer Linkage Committee (RELC), collaboration with other stakeholders such as the CSIR-CRI COTVET Project, the Wageningen University, the Department of Social Sciences, WAAPP, CSIR-Food Research Institute (CSIR-FRI), CONCERN (NGO) and others have influenced the success of the IP to date.

Achievements

The IP boasts of a total of 1180 direct and indirect beneficiaries. Access to improved cassava varieties *(Nkabom, Ampong, Bronibankye, Esambankye, Otuhia and Sika)* has improved tremendously, beyond the two *(Bankyehemaa and IFAD)* that existed prior to the IP.

Knowledge and adoption of good agricultural practices (GAP) like proper pesticide use and application, row planting, preparation of planting materials etc. have increased yields from an average 12 t/ha to average of 35 t/ha.

Outcomes

- A successful execution of an MOU among all stakeholders for the purchase of a cassava processing equipment to establish a functional IP.
- The "Ayigbe" IP Good Processing Centre (GPC) continues to be a learning hub for different organizations and has benefitted from another mill, while the support from CONCERN has led to the establishment of a credit 'susu' scheme for loan servicing and an increased demand for cassava.
- A member of the IP was awarded the "Best Cassava Farmer" award in the Wenchi Municipality.

Knowledge and information sharing

A number of Innovation Platforms have been established by the institute. Districts that have benefited from this include Pusiga, Garu-Tempane, Amantin, Atebubu, Nincongo, **Karaga, Nkawie, Afigya-Kwabre, Ejura Sekyeredumasi, KEEA, Adziedukope** and the Bawku Municipality.

- Over 200 farmers have been trained on integrated pest management (IPM) and Agricultural marketing for sweet potato and the safe use of agro-chemicals.

- 30 IP members on the Adziedukope IP were supplied with 160, 000 *Sika Bankye* cuttings for planting 111acres
- 66,660 *CRI Ligri and CRI-Apomuden* sweet potato vines were supplied to the Nincongo IP for planting 20acres
- With support from WAAPP PCU, 14 IPs in 7 districts were supplied with maize, soybean, groundnut and cassava planting materials to plant 612 acres altogether.

"Sika Bankye" cuttings supplied to beneficiaries

Farmers being introduced to good agricultural practices

Equipment Support

A processing shed

A sheep/goat pen

The IP was succesful in providing some equipment for the beneficiaries. Such equipment include 2 Solar dryers, 3 smokeless stoves, 10 sheep/goat pens, a cassava grater, a cassava peeler and a processing shed.

More Outcomes

Komtin Yam IP (Karaga District, Northern Region)

- An input dealer on the IP supplied 30 members with agro chemicals worth 2,000.00 to be repaid in kind after harvest.

Nyame Na Aye Crop Small Ruminant IP(Amantin, Brong Ahafo Region)

- The IP was able to link up with Borix B. Farms in Kumasi who bought 600kg of maize worth GH¢ 30,000
- Two members of the Adziedukope IP were awarded during the National Farmers' Day celebration.

Monitoring of Research Activities

Scientists participate in Research Monitoring, Evaluation and Learning Visits

The institute undertakes regular visits to on-station fields of scientists to monitor and evaluate on-going research activities. The purpose of these visits is to review scientists' field and laboratory trials to ensure that they conform with the proposals they presented at the In-House Review and Research Planning at the beginning of the year. The visits also present an opportunity for other scientists and participants to "peer review" activities being carried out by their colleagues.

In 2016, research scientists and technicians of the institute actively participated in a two-day research monitoring, evaluation and learning visit to on-station fields at Fumesua and Kwadaso and out-station fields at Ejura, Atebubu, Wenchi and Kintampo. The team was led by the Director of the institute and was the first time field monitoring had been done on out-station fields.

Presentations were made on trials of all the institute's mandate crops including cereals (maize and rice), legumes and oil seeds (cowpea, soybean and groundnut), roots and tubers (cassava cocoyam, sweet potato, yam and taro), horticultural crops (plantain and banana), tropical fruits (citrus and mango) and vegetables (pepper, garden eggs and tomato).

Scientists were encouraged to take the lead and practice the technologies they disseminate to farmers in order to help them adopt such technologies.

The Director of the institute leading participants to inspect fields at the Horticulture Division of the institute.

The Deputy Director, Dr. J. Manu-Aduening briefs participants on cassava planting material multiplication at Wenchi

Dr. Grace Bofrey-Arku, a Senior Research Scientist (right) briefs participants on linkages between speargrass and root rot disease in a weed management trial

A section of participants at the monitoring, evaluation and learning visit

Research Support Activities

Output 1: Our Thoughts on The Raging GMO Debate

As a key stakeholder in agricultural technology and research, the CSIR-Crops Research Institute has vested interest in the use of biotechnology for food production. One such instance is where food is genetically modified. Farmers in other parts of the world have embraced this new technology as it not only increases efficiency but it also protects and increases yields as well as reducing the over-reliance of farmers on chemicals. Food ingredients produced from biotech crops are found in thousands of food products consumed worldwide. However, the jury is still out on the value and safety of the technology even though no evidence of harm to human or environmental health is known

Genetically modified (GM) foods are organisms that have had new genes added to themselves from other organisms. Some people suggest that the use of this technology will lead to a decrease in the wastages within the agricultural value chain among other benefits. However, some potential drawbacks have also been identified. Societal anxiety over genetically modified (GM) food is understandable, and it is fueled by a variety of causes, including consumer unfamiliarity, lack of reliable information on the current safeguards in place, a steady stream of negative opinions in the media, and a general lack of awareness of how our food production system has evolved.

The scientific community has neither adequately addressed public concerns about GM foods nor effectively communicated the value of this technology.

Conventional Breeding versus Genetically Modified (GM) Crops

Traditional breeding methods are slow, requiring intensive labor: while trying toget a desirable trait in a bred species, undesirable traits will appear and breeders must continue the process over and over again until all the undesirables are bred out. One main advantage of GM crops is that the farmer involves crosses either within species or between very closely related species. GM crops can have genes either from closely related species or from distant species, even bacteria and viruses.

Benefits: One side of the debate

Genetically Modified Maize

Economical

GM supporters tell farmers that they stand to reap enormous profits from growing them. Initially, the cost is expensive but money is saved on pesticides and herbicides. To produce the GM crops, modern biotechnology is used which requires highly skilled people and sophisticated equipment.

Herbicide-resistant crops

GM crops can be produced to be herbicide-resistant. This means that farmers can spray these crops with herbicides and kill the weeds, without affecting the crops. Biotechnology companies are even experimenting with crops that can be genetically modified to be drought and salt-tolerant, or less reliant on fertilizer, opening up new areas to be farmed and leading to increased productivity. However, the claim of less herbicide usage with GM crops is yet to be supported by facts.

Better quality foods

Even animals can be genetically modified to be leaner, grow faster, and need less food. They could be modified to have special characteristics, such as greater milk production in cows. These modifications again lead to improved productivity for farmers and ultimately lower costs for the consumer. Modified crops could perhaps prevent outbreaks such as foot and mouth disease, which has devastated many farmers and local economies.

Risks: The Other Side of the Debate

Environmental damage

The problem with GM crops is that there is little known about what effect they will have in, say, 20 years' time. The genetic structure of any living organism is complex and GM crop tests focus on short-term effects. Not all the effects of introducing a foreign gene into the intricate genetic structure of an organism are tested. Will the pests that a crop was created to resist eventually become resistant to this crop?

Risk to food web

Further complication is that the pesticide produced in the crop may unintentionally harm creatures. In Britain, a native farm bird, the Skylark, was indirectly affected by the introduction of GM sugar beets designed to resist herbicides. In planting this crop, the weeds were reduced substantially. However, since the birds rely on the seeds of this weed in autumn and winter, researchers expect that up to 80% of the Skylark population would have to find other means of finding food.

Cross-pollination

Cross-pollination is a concern for both GM crops and conventional breeding, especially with the more serious weeds that are closely related to the crops. With careful management this may be avoided. For example, there is a type of maize that will not breed with other strains and scientists are hoping that it could help to prevent cross-pollination. Genetic modification to herbicide resistant crops could insert the gene that prevents the problem. The number of herbicide-tolerant weeds has increased over the years from a single report in 1978 to the 188 herbicide-tolerant weed types in 42 countries reported in 1997. They are an ever-increasing problem and genetic engineering promises to stop it. But will genes from GM plants spread to other plants, creating super weeds and superbugs we won't be able to control?

Disease

Another concern is disease. Since some crops are modified using the DNA from viruses and bacteria, will we see new diseases emerge? What about the GM crops that have antibiotic-resistant marker genes? Marker genes are used by scientists to determine whether their genetic modification of a plant was successful. Will these antibiotic-resistant genes be transferred to microorganisms that cause disease? How can we develop new drugs to fight these new bugs?

The institute continues to make its thoughts on the matter known through various newspaper publications. Three articles related to Genetically Modified Organisms were published in 2016

Output 2: Research Information (Library)

The Crops Research Institute believes that a key component of research is access and dissemination of relevant, accurate and timely information. The institute's library is tasked with achieving this mandate and also training users on information literacy.

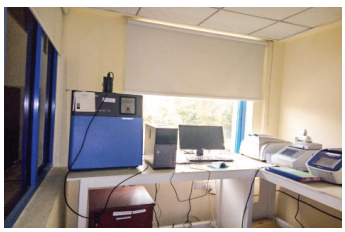
Over the course of the year, about 179 users visited the library. This comprised staff of the institute, students from different tertiary institutions, visiting foreign students as well as staff of other institutes within the council. This number was a marked improvement from the previous year. In all, 582 materials were acquired within the year. These included electronic and printed journals, scientific books, annual reports, manuals and newsletters. The institute also has access to 28 online databases and journals. The Essential Electronic Agricultural Library (TEEAL) has been updated and now has over 550,000 articles on agriculture and other related areas ensuring constant access to information for research.

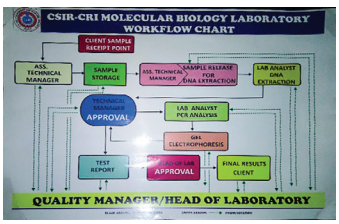
Scientists making use of the library for research A number of scientific publications available at the library

Output 3: Journey towards obtaining ISO 17025:2005 Accreditation Label for the CSIR-Crops Research Institute's Molecular Biology Laboratory

Under the West African Agricultural Productivity Programme (WAAPP), the CSIR-Crops Research Institute was identified as a National Centre of Specialization (NCoS) for root and tuber crops. In migrating from a National Centre of Specialization (NCoS) to a Regional Centre of Excellence (RCoE), ISO accreditation was identified as one of the major criteria. Hence, the Molecular Biology Laboratory is seeking accreditation to the International Standard (ISO) 17025:2005 to demonstrate competence in one of its selected test methods.

In November 2014, local consultants Sky Portal Consults were contracted to assist the laboratory prepare for the accreditation. A gap audit was conducted to assess the status and operations in the laboratory in relation to both management and technical requirements of ISO 17025:2005. A series of training programmes were organized for management, senior members and other technical staff of the Biotechnology laboratory on the importance, requirements and benefits of implementing ISO 17025:2005. A test method to be accredited for ISO 17025:2005 was identified. This test method is the "detection of African Cassava Mosaic Virus (ACMV) in Cassava using Polymerase Chain Reaction (PCR)". An Accreditation Committee/Quality Team has been established and trained. Relevant documents (Quality manual, Technical manual and Documented procedures and forms) have been developed and the Quality Management System has been implemented. For the improvement of the Quality Management systems, Quality Internal Auditors have been identified and trained. Inter-laboratory testing has also been conducted with KEPHIS in Kenya and IITA in Nigeria and Tanzania. An application has been sent to the South African National Accreditation System (SANAS) for assessment of our Quality Management System and subsequently for the award of ISO 17025:2005 accreditation.





Newly established diagnostic laboratory for ISO 17025:2005 Accreditation

Output 4: ISO 9001:2015 Quality Management System

ISO 9001 is a standard that sets out the requirements for a quality management system. This standard is based on a number of quality management principles including a strong customer focus, the motivation and implication of top management, the process approach and continual improvement. Businesses and organizations that certify to this standard become more efficient and also improve customer satisfaction. The objectives relating to "quality" are not specified but are defined by the organizations themselves as they seek to continually improve their

processes to achieve them. ISO 9001 is used successfully all over the world. In 2013 alone, over one million certificates to the standard were issued across 187 countries, and many other companies and organizations have used the standard without seeking certification. The seven quality management principles (QMPs) are:

QMP 1 – Customer focus; QMP 2 – Leadership; QMP 3 – Engagement of people;

QMP 4 – Process approach; QMP 5 – Improvement; QMP 6 – Evidence-based decision making

QMP 7 – Relationship management

These principles are not listed in priority order. The relative importance of each principle will vary from organization to organization and can be expected to change over time. The institute has formed an ISO Implementation Committee together to lead the discussions towards the accreditation. Members have been introduced to a quality manual and different Standard Operating Procedures (SOPs). Various sub-committees are to be formed to help in the preparation of the SOPs for the Technical and Support Divisions of the institute. The institute hopes to acquire the accreditation this year.

Training and Technology Dissemination

Output 1: CSIR-CRI Agricultural Productivity Technology Centre (APTC)

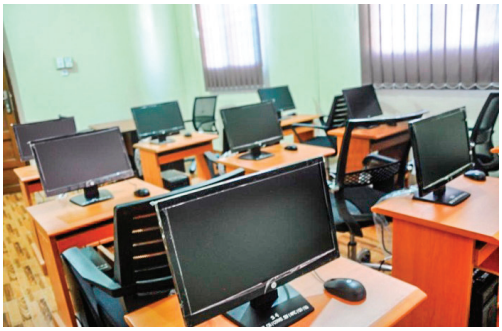
The Agricultural Productivity Technology Centre (APTC)

The need to package and brand developed technologies by the institute so that they are available to end users was envisioned some years ago. In order to bring this vision to fruition,

the Agricultural Productivity Technology Centre (APTC) was set up with support from COTVET with the following objectives:

- Provide essential improved agricultural technologies to end users through technical and advisory services
- Develop commercial new innovative learning material
- Build capacity of relevant actors of priority commodity value chains
- Identify and develop young agribusiness entrepreneurs through agribusiness incubation.

The centre has contributed to the training of about 609 beneficiaries in various capacity building processes such as the use of statistical software packages like STATA, extension, seed quality assurance, data quality and presentation. Beneficiaries were also trained in GIS and GPS technology. The centre has also produced a number of scientific video documentaries, purchased some post-harvest equipment, published a guide for yam production and is engaged in a range of activities as well.



A computer room available at the APTC

A conference center at the APTC

Output 2: Korea-Africa Food and Agriculture Cooperation Initiative for The Enhancement of National Agricultural Extension Services (KAFACI-ENAES) – Ghana-Phase I

The Korea-Africa Food & Agriculture Cooperation Initiative is an intergovernmental and multilateral cooperation body aiming to improve food production, achieve sustainable agriculture and enhance extension services of African countries through knowledge and information sharing on agricultural technologies.

In Ghana, the main objective of the project was to promote the production and utilization of drought tolerant maize varieties for enhanced nutrition (quality protein and micro - nutrients) in the Atwima Kwanwoma District of Ashanti Region

Specific Objectives

- To facilitate the dissemination of high yielding, disease, pest and drought tolerant maize varieties
- To support at least three (3) FBOs to adopt Good Agricultural Practices that will ensure increased production.
- To demonstrate the nutritional superiority/importance of Quality Protein Maize (QPM) in feeding (local and continental dishes).

Demonstration of GAPs (Fertilizer Application)

Demonstration of Herbicide Application

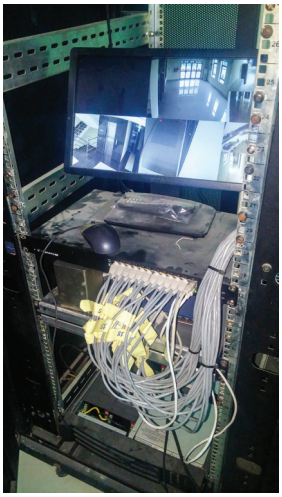
Highlights of Achievements

- Farmer participation increased from 95 to 182 and from four (4) communities to six (6).
- Increased adoption of production technologies (Good Agricultural Practices) including non-registered farmers.
- Demonstration/learning plots have equipped a total of 326 farmers
- Cluster farming has fostered the spirit of unity amongst farmers, encouraged and facilitated horizontal technology transfer and ensured easy supervision and monitoring.
- Reduction in postharvest losses of maize as a result of good postharvest management practices
- Increased in average yield from 0.9 tons/ha in the base year to 2.4 and 3.3 tons/ha for year one and two respectively.
- Capacity Building for all fifteen (15) Agricultural Extension Agents (AEAs) and Management Information System Officers (MISO) in the District including five (5) District Officers.
- Fifteen (15) completed improved maize storage/drying structures constructed by farmers
- Adequate technical backstopping and support for participating farmers provided to enable them reach the expected yield target of 4.5 to 5.0 tons per hectare

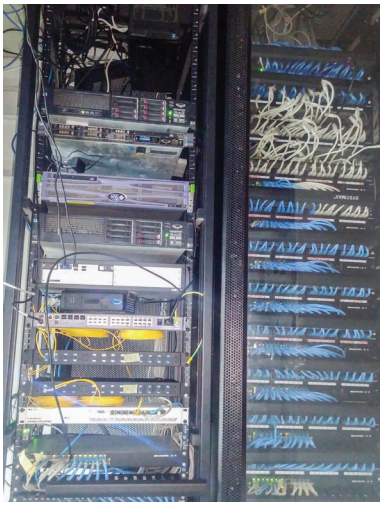
- Participating farmers have also been trained in other income generating activities (soap making/rabbit rearing) due to their exposure.
- Increased varieties of maize food forms including Weanimix and Cerelac to feed babies.

Demonstration of maize food forms

Information, Communication and Technology (ICT)



CCTV Cameras recorder



Network racks with server, switches and router

The institute has an ICT department that provides computing services to support research activities among other duties. The department is also responsible for maintaining the institute's Local Area Network and the Wireless network. Other duties undertaken by the department include:

- Installation of IPBX server Intercom system: 36 IP phones configured and deployed.
- Installation of Digital Repository (DSPACE): This is a repository for the institute's library and also hosts research works, journals and publications.
- Maintenance of the institute's website and weather station
- Installation of backup server
- Installation of Linux Email Server
- Setting up of a clocking system for staff
- Setting up of a bulk SMS system for staff

A scientist downloading data from the institute's weather station

Biometry and Statistical Analyses

Modeling of Grain Yield in Maize

The Biometrics unit of the institute is responsible for providing support to researchers and students on the application of mathematics and statistics. It is also involved in analyzing and interpreting experimental data for researchers. One of the many research works undertaken by the unit was to "model grain yield in maize". The purpose was to come out with a time series model that best fits maize grain yield data and to formulate a regression model that can predict maize yield in the future.

A maize field

Secondary data was used. The data was analysed using the "R" statistical software. This resulted in a very good model that fit the data perfectly and is being used to correctly predict maize yields by the institute.

Commercialization (Income Generation Activities)

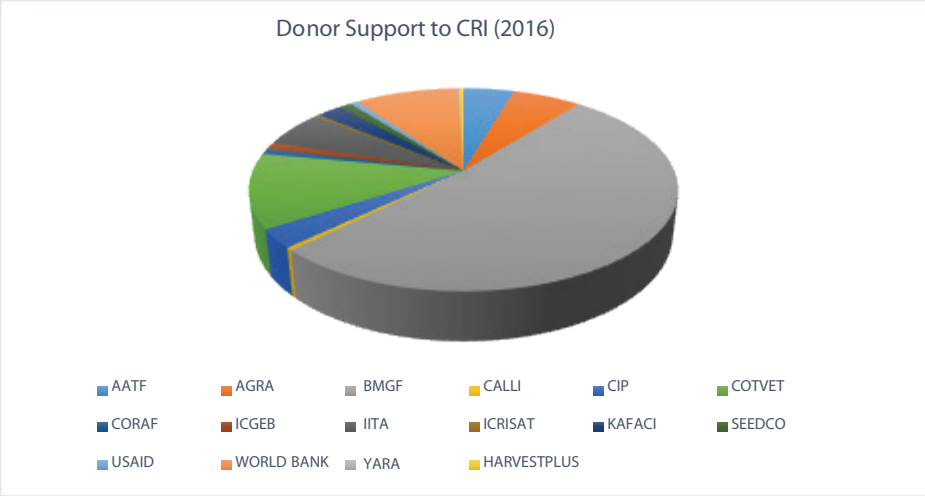
The institute engages in a number of activities to generate extra income to complement the support from the Government of Ghana. One of such activities is the sale of mango and lime seedlings by the commercialization division. In 2016, the institute sold 22,000 lime seedlings, 74 ,830 mango seedlings and 68 bags of maize. This contributed to a 6.5 percent increase in the institute's Internally Generated Funds (IGF). A Memoranda of Understanding (MoU) has been developed with Hen Mpoano Company Ltd for the establishment of 46.26 acres of cassava planting materials. Another 1.5 acres of cassava has been cultivated at Fumesua to be supplied to Hen Mpoano Company Ltd with a further 3.5 acres cleared at Fumesua 2017. This is to ensure constant supply of planting materials. Overall, the commercialization division made a 57.10 percent profit from the sale of materials. The division projects a 60 percent profit in 2017.

Seedlings available for sale at the Commercialization division of the institute

Financial Overview

The institute continues to receive support from a number of donors for its research and dissemination activities. The year under review saw a number of donors contributing towards the work of the institute. The total amount received from donor funding was GH¢11,118,810.84.

Majority of our donor support for the year came from the World Bank (WAAPP), the Bill and Melinda Gates Foundation , BMGF(CAY-SEED Project) and COTVET (APTC). Other donors included AGRA, CALLI, IITA, KAFACI, YARA GHANA, CORAF, SEEDCO, USAID, CIP among others.



Donor support to CRI in 2016

ADMINISTRATIVE REPORT

Farm Management

The farm management section of the institute is responsible for the maintenance and general up-keep of all properties belonging to the institute. Over the course of 2016, the section not only renovated and managed the institute's guest houses and bungalows but also mowed lawns, trimmed hedges and installed 25 water meters. The section also successfully oversaw the de-silting of the institute's dams to ensure that they hold more water for irrigation purposes.

Transport

The transport section of the institute is responsible for the repair and maintenance of the institute's vehicles, tractors, plants and equipment. The section also engages in installation and repair services as well as welding and fabrication works. In 2016, the section acquired two brand new vehicles and re-registered 35 others. One major achievement was the fabrication of 15 elephant groundnut shellers for USAID-Spring and 20 pieces of seed cages for the Biotechnology division. Aeroponics screen houses were also fabricated for the YIIFSWA project.

An aeroponics screen house constructed by the Transport section of the institute

CRI Credit Union

In order to support staff, CSIR-CRI has invested in a credit union scheme which runs on its premises. The scheme is opened to all staff and residents within a catchment area of the

institute's location in Fumesua-Kumasi. About 90 percent of staff are members of the scheme. Due to very good management practices, the scheme realized an increase of 7.34 percent on its savings within the last year.

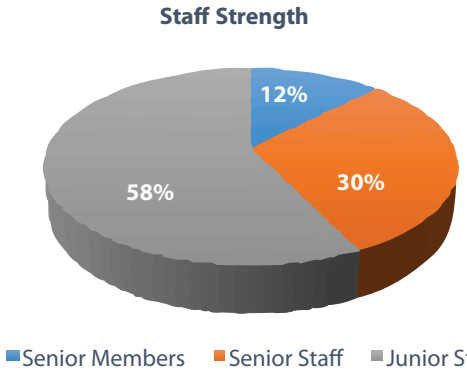
The Credit Union Building on the premises of the CRI

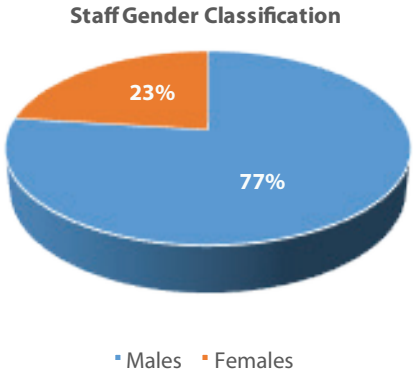
Human Resource/Capacity Building

One major selling point for the CSIR-CRI is the quality of human resource available to it. The institute can boast of very qualified and knowledgeable senior members, senior staff and junior staff. Nonetheless, the institute continues to encourage staff to add value to themselves and rise through the ranks as quickly as possible. This drive resulted in a number of promotions in 2016. In all, about 95 persons were promoted across various divisions and sectors.

Here at CRI, we believe in sharing and passing on knowledge unto the next generation. As a result, a number of workshops, conferences and symposia were organized for staff and interested members of the general public. Students from 17 agricultural and other institutions visited the institute to acquaint themselves with practical field and laboratory activities. Over 100 students have been posted to the institute and are being trained as interns and national service personnel.

The staff strength of the institute stood at 633 by December 31, 2016. Senior members constituted 12% of this number with senior and junior staff members constituting about 30% and 58% respectively. This number also comprised 87 post-graduate degree holders (Ph.D,M. Phil, M.Sc/M.A.), 48 Bachelor degree holders (BSc./B.A.), 31 Diploma holders with the remaining 467 holding either College Certificates or other qualifications. The staff is male-dominated with just about 23 percent staff members being female.





OUR PEOPLE (Senior Members and Senior Staff)

DIRECTOR

Stella Ama Ennin

DEPUTY DIRECTOR

Joseph Manu-Aduening

ROOT AND TUBER IMPROVEMENT DIVISION

Emmanuel Otoo	Regina Sagoe	Kwadwo Adofo
Yaw Danso	Peter Appiah Danquah	Bright Boakye Peprah
Asamoah Obeng Nyarko	Joseph Esuman K. Awoodzie	Edem Lotsu
Oswald Ohene Gyan	Nanaebo Blankson	Cynthia Oppong Darko
Habbibah Aggrey	Luke Opoku Amankwah	Irene Dufie
Prince Opoku	Kwadwo Alhassan	

CEREALS IMPROVEMENT DIVISION

Kwadwo Obeng Antwi	Manfred B. Ewool	Martin Luther Tengan
Frank Coffie Danso	Joseph K. Amponsah	C.K.A. Adaabre
E. Abugbila	Stephen Oware Kunkumah	Eric Baffoe
Raphael K. Bam	Paul Kofi A. Dartey	Ebenezer Annan-Afful
George Kwasi Acheampong	Maxwell Darko Asante	William Lelabi Kota
Samuel Tandoh	Sober E. Boadu	Vida Amuzu
Isaac Owusu Konadu	Phyllis Aculey	Elizabeth Norkor Lartey

LEGUMES AND OIL SEEDS IMPROVEMENT DIVISION

James Yaw Asibuo	Hans Adu-Dapaah	Stephen Amoah
Sylvester Addy	K. Adjei-Bediako	Michael Adu
Victoria Larweh	Paul Manor	Maxwell Lamptey
Afua Gyaamah Gyima	Seth Odjerh	Franklin Bosompem Denkyira

HORTICULTURE DIVISION

Beloved Mensah Dzomeku	Alberta Nsenkyire	Paul Mintah
Ernest Baafi	K. Offei Bonsu	Seth Obosu-Ekyem
Michael Osei Kwabena	Hillary Mireku Bortey	Isaac Osei Bonsu
Adama	Haruna	Joshua Atisu

RESOURCE, CROP MANAGEMENT AND SOCIO- ECONOMICS DIVISION

Joseph Nketia Berchie	Patricia Oteng Darko	Shadrack K. Amponsah
Stephen Yeboah	Eric Owusu Danquah	Kennedy Agyeman
Erasmus Narteh Tetteh	Felix Frimpong	Mavis Numafo
Michael T. Odamtten	S. Obeng Antwi	Aisha Karim
John K. Fordjour	Patterson Osei-Bonsu	Offei Micah Apraku
P.E. Amoa-Darko	Beethoven Ameho	Joseph B. O. Antwi
Zakaria Atohulo	Joyce A.S. Haleegoah	Bright Owusu Asante
Jonas Osei-Adu	Patricia P. Acheampong	Natson Eyram Amengo
Alexander Adu-Appiah	Benedicta Nsiah Frimpong	Lydia Brobbey
Harriet Yeboah		

PLANT HEALTH

Haruna Braimah	Moses Mochiah	Adama Ibrahim
Umar Sanda Issah	W. Amoabeng Blankson	Anthony Gyimah
Adama Amadu	Matilda Frimpong	Grace E.K. Bolfrey-Arku
Stephen Arthur	Kingsley Osei	Allen Oppong
Joseph Adomako	Atta Kwasi Aidoo Snr.	J. Sackey Asante
Zippora Appiah-Kubi	Francis Ayueboteng	Esther Agyemang Marfo
Bismark Abugri	Edwin Odame Darko	James Konadu Boafo

BIOTECHNOLOGY, SEED TECHNOLOGY AND POST-HARVEST DIVISION

Marian Dorcas Quain	Michael Akuamoah Boateng	Evelyn Adu-Kwarteng
John Kwadwo Addo	Albert Aubyn	Francis O. Amoako-Andoh
Ruth Thompson	Charles Afriyie Debrah	Priscilla F. Ribeiro
Harry Okyere	Victor Acheampong Amankwaah	Henry Akrofi Doku
David Appiah Kubi	Linda A. Abrokwah	Belinda Akomeah
Faustina Okyere	Stanley Asare	Theodora A. Mensah
Agnes Achiaa Aboagye	Gertrude Osei-Diko	Daniel K. Cudjoe
Lily Naa Adoley Allotey	Agnes Nimo Bosompem	Monica Ode Adu-Gyamfi
Sylvia Kafui Artcher	Joyce M. Gbarimaa	Abigail Amoa-Owusu
Mary Arthur	Hillary Mireku Bortey	Sadia Osuman Alimatu

SCIENTIFIC SUPPORT SERVICES DIVISION

Bernard Sakyiamah	Lynda G. S. Nsafoah	Solomon Gyasi Boakye
Solomon K. Darkey	Dora Aninakwa	Adelaide Agyeman
Emmanuel Sosu	Harriet A. Dwamena	David Kow Amo
George Sefa-Anane	Enock Osei Tutu	William F. K. Aidoo
Lawrencia D. Acheampong		

COMMERCIALIZATION DIVISION

Emmanuel Agyei Asamoah	Martin Osei Bonsu	Joseph Owusu
Mark Anti		

ACCOUNTS DIVISION

Samuel Adu	Isaac Donkor	Samuel Sakyi Darko
Abraham Walden	Anthony Ofori	Isaac Osei Mensah
Peter Amoah	Emmanuel Manu	Daniel Tetteh
James Nyag	Fredrick Owusu	Esther Boakye
Robert Adu-Gyamfi	John Amihere Mensah	Heyford Asiedu Boateng
Mawusi Lotsu	Thomas Konadu Yiadom	Olivia Opoku
Prince O. Agyeman	Naomi Agyebeng	

ADMINISTRATION

Lawrence K. Mensah	Emmanuel Afriyie	Hagar Assan
David Denu	Linda Agyeman	Christina Ivy Tetteh
Joyce Larbi-Siaw	Mary Gyapong	Paulina A. Sarkodie
Emmanuel Dadzie	Martina Sikinya	Charlotte Agyapong
Linda Kumah	Elizabeth Nyako	Vida Antwi
Ophelia Nketiah	Christiana Nti	Bridget Adjei
Sandra Baah-Sakyi	Vera Fosua Yeboah	Paulina Asieduaa
Maxwell Kwodane		

RESEARCH PUBLICATIONS

The year 2016 saw a number of scientific publications by staff of Crops Reaserch Institute. The publications included various refereed scientific journals, conferences and books.

Refereed Journal Papers

Abengmeneng, C.S., Ofori, D.A., Kumapley, P., Akromah, R., Jamnadass, R., Quain, M. 2016. Genetic relationships among 36 genotypes of Ceiba pentandra (L.) as revealed by RAPD and ISSR markers. *American Journal of Agriculture and Forestry 4(4): 86-96.*

Acheampong, P. P., Osei-Bonsu, P., Omae, H. and Nagumo, F. 2016. Disadoption of Improved Agronomic practices in Cowpea and Maize at Ejura-Sekyeredumase and Atebubu-Amantin Districts in Ghana. *Sustainable Agriculture Research, 5(3); 93-102.*

Adama I., Fening, K. O. Mochiah, M. B., Owusu-Akyaw M., and Andoh-Mensah, E. 2016. Knowledge of Cassava Pest Management: The case of farmer training on integrated Management of Millipede Infestation in outbreak in Western region of Ghana. *Asian Journal of Agriculture Extension, Economics & Sociology, 14 (4): 1-8.*

Adama, I., Braimah, H., and Amoabeng, B.W. 2016. Efficacy of Super neemol granules for the control of cowpea (*Vigna unguiculata* L.) Walp) insect pests in the forest region of Ghana. *Journal of Biodiversity and Environmental Sciences, 8(5):187-194*

Addo J. K., Amoah S., Akuamoah Boateng M., Okyere H., Adu-Dapaah, H., Amoa-Owusu, A. 2016. Physical, Functional and cooking characteristics of six newly released cowpea (*Vigna unguiculata* [L] Walp) varieties. *Agricultural and Food Science Journal of Ghana, 9(1):742-753.*

Adomako, J., Osei, K., Danso, Y., Sackey-Asante, J and Abugri, B and Kankam, F. 2016. Response of five cowpea varieties to some phytonematodes under field conditions. *International Journal of Plant & Soil Science 12 (4): 1-5.*

Amengor, E. N., Yeboah, H., Fordjour, E., Acheampong, P. P., Adu, J. O., Frimpong, N. B., Adofo, K. and Sagoe, R. 2016. Gender Analysis of Sweet Potato Production in Ghana. *European Journal of Applied Sciences, 8(1), 10-17.*

Amoah, A. R., Akromah, R., Asibuo, J. Y., Oppong, A., Nyadanu, D., Agyeman, A., Bediako, A. K. 2016. Genetic control of resistance to rosette virus disease in groundnut. *Journal of Plant Breeding and Crop Science 8(6):87-93*

Amoah, R. A., Akromah, R., Asibuo, J. Y., Oppong, A., Nyadanu, D., Agyeman, A., and Bediako, A. K. 2016. Genetic control of resistance to rosette virus disease in groundnut (*Arachis hypogaea L.*). *Journal of Plant Breeding and Crop Science, 8(6):87-93.*

Appiah-Kubi Z. and Aidoo A.K. 2016. Efficacy of Garlic (*Allium sativum*) Bulb and Ginger (*Zingiber officinale*) Rhizome Extracts in Controlling Seed-Borne Fungi of Rice (*Oryzae sativa*). *Journal of Biology and Nature 6(2): 99-103*

Appiah-Kubi Z., Apetorgbor A. K., Moses E., Appiah-Kubi D., Marfo, E. 2016. Variability of Colletotrichum gloeosporioides isolates the causal agent of Anthracnose disease of cassava and yam plants in Ghana. *International Journal of Pytopathology, 5(1):01-09*.

Baafi, E., Gracen, V.E., Manu-Aduening, J., Blay, E.T., Ofori, K., and Carey E. E. 2016. Exploitation of genetic potential of sweetpotato for end-user traits improvement. *African Crop Science Journal 24(4):377-387*.

Baafi E., Gracen V.E., Manu-Aduening J., Blay E.T., Ofori, K., and Carey E. E. 2016. Genetic control of Beta-carotene, Iron and zinc content in Sweetpotato. *Journal of Plant Studies, 6(1):112-117*

Baafi E., Gracen V.E., Manu-Aduening J., Blay E.T., Ofori, K., and Carey E. E.2016. Genetic control dry matter, starch and sugar content in sweetpotato. *Acta Agricultural Scandinavica, Section B- Soil & Plant Sciences, 67(2): 110-118*.

Baidoo, P.K. and Mochiah, M.B. (2016). Comparing the Effectiveness of Garlic (*Allium sativum* L.) and Hot Pepper (*Capsicum frutescens* L.) in the Management of the Major Pests of Cabbage *Brassica oleracea* (L.). *Sustainable Agriculture Research, 5(2):83-91.*

Berchie, J.N., Adu-Dapaah H., Agyemang, A., Sarkodie-Addo, J., Addo, J.K., Addy, S., and Blankson, E. 2016. Performance of five Bambara groundnut in the Transition Agroecology of Ghanaunder different sowing dates. *Agricultural and Food Science Journal of Ghana, 9(1):705-718.*

Bortey, H. M. and Dzomeku, B.M. 2016. Fruit and Seed Quality of Okra (Abelmoschus esculentus (L.) Moench) as influenced by harvesting stage and drying method. *Indian Journal of Agricultural Research, 50(4):330-334*

Bortey, H. M. and Mpanju, F.2016. Adoption of Plant Breeders' Rights System: Perceived Implication for Food, Seed Security and Sovereignty in Ghana. *Journal of Intellectual Property Rights, 21(4):96-104.*

Bortey, H. M., Alimatu O. S. and Asibuo, J. Y.2016. Influence of Seed Storage Techniques on Germinability and Storability of Cowpea (*Vigna unguiculata* (L) Walp) *Journal of Agricultural Science, 8(10):22-26*

Bortey, H.M. and Alimatu, O.S.2016. Analysing the Constraints faced by the Small Holder Tomato Growers in Ghana. *International Journal of Agricultural Extension 04(2):111-117.*

Danso, Y., and Kwoseh, C. 2016. Some Okra Production Decisions and Farmers' Awareness of *Meloidogyne* spp. Infection in Two Agro-ecologies, Ghana. *American Journal of Experimental Agriculture, 11(5): 1-6.*

Danso,Y., Osei, K., Adomako, J., Asante-Sackey, J. and Abugri, B.2016. The Impact of Organic Soil Amendments on Population Densities of Plant parasitic nematodes and okra yield. *Journal of Agriculture and Ecology Research International, 6(3): 1-6*

Danso-Wiredu, E.Y., Dadson, Y.I, and Amoako-Andoh F.O. 2016. Social, economic and environmental impacts of the recent power crisis in Ghana: A study of Winneba. *Journal of Social. Sciences, 49(3): 277-288*

Darkey, S.K, Okorley, E.L., Gyimah, N, A., Bluwey, F.A. and Dzomeku, B.M. Production and Marketing Challenges of Vegetable Farming: A case study of Kumasi Metropolis of Ashanti Region, Ghana. *Agricultural and Food Science Journal of Ghana 9(3):2-5*

Dzomeku B. M., Sarkordie-Addo J., Darkey S. K. Bam R.K and Wuensche J. 2016. Evaluating postharvest characteristics of Apantu (Local False Horn) plantain for harvest indices determination. *International Journal of Plant Physiology and Biochemistry 8 (1): 1-6*

Dzomeku, B.M, Sarkordie-Addo, J., Darkey, S.K, Bam, R.K, Wünsche, J and Staver, C. 2016. Responses of Leaf Stomatal Parameters to Induced Water Stress and its Relationship with Stomatal Conductance in False Horn Plantain. *International Journal of Plant & Soil Science 12(2): 1-14*

Dzomeku, B.M., Darkey, S.K., Bam, R.K., Sarkodie Addo, J and Wunsche, J. 2016. Exploratory Assessment of Potential Mycorrhization of Two Landraces of Plantain. *Journal of Basic and Applied Research International. 18(3):146-151.*

Ewool, M. B., Akromah, R. and Acheampong, P. P. (2016). Performance of Pro-Vitamin A Maize Synthetics and Hybrids Selected for Release in Ghana. *International Journal of Science and Technology 5(6):268-293.*

Ewool, M. B., Akromah, R. and Kwoseh, C. 2016. Selection for Pro-Vitamin a Maize Varieties Using Molecular Markers. *International Journal of Science and Technology. 5 (7): 296-308.*

Ewool, M.B., Dankyi, A.A. and Akromah, R. 2016. Marginal Rate of Returns of Local and Improved Open Pollinated Maize Varieties Compared with Quality Protein Maize Hybrids in Ghana. *International Journal of Science and Technology*, 5(3):123-129

Ewool, M.B., Sallah, P.Y.K. and Akromah, R. 2016. Estimation of Genetic Improvement of Maize in Ghana under Three Levels of Nitrogen Fertilizer Application. *International Journal of Science and Technology*, 5(3):106-116.

Fening, K.O., Adama, I., Mochiah, M.B., Billah, M.K., Braimah, H., Owusu-Akyaw, M. and Manu-Aduening J.A. 2016. 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, 50(1):17-26.*

Ibrahim, S., Akromah, R., Nyadanu, D., Asante, M. D., and Tamu, A. 2016. Genetic diversity of rice germplasm using molecular markers. *African Journal of Biotechnology, 15(37): 2038-2044.*

Osei, K., Braimah,H., Issa,U.S. and Danso, Y. 2016. Mixed Cropping System on Diversity and Density of Plant Parasitic Nematodes. *Journal of Agricultural Science, 8(11):1916-1925*

Lamptey, J.N.L., Oppong, A. and Ofori F.A. 2016. Impact of Yam mosaic virus (YMV) on tuber yield of white yam (*Dioscorea rotundata* Poir) in Ghana. *Journal of Agricultural and Food Science Journal of Ghana, 9(1):730-740*

Ofori, J., Asante, M. D., Narh, S., MacCarthy, D. S. and Godson- Amamoo, S. (2016). Validation of System of Rice Intensification on Vertisol in Coastal Savannah Ecological Zone of Ghana. *Ghana Journal of Agricultural Science, 50(1):27-35.*

Osei, K., H, Braimah., Sanda, U.I and Danso, Y. 2016. Mixed cropping system on the diversity and density of plant parasitic nematodes. *Journal of Agricultural Science, 8(11): 147-153.*

Osei-Adu, J., Acheampong P. P., Amengor E. N., and Sagoe R. 2016. Input Supply Structure for Yam Production in Ghana. *Journal of Economics and Sustainable Development, 7(2):72-78.*

Osei-Bonsu, I; Dzomeku, B. M. Offei K. B.; Osei, M.K. Agyeman, K.; Ekyem, S.O. and Berchie, J.N. 2016. Assessing Flood Tolerance Potential of Papaya Germplasm at the Juvenile Stage. *International Journal of Plant and Soil Science 9(6):1-14.*

Osei-Bonsu, I., Dzomeku, B.M., Offei, K.B., Osei,M .K., Ekyem, S.O. and Berchie, J.N. .2016. Assessing Flood Tolerance Potential of Papaya Germplasm at the Juvenile stage. *International Journal of Plant and Soil Science 9(6) 1-14.*

Osei Bonsu, P., Osei Bonsu, A., Nagumo, F., Omae, F. 2016. Four planting devices for planting no-till maize. *International Journal of Development and Sustainability, 5(5):213-219*

Osei-Tutu, I, Banful, K.B., Amoah, S., Apuri, S., Emmanuel Amomba Seweh. 2016. Effect of Harvesting stages on seed quality characteristics of three soybeans (*Glycine max*) (L) Merrill) varieties. *Journal of Scientific and Engineering Research. 3(4):326-333.*

Books/Conference Papers

Abebrese S.O., Dartey P.K.A., Akromah R., Gracen V., Offei S.K. and Danquah E.Y. 2016. Identification of Maintainers and Restorers for Hybrid Rice Development in Ghana. *SATREPS International Symposium - Tailor-made rice breeding and cultivation technology development for sub-Saharan Africa - Progress and future prospects of the SATREPS project in Kenya*. Coalition for African Rice Development. Nairobi, 6 - 7 Dec 2016. P.15.

Abebrese S.O., Dartey P.K.A., Amoah N.K.A., Bimpong, I.K., Akromah R., Gracen V., Offei S.K. and Danquah E.Y.2016. Mapping Quantitative Trait Loci Associated with Anther Indehiscence and Stigma Exertion in Rice. *SATREPS International Symposium - Tailor-made rice breeding and cultivation technology development for sub-Saharan Africa - Progress and future prospects of the SATREPS project in Kenya*. Coalition for African Rice Development. Nairobi, 6 - 7 Dec 2016. P.16.

Allen O., Lamptey J.N.L., Mochiah B., Prempeh R.N.A., Abrokwah L., Marfo E., and Appiah-Kubi, D.2016. Abstracts; *Cassava virus disease diagnostic survey in Ghana. Published abstract 13th IPVE Symposium Avignon, France; Poster 61*

Allen, O., Abrokwah L. A., Adofo K., Amankwaah V., Marfo E. A., and Bolfrey-Arku, G. 2016. Detection of sweetpotato viruses on weed species from sweetpotato fields in the forest and coastal savanna agro-ecologies of Ghana. Abstracts; *West Africa Agricultural Productivity Programme National Centre of Specialization on Root and Tuber Crops Regional Conference (May 1st – 7th, 2016)*

Amengor, E.N., Adu-Appiah A., Frimpong, B.N., Osei- Adu J., Adofo, K. 2016. Adoption Potential of Improved Sweetpotato Varieties in Ghana. *WAAPP-Ghana National Centre of Specialization on Roots and Rubers (CSIR-CRI) Regional conference*. 2nd -6th May, 2016

Arthur, S., Bolfrey-Arku, G., Mochiah, M. B., Sarkodie-Addo, J., Appaw, W.O., Jordan, D. L., and Brandenburg, R.L. 2016. Influence of Herbicides and Fungicides on Peanut Production and Quality in Ghana. *Proceedings of the 48th American Peanut Research and Education Society, Inc. annual meeting*, Hilton Clearwater Beach Hotel, Clearwater, Florida, July 12-14, 2016. p100

Osei-Adu, J., Osuman, A.S., Adjei, E.A., Bortey, H.M., Asante B. O. and Dartey, P.K.A. 2016. Three upland rice varieties developed for the Ghana market competes with major varieties in visual acceptance.

Osei-Adu, J., Bonsu, O., Ekyem, S. O., Afari-Sefa, V., and Osei, M.K. 2016. *Structure of Cocoa Based Vegetable Seed System for Selected Locale in Ghana Sustainable Agriculture Research;* Vol. 5, No. 4; 2016 ISSN 1927-050X E-ISSN 1927-0518 *Published by Canadian Center of Science and Education*. pp 107-112

Prempeh R.N.A., Lotsu E., Ohene-Djan O., Bosompem A., Allotey L.A. and Manu-Aduening J.2016. *Evaluation of selected cassava varieties for delayed Postharvest Physiological Deterioration (PPD) in Ghana*. Presented at the West Africa Root and Tuber Crops Conference, 1-7 May, 2016. Pp37.

Sagoe R., Osei K., Frimpong F. (2016) NCO>s Regional Conference on Root and Tuber crops. Theme: Research in root and tuber crops value chain development: The hope for food security in the ECOWAS sub-region held at CSIR-CRI, Kumasi, Ghana. Technical Report submitted to WAAPP PCU.